Mechanisms used in Brazil to develop essential competencies in undergraduate Engineering programs

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by

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1. Introduction

In this report, we analyze nine different learning experiences offered by higher education institutions in Brazil in order to develop in undergraduate engineering students the essential competencies required of recent graduates for the exercise of engineering as a profession in Brazil. We also describe the processes, governance and resources involved in offering these learning experiences as well as the obstacles that hinder their widespread adoption.

2. Developing essential competencies through meaningful learning experiences

In the first part of this study (Licks, 2016) presented a framework originally introduced by (Male, 2012) that aggregates the essential competencies for the professional performance of Engineering in Brazil. This framework, in the form of a '11-factor competency model', is shown in Table 1.

In this schematic framework, each factor encapsulates a set of interrelated competencies that have appeared repeatedly across several studies published in Brazil about the desirable competency profile of an engineering graduate from the perspective of the local labor market.

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[1] This report was commissioned by the Brazilian Ministry of Industry, Foreign Trade and Services (MDIC) under the framework of the *EU-Brazil Sector Dialogues,* a project sponsored and funded by the European Union. The author is a Professor at INSPER and can be contacted at vinicius.licks@insper.edu.br .

As a departing point for a curriculum design exercise, this framework provides useful information to guide those educational designers interested in creating an undergraduate engineering curriculum that prepares students to succeed in their chosen professions. Although the framework is useful in itself, it represents just one stage in the curriculum design process, the part where the program's learning objectives are defined. Once the goals have been set, it is time to develop the mechanisms (ie. the learning experiences) that will provide opportunities for students to acquire the skills and knowledge stated in the objectives.

Table 1. The 11-factor competency model. Adapted from (Male, 2012).

Factor	*Competencies reflecting factor*
Communication	Graphical communication, English, Written communication, Verbal communication
Working in Teams	Interdisciplinary Skills, Diversity skills, Teamwork
Professionalism	Honesty, Loyalty, Commitment, Ethics, Demeanor, Concern for others
Self-Management	Managing development, Information-management, Self-management, Managing communication, Action orientation
Ingenuity	Critical thinking, Sourcing information, Creativity, Embracing change, Problem-solving, Flexibility, Design, Systems
Management and Leadership	Supervising, Coordinating, Managing, Leading, Risk-taking, Decision-making, Meeting skills
Engineering Business	Liability, Cross-function familiarity, Focus
Entrepreneurship	Entrepreneurship, Marketing, Networking, Presenting, Keeping up to date
Practical Engineering	Maintainability, Manufacturability, Reliability, Integrated design
Professional Responsibilities	Sustainability, Social context, Community, Safety
Applying Technical Theory	Theory, 3D skills, Modelling, Research

3. Learning experiences that develop essential competencies

In the following, we present a series of learning experiences adopted by Brazilian schools of Engineering in order to infuse the curriculum with opportunities for the development of meaningful competencies for the exercise of engineering in Brazil. These mechanisms, either formal or informal depending on their ability to grant credits, are exceedingly popular among engineering students because they provide opportunities to experience with practical activities that are commonly associated with the kind of tasks performed by professional engineers.

3.1. Competition teams

Competition teams are informal groups of students and faculty that are formed around the collective desire to participate in a student competition. Several such competitions exist and they frequently span several months dedicated to the preparation of a project that involves engineering design principles around a certain theme of interest. Among these competitions, we can mention the following that are particularly popular amid undergraduate students in Brazil:

1. Baja SAE;
2. Formula SAE;
3. Aerodesign;
4. First Robotics Competition.

Usually, a competition culminates in a comparative performance evaluation event where teams will gather and participate in rounds of eliminatory matches in which the performance of each team's engineering artifact will be assessed based on first design principles and objective performance indicators that will be then used to rank the teams and recognize those that have achieved the highest marks.

3.1.1. Connections to essential skills and innovation

Student competitions are usually related to an engineering discipline such as automotive, aeronautics, robotics and so forth. This disciplinary identification appeals to students because it provides the necessary connections between theory and practical application, whose absence is frequently mentioned as one of the main factors influencing both the loss of student interest in engineering and the lack of competencies related to innovation among engineering graduates.

But in addition to the obvious appeal represented by the competitions' technical challenges, student competitions can also be designed in a way to serve as meaningful learning experiences to the development of other essential competencies besides the practical application of theory. There are abundant opportunities to exercise team work, management, leadership and management skills, just to mention a few, both unintentionally (because participation in the competition ultimately requires them) and intentionally. When competitions include rules that encapsulate certain processes and assessments that create opportunities to experience these competencies, their designers are intentionally allowing the student the chance to live through a meaningful experience and to reflect on his level of development in some of these competencies.

3.1.2. Resources, processes and governance

The different competition teams all share the need for similar resources (including laboratory space, machine workshops, technical and administrative staff) and processes, which provides the incentive to the emergence of organizational structures that will deliver those capabilities. As a general rule, competition teams are student-driven organizations in which often times the presence and involvement of key faculty members is expected but institutional involvement and support is minimal. As few exceptions to this rule, there are some institutions that have perceived value in these activities (either for pedagogical or for marketing purposes) and provided institutional support for their development. Some examples of institutional involvement in the organization of these activities are provided below.[2]

CEFET-MG has created an organization structure named NEAC (*Núcleo de Engenharia Aplicada a Competições*) that pools different competition teams under the same institutional umbrella in order to share physical and human resources and also to expedite internal processes and governance.[3] According to its mission, NEAC "subsidizes laboratories and workshops for the production of industrial prototypes, planning and execution of projects related to curriculum subjects and guidance for the preparation of monographs." NEAC's governance structure includes the department faculty committee as well as four distinct coordinators: technical, quality control, consulting/training/events, and administrative.

Universidade de Passo Fundo has incorporated the competition teams in its organizational structure by transforming it in an institutional project, with the corresponding resources and support being offered in support of the teams' projects.[4] As a consequence, the teams have maintained a long track record of participation in regional and national competitions and could count on significant support from the local community as can be noted by the extensive list of sponsors.

The Universidade de São Paulo brought an innovation in terms of the financing mechanism adopted by its competition teams that in addition to corporate sponsors, also rely on

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[2] The reader should note that this is not by any means an exhaustive list. The examples provided are illustrative of relevant points to the author's argument and the fact that an institution is not included in this list does not mean that it does not value the activity.

[3] http://bit.ly/1UK4Ezg

[4] In: http://bit.ly/1R1gB3K

investments from the school's alumni endowment fund, whose resources are allocated according to a competitive process run by the school alumni committee.[5]

Some institutions, such as Centro Universitário FEI, for example, place a high degree of relevance to student participation in competition teams, even making their existence and tradition as part of the institution's value proposition to students, arguing that by participating in these activities the students will make themselves more appealing to future employers. FEI was one of the first institutions in Brazil to participate in national and international competitions such as the Baja SAE.[6]

Competitions that have achieved widespread diffusion have been usually organized and promoted by organizations outside the university, with a predominance of trade associations (e.g. SAE) and not for profit institutions (e.g. First Robotics). While there are examples of competitions that have emerged from inside the university, their survival is still limited.

3.1.3. Common Obstacles

Despite their warm reception amongst students and potential as meaningful learning experiences, engineering design competitions are usually disconnected from the formal curriculum and therefore are considered as extra-curricular activities. As a consequence, the most common obstacles facing the introduction and continuity of competition teams in higher education institutions are related to the limited availability of resources, faculty involvement and incentives for student participation.

Limited availability of laboratory infrastructure and resources

[5] In: http://bit.ly/1M1mLJF

[6] In: http://bit.ly/1oZOWUe

Resource allocation in higher education institutions is normally driven either by concerns with instruction or research. The availability of laboratories and workshops for either classes or research projects is given priority over extra-curricular activities and as a consequence limited space and laboratory infrastructure is available for competition teams, whose activities demand substantial physical space and machine time due to their applied and practical nature. Furthermore, there is no clarity about the allocation of current costs associated with competition teams' activities; should they be charged against instruction or research cost centers, for example? This creates uncertainty that often slows down administrative processes related to the procurement of supplies such as parts and tools, especially when there is a need to import such components. For the same reasons, financial resources coming from the university's budget are limited, requiring substantial involvement of students in fundraising efforts.

Limited involvement of faculty and technicians

Due to the extra-curricular nature of these competitions and the fact that they are not necessarily related to research opportunities, it is unlikely that they will attract attention from faculty members who must already deal with daily pressures to allocate their limited time between instruction, research and administrative duties. Limited institutional recognition of these activities create additional disincentives for faculty participation since this will require substantial time investment into solving administrative processes originating from the lack of clarity about the status of these extra-curricular and its associated responsibilities. These same limitations will also impact the likelihood that lab technicians will get much involved in these activities since the allocation of their time to these tasks will depend on faculty engagement.

Limited incentive for participation

In most Brazilian universities, time spent by students in competition teams does not count as credit towards the requirements for the Bachelor's degree. Since the participation in competition teams is often time intensive, students will face allocation challenges when it comes to divide their limited time between competition teams, curricular requirements and other opportunities such as paid internships, for example. Thus, despite the attractiveness of their programmatic nature, participation in competition teams offer limited incentives for time-constrained students, specially does involved in a work-study routine, which is typical of engineering students enrolled in private universities.

3.1.4. Examples of student competitions

It is not uncommon to find professional and trade associations involved in promoting these student competitions since they can be seen as an instrument to advance the associations' interests among which are the attraction of engineering graduates to their industries as well as the opportunity for recruiting. SAE International (once known as the Society of Automotive Engineers), for example, has been an active organizer of some of the most popular competitions among engineering students, including the SAE Baja, Formula, Aerodesign and Milleage competitions, and it makes the value proposition of these experiences to students very clear:

> "Extreme Engineering is what you get with the SAE Collegiate Design Competitions. Go beyond textbook theory by designing, building and testing the performance of a real vehicle. Join other students from around the globe in exciting and intense competitions. Land your first engineering job by talking with recruiters from leading companies in the mobility industry." [7]

[7] In: http://students.sae.org/cds/

Baja SAE

The Brazilian Chapter of SAE promotes a series of activities related to Baja SAE at the country level8 that currently counts with 74 teams participating in the national phase of the competition.[9] The first Baja SAE competition has taken place in the United States, in 1976.[10] In Brazil, the Baja SAE project started in 1994, while the first competition has taken place in Sao Paulo, in 1995. The project's goal is to allow college students to work in teams in order to design, build, test, promote and pilot their own off-road vehicles. Every year, a global competition is held that includes national and regional phases that will lead teams to a final competition, in which teams are usually evaluated based on their vehicles' performance (acceleration, hill climbing, maneuverability, endurance race) as well as on presentations, written reports and design appraisals. Every year, these competitions are held in the United States, India, China, Brazil, South Africa and South Korea.

Formula SAE

Formula SAE is a student-based design competition that started in the United States in 1981, in which students form a team to design and build a small "Indy-style" vehicle that is evaluated for its potential as a production item for a fictional manufacturing company. From its beginnings, the competition was sponsored by auto manufacturers such as General Motors, Ford and Chrysler, that perceived it as an opportunity to promote automotive engineering and

[8] Please refer to the following URL for more information about the competition: http://portal.saebrasil.org.br/programas-estudantis/baja-sae-brasil

[9] Please refer to the following URL for the list of all 74 participating teams in the Brazilian phase of the Baja SAE competition: http://portal.saebrasil.org.br/programas-estudantis/baja-sae-brasil

[10] For an account of Baja SAE's history, the interested reader is referred to http://bit.ly/21oyOrC

to recruit talented engineers to their design teams. Currently, the competition takes place in the United States, Australia, Italy, England and Brazil.[11]

The teams enrolled in the competition must be formed solely by college students and although the teams may be advised by professional engineers and technicians, it is expected that the students themselves will design and build their own race car prototypes. These prototypes are then evaluated in different dimensions, from design to cost and manufacturing analysis, presentation, acceleration, endurance and fuel economy. Thus, Formula SAE creates the opportunity for student to experience several aspects of engineering design and management, including design, research, marketing, manufacturing, testing, management.

Aerodesign SAE

Aero Design is part of the SAE Collegiate Design Series that allows student competition teams to design and build a radio-controlled model aircraft that will lift payloads of various dimensions while maintaining structural integrity and adherence to the flight mission requirements. The competition started in the United States in 1986 and since 1999 has been taking place in Brazil.[12] The competition is divided into two phases: in the first phase, projects will be evaluated by aeronautic Engineers according to engineering design first principles; in the second phase, all teams will have the opportunity to participate in a flight competition in which their model aircrafts will follow a predetermined flight mission plan.

Robotics Competitions

Robotics competitions have been largely diffused in Brazil during the last ten years, involving a multitude of different events promoted by academic organizations at different scales. The

[11] For a description of Formula SAE Brazil Competition and a list of enrolled teams the reader should refer to the following sources, respectively: http://bit.ly/1P6whex , http://bit.ly/22aKqUN

[12] For a description of Aero Design SAE Brazil Competition the reader should refer to: http://bit.ly/1YMPCJ6

challenges of robotics are inherently multidisciplinary, involving knowledge gathered from physics, computer science, design, mechanical and electrical engineering. Since students will usually form teams to enroll in these competitions, skills such as teamwork and communication will be find an opportunity to flourish along the way. Moreover, since real prototypes are required from the competition teams, engineering design and project management become valuable assets for those involved.

As an example of a researcher that has been capable to make the connection between the academic curriculum and more practical competition based environment, we would like to emphasize the work of Professor Marco Antonio Meggiolaro[13], at PUC-Rio, and his RioBotz Team.[14]

Some of the most popular robotics competitions in Brazil are:[15]

- *Competição Brasileira de Robótica* (CBR): created in 2003, CBR targets Brazilian college students and serves as a selective phase for the RoboCup;
- *Olimpíada Brasileira de Robótica* (OBR): created in 2007 with the mission to diffuse the subject of robotics in Brazil, OBR targets mainly K-12 students and in 2015 alone has enrolled more than 90,000 students;[16]

[13] About Prof. Marco Antonio Meggiolaro (PUC-Rio): http://bit.ly/1pnAvtO

[14] About RioBotz: http://bit.ly/1TFmN1K

[15] The reader should refer to a list of robotics competitions in Brazil at http://bit.ly/1pnAIx4

[16] OBR 2015 has been coordinate by Prof. Esther Colombini, from UNICAMP (http://bit.ly/1RXQeIW). More information about the Olimpíada Brasileira de Robótica can be found at http://bit.ly/1P6Bp2d.

- *Robocup* is an international competition whose national phase, *RoboCup Brasil*, has attracted significant attention between college students and academics alike. [17]

3.2. Empresas Juniores (Junior Enterprises)

Junior enterprises are non-profit organizations managed solely by students that provide products and services to other companies and individuals. The primary goal of a junior enterprise is to serve as a learning experience to participating students that translates knowledge gained in the traditional academic setting to applied practical context oriented to a job-like or entrepreneurial experience.

In 1967, the first Junior Enterprise was established in France and started to be diffused to several other schools around the country, leading to the creation of the French National Confederation of Junior Enterprises in 1969.[18]

According to the European Confederation of Junior Enterprises, an entity created in 1992 and that congregates 200 enterprises all over Europe, the objectives of a Junior Enterprise are the following:[19]

- Providing a 'learning by doing experience for students';
- Connecting academic knowledge and the business world;
- Fostering entrepreneurial skills;
- Enhancing employability in a local market;
- Improving economic and social growth.

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[17] Robocup Brasil is currently chaired by Prof. Flavio Tonidandel, from FEI (http://bit.ly/1RXQZBO). For more information about RoboCup and RoboCup Brasil, the reader is referred to, respectively: http://bit.ly/1YN2TBk and http://bit.ly/22aVOQC

[18] In: http://bit.ly/1Rga6nw

[19] From http://bit.ly/1QOWoLj

Studies carried out by the European Commission indicate that participation in a Junior Enterprise significantly improves a student's career perspectives (around 60% of students who participate are able to find a job before the conclusion of their studies; approximately 20% of students who participate end up starting their businesses within 3 years after graduation as compared to a 4-8% average in Europe).

Brasil Júnior is the national confederation of junior enterprises that congregates 311 Brazilian affiliate companies, comprising 11,400 students that have allegedly implemented 2,800 projects and attracted R$ 13 million in revenue in 2015 alone.[20] The confederation determines the following criteria as prerequisites for the nomination of new affiliates:[21]

- The enterprise must be registered as a non-profit association;
- The enterprise must be constituted by students regularly enrolled in undergraduate programs at an associated higher education institution as registered in the association's bylaws;
- The goal of the enterprise is to promote the professional development of its members through meaningful entrepreneurial experiences in the field of knowledge associated with the undergraduate program with which the enterprise is related;
- All associated members of the junior enterprise must be volunteers;
- The enterprise cannot be associated with a political party.

It is interesting to note that Brazil is the country with the largest federation of junior enterprises (Brasil Junior, with 311 members) followed by the European Federation of Junior Enterprises (JADE). One resulting effect of that popularity was the choice of Brazil as the host

[20] For more information about Brasil Junior refer to: http://bit.ly/22dmvRl

[21] Please refer to the following URL in order to access the document that defines the concept of a junior enterprise in the context of *Brasil Junior*: http://bit.ly/1WiAVMb

for the Junior Enterprise World Conference, which expects to attract an attendance of 4,000 entrepreneurs to Florianopolis in 2016.

3.2.1. Connections to Essential Skills

Communication (both written and verbal), teamwork, professionalism, leadership, management and entrepreneurship are at the essence of the junior enterprise experience. Depending on the success the organization has in attracting challenging projects from the perspective of the level of technical challenge involved, the junior enterprise may also serve to develop practical engineering skills and as an opportunity to apply technical theory. Thus, due to the breadth of essential skills covered through participation in a junior enterprise, it is fair to say that this is potentially the most relevant skill development experience that the engineering student can have in terms of career preparation among those covered in this report.

It is important, however, to emphasize that in order to make the most out of the junior enterprise as a learning experience it is recommended that it be complemented by additional activities aimed at the consolidation of learning. According to Experiential Learning Theory literature, living the experience without the opportunity to reflect about it does not necessarily lead to learning outcomes. Instead, concrete experience followed by reflective observation (i.e. reflecting on the experience), abstract conceptualization (i.e. drawing conclusions from the experience) and active experimentation (i.e. planning or trying out what one has learned) is necessary if knowledge is to be created through the transformation of experience.[22,23]

[22] (Kolb, 1984), p.38.

[23] According to (Dewey, 1907 cited in Govender, 2008), "experiential learning takes place when a person involved in an activity looks back and evaluates it, determines what was useful or important to remember, and uses this information to perform another activity".

3.2.2. Resources, Processes and Governance

The need for resources for the junior enterprise will vary according to the nature of the projects that the enterprise intends to embrace. While the typical management consulting project might not demand much more than the availability of people and computers in order to get through, more technically complex projects related to product design might require machines and tools for the rapid prototyping of parts, for example. Therefore, there is no general rule about the need for resources to start a junior enterprise.

In terms of processes, the junior enterprise resembles a standard organization in which there is a need for functional processes in place that will allow the organization to deploy its resources towards the pursuit of its mission. Thus, functional areas such as human resources, accounting, operations, communications and sales will all be required to the functioning of the junior enterprise. Within each of these areas, the existence of suitable processes will be required, whether these processes are formalized or not. In fact, defining the organizational structure as well as its processes and controls is as much valuable as a learning experience as the more technically oriented tasks themselves!

Governance has the potential to become a thorny subject, especially for higher education institutions that deal with the formation of junior enterprises for the first time. As it is usually the case, the prevailing academic culture is such that it values the fact that every project occurring within the university must be faculty driven and therefore it follows that the junior enterprise should have a senior professor either in charge of the operation or in a position of oversight. A junior enterprise, on the contrary, should leave governance and oversight in the hands of the participating students themselves because this is the way in which they develop agency and higher order essential skills. There is no general rule regarding the governance structure of a junior enterprise in Brazil; between the extremes of complete autonomy to students on one end and a fully faculty driven governance on the other, most schools will find the balance between autonomy and oversight that is appropriate to their own realities.

3.2.3. Common Obstacles

As it happens with other extra-curricular initiatives, Junior Enterprises face the challenges of limited availability of resources, low faculty involvement and reduced incentives for student participation for pretty much the same reasons that were discussed in previous sections. Besides these common obstacles, it is important to emphasize those that are particular to junior enterprises:

1. Lack of an appropriate legal framework for junior enterprises;
2. Structural obstacles of doing business in Brazil;

Lack of an appropriate legal framework

Brazilian higher education institutions have been often times reluctant to establish junior enterprises due to the possible liabilities in which they might incur as a result of the connection between the enterprise's activities and the institution that hosts its operations.[24]

In Brazil, these liabilities are of particular concern when there is possibility to claim that an employer-employee relationship has been established between the university and the students due to their participation in the activities of the junior enterprise. Labor laws in Brazil are very strict and the mere mention that such risks exist would be enough to discourage the participation of the university in the project.

At the time of this writing, a bill was approved in the Brazilian Senate that regulates the activities of junior enterprises in universities. This bill was much anticipated and as it will most likely mitigate many of the risks and liabilities that previously prevented universities from opening junior enterprises. [25]

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[24] (Silva, 2014)

[25] The interested reader should refer to http://glo.bo/1R9zI8H and http://bit.ly/1Pktezn.

Also of similar importance is the need to establish a legal institution in order to access the means and services necessaries for the enterprise's day-to-day operation. Without a legal institution in place, the junior enterprise will not be able to sell its services and thus raise resources to cover its expenses, making its operation economic unfeasible. As mentioned before, a new bill was approved that will bring this issue under a more solid legal framework.[26]

Structural obstacles of doing business in Brazil

It is hard to conduct business in Brazil. The country is known for the difficulties that its regulation imposes on the exercise of entrepreneurial activities. Brazil occupies the 116th position in World Bank's Doing Business rank and, in particular, starting a business (174th position), paying taxes (178th position) and dealing with permits (169th position) can be especially burdensome.[27]

Nevertheless, with all inherent obstacles of doing business in Brazil, it is interesting to note that Brazil is the country with the largest federation of junior enterprises (Brasil Junior, with 311 members) followed by the European Federation of Junior Enterprises (JADE).

3.3. Undergraduate Research (*Iniciação Científica*)

Undergraduate research opportunities are commonplace in Brazilian higher education institutions and are usually referred to as scientific initiation (or *iniciação científica*, in Portuguese). These opportunities are usually offered by professors working at research laboratories, which recruit undergraduates based on their willingness to learn about scientific methods and techniques and to work as lab assistants for specific research projects or for general laboratory processes.

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[26] The bill (*Projeto de Lei do Senado no. 437, de 2012*) can be accessed at http://bit.ly/22qwh5V

[27] Brazil's profile in World Bank's Doing Business can be found in http://bit.ly/1nZoGbB

Scientific initiation serves to prepare undergraduates for future enrollment in graduate programs, since students receive scientific training and the chance to be mentored by an experienced professor that can possibly become a research advisor in case the student decides to apply for a graduate program.

3.3.1. Connections to essential skills

Undergraduate research can potentially serve as learning opportunities for a significant number of essential skills for the engineering graduate.

Students will develop their communication skills by drafting scientific papers and project proposals, presenting their findings in meetings and seminars and besides they will usually receive feedback from these experiences in the form of peer reviews from their papers or oral presentations, creating the opportunity to reflect on action and improve their future performance.

Students will develop their critical thinking and the ability to source information in the process of literature review but also on exercising critical judgment about the results of the experiments they design. Students will apply the technical theory they learn from curricular courses in order to solve problems and devise scientific experiments to test their research hypothesis.

However, it is less common for scientific initiation students to find opportunities to develop skills aimed at management, leadership and entrepreneurship than it is for other skills that correlate better with the application of technical theory.

3.3.2. Resources, processes and governance

Undergraduate research opportunities can be either paid or unpaid experiences. When they are paid, the financial support will often times be provided by a research funding agency either at the federal level (i.e. CNPQ) or at the state level (i.e. Fapesp, Faperj, Fapemig and other similar agencies).

The Institutional Research Initiation Scholarship Program (or *Programa Institucional de Bolsas de Iniciação Científica* - PIBIC) is probably the best known program to promote undergraduate research opportunities in Brazil. Created in 1951 by the Ministry of Science and Technology and Innovation (MCTI), the main objective of the program was to attract young talent to science. Today, the scope of the program has been expanded to include goals such as to contribute to reducing the average length of stay of students in graduate school and to encourage greater coordination between undergraduate and graduate programs.

Currently, the Scientific Initiation program is operated by MCTI via public calls for proposals that are released periodically and that invite participation from Brazilian universities. Any higher education institution is eligible to participate as long as it develops research and has the infrastructure in place to support it. Upon submitting a proposal to the MCTI's Scientific Initiation request for proposals, the applicant university agrees to manage the resources internally according to certain conditions imposed by the ministry, for example:[28]

1. The research advisor must be affiliated to the university that has been selected by MCTI through the RFP process;
2. Preferably, the research advisor will have been awarded a productivity in research grant by MCTI;[29]
3. For the participating student should devote himself fully to the academic and research activities.

[28] More information about the program can be found at http://bit.ly/1pYFEZt

[29] The 'productivity in research fellowship' (*bolsa de produtividade em* pesquisa), is a fellowship awarded by MCTI to those researchers that have shown an academic production of quality journal articles that fulfil a certain minimum level in terms of volume and impact factor. More information is available at http://bit.ly/1Rg9m2S

4. In order to participate in the program, the student must search within his area of interest a research advisor who is willing to integrate him into his research and provide mentoring.

3.3.3. Common obstacles

The scientific initiation program is well established and has been successfully providing for decades an early opportunity to experience the day to day activities of a university researcher to students aspiring for a career in higher education and research. Typically, this kind of experience does not appeal to all engineering students, which limits its scope and therefore its potential to become a mandatory component in an engineering curriculum. Other mechanisms therefore are necessary to bring analytical thinking and the use of the scientific method to the formation of the engineer.

3.4. First year courses with substantial Engineering content

For every one hundred students that enroll in an Engineering Program in Brazil, on average only forty-five will eventually graduate.[30] Furthermore, a significant proportion of those who abandon the program do so during the first year of studies.[31] Among the main reasons given by students to justify evasion is the lack of professional engineering content in their first year courses. The student enters the school of engineering because it identifies with the professional activity of an engineer but then he is faced mainly with math courses, physics and chemistry during the first two years of his training. This lack of connection to the practice of the profession is in part responsible for a loss of motivation and the eventual abandonment of the program.

[30] (Agência de notícias CNI, 2013)

[31] According to (de Oliveira, 2013), 80% of student attrition in Engineering programs occur during the first year.

In order to address this problem, schools started to include more practical experiences and technical content to their first year courses. Some schools have even introduced a first semester course entitled Introduction to Engineering (IE), in which the students will engage in hands-on projects and design activities and will also have the opportunity to speak with professional engineers and engage in field visits to factories and construction sites. Curriculum designers hope that these experiences will keep the students' motivation to continue their programs and also will provide the context in which the content provided in theoretical courses will be applied.

3.4.1. Connection to essential skills

Introduction to Engineering courses have been identified with a series of essential skills such as communication, working in teams, ingenuity and applying technical theory. The extent to which these skills are going to be exercised is, of course, dependent on the both the learning objectives set by the curriculum designer as well as on the application of an appropriate methodology to develop them.[32]

3.4.2. Resources, processes and governance

Enrollment in Introduction to Engineering courses is usually mandatory in those universities in which it is an integral part of the curriculum. The content of the course as well as the structure of its activities is usually determined by a faculty committee that has the responsibility to deal with curricular issues. In some universities, the course is introduced as part of the so-called *supplementary activities*, that is to say that although in this case they do not constitute a course per se, they will count credits towards the requisites for degree completion.

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[32] According to (Dewey, 1907 cited in Govender, 2008), "experiential learning takes place when a person involved in an activity looks back and evaluates it, determines what was useful or important to remember, and uses this information to perform another activity".

3.4.3. Common obstacles

Introduction to Engineering courses are perceived by some to compete for students' time with more traditional first year courses such as Calculus and Physics in two different ways. First, they leave curriculum designers with the choice of either increasing the course load of the first semester or alternatively to move a course traditionally offered in the first semester to the second or third semesters. Second, critics of Introduction to Engineering courses argue that due to their hands-on and practical nature, these courses reduce students' time to study for their other first semester courses.

One obstacle that is often cited is the limited availability of resources for hands-on activities, including laboratory space, tools and parts. Another obstacle is the willingness of faculty to lecture this course and to design it around activities that elicit the professional aspects of the engineering profession. One risk is to turn introduction to engineering into a theoretical course in which students listen about engineering instead of actually practicing it.

3.5. Senior capstone project

The senior capstone project (*trabalho de conclusão de curso*, in Portuguese) is a mandatory component of any undergraduate engineering curriculum in Brazil and it is enforced by federal regulation that requires it for authorization and accreditation purposes.[33] In this mechanism, a student will engage in a semester-long or year-long pursuit of a technical project that is intended to integrate knowledge and skills acquired during his years of training. The project is supervised by a faculty member and results in a written report (and sometimes an oral presentation) submitted to the appreciation of a faculty committee.

The addition of the senior capstone project to the curriculum might be approached as a real opportunity to provide meaningful learning experiences for both students and faculty. Some

[33] According to (CNE/CES, 2002).

schools are experimenting with the possibility of having team-based senior capstone projects as a way to provide an extra-opportunity for their students to develop teamwork skills while at the same time maintaining a more manageable workload to supervisors that will allow them to dedicate more time to provide feedback to the teams.

Schools are also making efforts to connect industry sponsors to senior capstone projects, either by inviting industry to provide real problems for students to work with or by engaging professional engineers as advisors to students or teams of students working on projects that can eventually lead to innovative outcomes. This effort is a long overdue addition to the curricula of Brazilian schools of Engineering since they provide the opportunity for students to engage in real life problems while at the same time opening venues for the approximation of industrial partners with faculty and research laboratories. Other opportunities are turned to the proposal of senior capstone projects that are connected to the social interest challenges of local communities and open the possibility for students to be engage in real problems that can impact the lives of people in need.[34]

3.5.1. Connection to essential skills

Senior capstone projects provide opportunities for the exercise of such skills as communication, working in teams (when a team-based arrangement is in place instead of an individual project), ingenuity, applying technical theory, professionalism, management and leadership (also, when team-based).

3.5.2. Resources, processes and governance

The senior capstone project is usually governed by a specific set of rules defined by the faculty committee in charge of curriculum design and monitoring of its implementation. These rules will normally require that: every student is assigned a faculty supervisor for the duration of the project; that one of the outcomes of the project must be a report written by the student

[34] One such example can be found at (Paiva, Schumacher, Miyagi, & Piovezan, 2007).

(sometimes the report is supplemented by an oral presentation); the report (and the oral presentation, when applicable) to be evaluated by one or more professors and that it receives a final grade that determines whether the student is approved or not.

The resources required are specific to the nature of the project and are usually not provided by the university, being the responsibility of the student (together with an industry sponsor, if any) to raise the necessary funds to support the project. Universities will provide access to its laboratory facilities

3.5.3. Common obstacles

The compulsory nature of the senior capstone project as a mandatory prerequisite requires the university to organize a framework for its implementation that works at large scale and is economically feasible. The resulting structure becomes usually quite bureaucratic in that it requires both the student and the advisor the submission of forms and documents to a general coordinator of the senior capstone project (usually a professor as well) whose function ends up being in practice more focused on the fulfilment of bureaucracy than to ensure that the project is a significant learning experience for the student.

This structure also requires that each supervisor takes a relatively large amount of students to work with (often in the range of ten to fifteen students guided by each supervisor), which ends up limiting the amount of time dedicated to the student-supervisor relationship and the amount of feedback the supervisor can provide about the student's work. All of this might undermine the effectiveness of the senior capstone project as a meaningful learning experience once it becomes to be perceived as a final obstacle separating the student from graduating.

3.6. Integrated projects

While the senior capstone project usually provides the last opportunity to coalesce knowledge and skills learned all across the curriculum (because it typically takes place during the last year of studies), the integrated projects (*projetos integradores*, in Portuguese) are learning experiences whose objective is to integrate knowledge and skills learned in a subset of courses, or modules that take place along with the project. In this way the integrated projects serve to interweave learning experiences that would otherwise occur in separation, promoting the interdisciplinary view that puts learning in context.[35]

3.6.1. Connection to essential skills

Similarly to the senior capstone projects, the integrated projects provide opportunities for the exercise of skills such as communication, working in teams (when a team-based arrangement is in place instead of an individual project), ingenuity, applying technical theory, professionalism, management and leadership (also, when team-based).

3.6.2. Resources, processes and governance

Since the integrated project happens at the same time as other courses in a given academic period it is important that it be synchronized with the schedule of these other activities in order to guarantee that students will be exposed to a certain challenge that requires them to mobilize knowledge only after that topic is presented to them. This requires the existence of a certain degree of coordination among instructors that can benefit from the presence of an overall integrated project coordinator. The role of this person is to serve as both the academic *liason* among all instructors involved in that unit and the focal point to all matters related to project itself. Usually the academic *liason* will be appointed by faculty committee or the program director and will be responsible to convene the group of faculty and students involved in the project and connected courses.

[35] The interested reader should refer to a case for the introduction of integrated projects in engineering and technological courses in (Santos & Barra, 2012).

3.6.3. Common obstacles

The integrated project requires the investment by students and faculty of time and effort in addition to what is already involved in the traditional semester structure in which the courses are not integrated. In case appropriate incentive mechanisms are not present for both students and faculty to dedicate the necessary time and effort to the integrated project, it is possible that they will not feel invested in the activity, which can harm its progress and educational value.

Integrated projects create the need to account for both the achievement of learning outcomes as well as for the adequate timing of learning experience in each course that forms the integrated module. This can pose a challenge for the individual student as while coordination among simultaneous courses can in principle be achieved, there is no guarantee that the student will be able to reach the necessary level of competency development required for the successful completion of the project. In this case, a learning difficulty in a single module of the course could harm the overall progress of the student since without the necessary skills it is possible that he cannot make progress on the integrated project.

3.7. International mobility

The possibility to participate in experiences involving the interaction with students from other cultures and nationalities is a powerful learning opportunity for students both from a personal as well as professional standpoint. This is a main reason why international mobility constitutes relevant learning experiences to deliver the essential competencies required of engineering graduates in a globalized economy.

International mobility has been seldom considered as a prerequisite towards the undergraduate engineering degree however it has gained popularity among Brazilian students in the last years as a result of a federal government program named Science without Borders.[36] When a student engages in formal academic exchanges, he will enroll in an academic program, usually of the same designation he was enrolled at his local university, and will experience the same learning opportunities as his counterparts and in this process, will hopefully acquire skills that are relevant to his education in Brazil.

3.7.1. Connection to essential skills

International mobility experiences provide opportunities for the exercise of competencies that are seldom available elsewhere in the curriculum, including: the ability to manage time, priorities, motivation and emotions; ability to self-direct one's learning, thinking reflectively and reflexively, learning from advice and experience; the ability to evaluate the impact of engineering in diverse social, cultural and political contexts; of being concerned for the welfare of local, national and global communities.

3.7.2. Common obstacles

Uncertainty about the recognition of credits gained abroad can become a disincentive for the student considering participating in international mobility programs because the possibility of not having courses taken abroad recognized towards the requirements for graduation in their home institution can result in longer periods of time to graduate and therefore delay the student's entrance in the job market.[37]

[36] Science without Borders was until very recently the most important international mobility mechanism in Brazilian higher education having been responsible for sending tens of thousands of undergraduate students abroad. Nevertheless, it has lost momentum recently due to budget cuts undergone by Brazilian federal government that affected both the Ministry of Education and Ministry of Science and Technology. More information about the program can be obtained in http://bit.ly/1UQIH2v

[37] For an interesting report on the challenges of credit recognition in mobility experiences in the context of the Science without Borders program, the interested reader is referred to (Costa, Cesar, Pinto, & de Oliveira, 2014).

The costs involved in supporting the student abroad is clearly a limiting factor to the diffusion of international mobility in Brazil and therefore it makes a strong obstacle for its adoption as a prerequisite towards an undergraduate degree in Engineering. Science without Borders aimed at solving this limitation for an unprecedented number of students by offsetting the cost of tuition, monthly stipends, flight tickets and health insurance to qualifying students. The phasing out of Science without Borders left no other mechanism in its place to fund international mobility of undergraduate students and thus such a learning experience will possibly not make it to engineering curricula as a mandatory experience in the foreseeable future.

3.8. Internships

The internship is an integral part of the undergraduate engineering curriculum in Brazil and is enforced by federal regulation that requires it for authorization and accreditation purposes.[38] Internships are popular activities among engineering students in Brazil, which often seek them as early in their programs as the second semester. This popularity is due to distinct reasons, such as the perceived value of internships as learning opportunities and also due to the fact that internships are considered as natural gateways to the job market to the extent that companies use them as opportunities to assess the candidate's fit to fill open positions.

3.8.1. Connection to essential skills

Due to its all-encompassing nature in terms of essential skills development, industry internship can potentially be the ultimate form of learning experience in an undergraduate engineering program. The extent to which this potential is reached will depend on a series of factors among which student, mentor and faculty engagement are paramount.

[38] According to (CNE/CES, 2002).

3.8.2. Resources, processes and governance

An internship can be considered either a curricular component (in which case its minimum duration is expected to be 160 hours) or an extra-curricular activity, depending on whether it is a credit granting activity or not. In any case, from a legal perspective, internships in Brazil are ruled by specific federal regulation that determines the rights and duties of the employer, the intern and the higher education institution.[39] Under this regulation, internships require direct supervision of the educational institution through an appointed faculty supervisor that will evaluate the activity through technical reports and individualized follow-up with the student for the duration of the activity.

The internship is an experience composed of different participants: the student or intern; the company that hires the intern and the professional Engineer that serves as his mentor; the university where the student is enrolled and the faculty member that supervises the internship; and often times an 'internship agency', whose role is to match students to companies based on their mutual interests. The rights and duties of the participants are ruled by a contract that must be in accordance to federal legislation. While the company will ideally pair the student with an Engineer that will serve as his mentor, it is the university's responsibility to oversee the internship process in order to guarantee that the educational purpose of the internship is being achieved. In order to do that, the university must define an internal set of rules governing the experience and appoint a faculty member to serve as the student's internship supervisor and to enforce the compliance with these rules. Ideally, the supervisor will check the student's work on site but normally the compliance to the internship rules, however, is enforced by the submission of periodic reports by the student about his activities.

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[39] The interested reader should refer to http://bit.ly/232Nva2 .

3.8.3. Common obstacles

Despite their popularity among students and companies, internships in Brazil may be falling short of their potential as valuable learning experiences for the development of essential skills due to the lack of effective supervision. As we have previously mentioned, living the experience without the opportunity to reflect about it does not necessarily lead to the fulfilment of learning outcomes originally intended for the experience. According to (Dewey, 1907 cited in Govender, 2008), “experiential learning takes place when a person involved in an activity looks back and evaluates it, determines what was useful or important to remember, and uses this information to perform another activity”. In the case of internships, this experience-reflection-action cycle comes from the development of effective student-faculty advisor relationships, which, according to the technical literature, is failing.[40] The unproductive relationship between trainees and their mentors affect the exchange of knowledge, the acquisition of skills and the correct assessment regarding the adequacy of such training activities. The apparent mutual lack of interest by students and faculty in the mentoring component of internships is the main cause appointed to explain the limited reach of these relationships.

3.9. Project-based learning courses

Project-based learning (PBL) is not a learning experience *per se* but rather a method of instruction. In PBL courses, students will acquire skills and learn content matter concomitantly while working on their own projects, whether these projects are solutions to real-world problems or a fictitious problem created by the instructor to enable learning of a specific set of outcomes. PBL has gained popularity in Brazil as part of attempts to reform the engineering

[40] (Santos F. , 2003); (Ramos, Zago, Alves, & de Oliveira, 2014)

curriculum, nevertheless its adoption has been more frequently connected to isolated courses rather than to curriculum-wide redesign efforts.[41]

3.9.1. Connection to essential skills

PBL courses will often encourage students to work in teams in such a way that they will also develop communication and teamwork skills and bring their own perspectives and previous experiences to the project. PBL courses also allow for the development of ingenuity (critical thinking, sourcing information, creativity, problem-solving), professionalism (honesty, ethics, commitment) as well as for the application of technical theory. Depending on the way the problem is elaborated, the instructor can intentionally include opportunities for the development of other skills such as entrepreneurship, management and leadership, for example. This wide range of choices and flexibility in course design makes PBL a popular methodology in instructional design.

3.9.2. Common obstacles

The large scale adoption of PBL for curriculum rather than course design still faces several obstacles in Brazil. The perception that assessment is compromised in PBL courses is still a widely held belief among engineering faculty members who assume process evaluation to be somewhat less rigorous than high stakes tests and exams, for example. This distrust is amplified when projects are carried out in groups due to the possible development of a freeriding behavior among students.

Another obstacle lies in the amount of time and effort that must be dedicated to the development of PBL courses as compared to more traditional lecture-based methodologies. The design of such courses demand an investment of time and effort from a faculty member that faces incentives to allocate time to other competing alternative tasks. In addition to such

[41] The interested reader should refer to (CAMPOS, 2011), (Masson, Miranda, Munhoz, & Castanheira, 2012), (de Boer & Caten, 2014).

investment in the design phase, PBL courses also demand substantial investment of time during their execution, since the methodology relies on frequent feedback given to students as an integral part of the learning process. The methodology also requires the dedication of substantial time and effort from the student as compared to other more traditional learning methodologies.

The engineering curriculum in most Brazilian universities normally requires the weekly attendance by the student of something between 25 and 30 hours of in-classroom activities. If the curriculum is not restructured to account for the introduction of PBL courses, there is a risk of introducing unsustainable workloads that will certainly affect learning negatively. However, restructuring the curriculum will force designers to make choices about what content and which experiences will be affected by the introduction of PBL courses, which is always a difficult collective negotiation process to perform in most higher education institutions.

4. Conclusions

In this report, we analyzed the nine different learning experiences that we have found to be the most frequently used mechanisms by Brazilian higher education institutions to develop in their students the competencies deemed essential for the professional exercise of engineering in Brazil. The analysis in this report was based both in a survey of the technical literature on engineering education published in Brazil and on a survey of 42 faculty members associated with 14 public and private higher education institutions in Brazil.

Our analysis indicates that:

1. The nine learning mechanisms presented in this report are representative of the efforts made by instructors in Brazil to innovate in undergraduate engineering education;

2. Among the surveyed faculty members there is substantive agreement about the perceived value of project-based learning as an invaluable methodology for teaching and learning in the engineering realm;
3. There is a perceived key role to be played by non-mandatory curriculum components in the development of the essential competencies;
4. The lack of financial, human and material resources are relevant obstacles that hinder the effective adoption of these mechanisms, especially the non-mandatory curriculum components;
5. There is a low level of faculty engagement in the promotion and diffusion of these mechanisms among students and this is perceived to be due in part to misaligned incentives that emphasize commitment to research over the dedication to teaching;
6. The lack of student engagement with these activities is attributed in part to the substantial commitment of the student's time with lecture-based components of the curriculum;
7. It is important to mention that there is a perception that the prevailing culture of collegiate decision making between academic peers can substantially delay the introduction of these mechanisms in the curriculum.

Finally, the results of our analysis indicate that the path to the adoption of these mechanisms involves the adequacy of academic governance structures in order to encourage experimentation and intellectual risk taking behavior by faculty members.

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Appendix I – Results from the survey of meaningful learning experiences

A survey form was distributed broadly among engineering school instructors in Brazil. Thirty-nine responses were received. Learning experiences were then grouped according to their similarities and the answers were presented in an aggregated manner in the following sections. Respondents were affiliated with the following universities:

- Universidade de São Paulo (Poli),
- Universidade Federal de Campina Grande,
- Universidade do Vale do Rio dos Sinos,
- Universidade Presbiteriana Mackenzie,
- Universidade Estadual de Campinas,
- Universidade Federal do Ceará,
- Escola de Engenharia de São Carlos (EESC-USP),
- Universidade Técnica Federal do Paraná,
- Universidade Federal do Rio de Janeiro,
- Universidade Federal do Rio Grande do Sul,
- Universidade de Brasília,
- Universidade Federal de Juiz de Fora,
- Universidade Federal de Santa Catarina,
- Escola de Engenharia Mauá.

I.1. Competition Teams

Describe the learning experience

“Support to student groups involved in robotics, automotive and software development competitions both national and international. Besides the competition teams, there is also a Junior Enterprise.”

How is the experience integrated in the curriculum? Is it mandatory?

“The experience is not mandatory.”

What were the obstacles for the adoption of this experience in the program?

“Resources and financing”

I.2. Junior Enterprises

Describe the learning experience

“We have a Junior Enterprise here at the university.”

“Junior enterprise.”

How is the experience integrated in the curriculum? Is it mandatory?

“It is optional.”

“Optional.”

What were the obstacles for the adoption of this experience in the program?

“Main obstacles involved resources and financing.”

“Lack of physical space and financial resources to support the operation of the junior enterprise.”

I.3. Undergraduate Research

Describe the learning experience

“Student involvement in research activities that will turn him into a better engineer.”

“Undergraduate research projects and research projects in partnership with companies.”

“Research laboratories.”

How is the experience integrated in the curriculum? Is it mandatory?

“The activity is optional.”

“It is optional.”

“The activity is optional.”

What were the obstacles for the adoption of this experience in the program?

“The activity’s fast pace becomes an obstacle.”

“Because they are not mandatory activities, one of the challenges is to attract the attention and interest of students. The other challenge is to obtain resources to finance such projects.”

“Lack of curricular flexibility.”

I.4. First-year courses with substantial engineering experiences

Describe the learning experience

“An Introduction to Engineering course.”

“Introductory courses with practice and theory along with explanations about the inclusion of the Engineer in the labor market and their specificities.”

“In the introduction to engineering course, I and another instructor are trying to teach the classes using project case studies. Students are free to decide the subject, provided they fulfill all course requirements on time. The course is mandatory. Instructors have not shown to be good authors, essential feature to write a good case study. There is a resistance to adoption of any non-traditional method by the older instructors, but this has slowly been broken by studies published in reputable journals."

How is the experience integrated in the curriculum? Is it mandatory?

"The course is mandatory. The course is interesting but should be more practical. We are making it more hands-on little by little but with great difficulty."

"It is mandatory."

What were the obstacles for the adoption of this experience in the program?

"This is a traditional course in our engineering program. The challenge is to modernize it, making it more hands-on in such a way that theory can be applied in practice."

"Lack of motivation among faculty and lack of structure to develop the activities."

I.5. Senior Capstone Project

Describe the learning experience

"The project is developed in teams of five students; the projects should involve courses from all four areas of Civil Engineering (Structures, Hydraulics, Transportation and Construction)."

"The capstone project is composed of two courses that should favor: (a) initiation to research; (b) experience in selecting and evaluating bibliographic sources; (c) writing of technical reports; (d) oral presentation; (e) teamwork."

"Capstone project executed in teams and in partnership with local industry."

"Lean manufacturing project in a real company."

How is the experience integrated in the curriculum? Is it mandatory?

"The course is mandatory."

“This is a mandatory course that lasts for two semesters”

“The capstone project is mandatory and is composed of two courses making a total of one year”

“The course is mandatory.”

“The course is mandatory.”

What were the obstacles for the adoption of this experience in the program?

“The main obstacle is the attitude of the faculty that supervise senior capstone projects!”

“There main obstacles were the need to change the curriculum, the burocratic procedures involved and the counterproductive mentality of faculty responsible for the supervision of the projects.”

“Main obstacle was the availability of time from both students and faculty since the institution traditionally values more introspective activities. Learning must be fun and spontaneous.”

“Shortage of instructors with multisector knowledge.”

“Large quantity of projects to grade.”

I.6. Integrated Projects

Describe the learning experience

“The integrated project is a learning experience offered during the 7^{th} semester in which students form groups of six to eight members and then choose one project that will be designed with contributions from the five courses offered during that semester (microcontrollers, real time software, mechanisms, control and driving circuits). Performance specifications are presented to the teams that must then implement their designs in order to fulfil these requirements. Besides working on viability analysis and the choice of feasible technical solutions, the course also offers opportunities to develop skills related to teamwork, leadership and project management."

"The mechanism is required for degree completion. Having as the foundation the methodology of project-based learning whose solution is achievable through sustainable designs, the mechanism integrates the synthesis, integration and entrepreneurial components that form the backbone of the program. Starting in the fourth semester the students develop eight integrated projects from which six are mandatory and two are optional; the complexity of these projects increases gradually and go along with the required courses in each semester. Each one of the eight projects contemplates four dimensions: (a) sustainability of the solution; (b) technical content related to the mandatory courses in the respective semester; (c) contextual problems must be brought by an external partner; (d) must be related to other courses whose content is related to the project. From 2011 to 2015 there were 1,320 enrollments in the eight projects, a total of 243 teams with an average of 5.43 students per team."

"Another important mechanism which permeates the entire course are the integrative activities; these are courses working to integrate knowledge of same semester courses. These activities also prepare students in encouraging them with issues that are yet to come in their curriculum."

How is the experience integrated in the curriculum? Is it mandatory?

"The experience is mandatory for 7th semester students."

"There are eight projects: six are mandatory and two are optional."

"The introductory activity takes place in the first half of the course and other integrative activities occur at least every six months and are required activities in the curriculum."

What were the obstacles for the adoption of this experience in the program?

“The main obstacle for adoption is trying to convince faculty assigned to other courses in the same semester to collaborate and coordinate. Also, it is difficult to convince the students that the time and effort are worth the learning.”

“The main challenge was to prove to the faculty as a whole that the innovative approach, far from being a ‘fad’ would result in well-prepared graduates for professional life. The greatest evidence of efficacy in choosing the approach was the result obtained by graduates of the first cohort in the national examination (Enade): second highest score among the 329 production engineering courses in Brazil and highest score among all courses at the University.”

“None, the curriculum was already conceived having this experiences in mind.”

I.7. International Mobility

Describe the learning experience

“We allow the capstone project to be developed in partnership with foreign universities.”

“The student can fulfil his mandatory internship requirement working for companies abroad.”

“Participation in international collaborative projects.”

How is the experience integrated in the curriculum? Is it mandatory?

“The experience is optional.”

“Optional.”

“It is not mandatory.”

What were the obstacles for the adoption of this experience in the program?

"Few - easy implementation and management, because it is a small activity (5 students per project per year). But we could expand actions like this with greater collaboration with national companies."

I.8. Internships

Describe the learning experience

"The supervised internship requires work in the field as a way to acquire experience in a real setting where engineers develop their work. It should preferably be developed in association with the senior capstone project so as to conciliate the topic of the project with the activities developed during the internship."

How is the experience integrated in the curriculum? Is it mandatory?

"Yes, the course is mandatory."

I.9. Project-based Learning

Describe the learning experience

"We implemented a mandatory project-based course in which the students interact with professional Engineers. The theory is used as the basis for the design of complex engineering projects, similar to the type of problems students will fund when they graduate. Committees formed by experienced professional Engineers supervise the projects and serve as role models for the students."

"Courses that involve projects with the development of experiences that aim to apply theory to practical problems."

"Project development."

"Project-based learning with projects that lead the student to design sustainable solutions."

“Projects.”

“Two semesters with project-based learning experiences.”

“Project requirement with multiple decision variables, leveraged by field visits and bibliographical research.”

“Project-based learning, where a real problem is presented, and it is deployed within an academic activity seeking possible solutions.”

“Product design in a multidisciplinary environment with students from several courses working as a group.”

“Participation in projects and challenges (contests) with technical and social problems to be solved.”

“Project-based learning techniques that integrate theory and practice.”

“Simulation of real design situations: from what has been studied, it is proposed to students situations in which skills are mobilized for the development of a project. From this challenge, students must seek transversely in the curriculum the knowledge acquired to implement the project. There is room also for the search of useful skills beyond the course, such as contact with professionals already trained and / or students of other courses.”

“PBL for physics and calculus courses.”

“Currently it is used in some academic activities the concept of hands-on projects, where the student performs the entire product development cycle or process, experiencing the various stages of the project.”

How is the experience integrated in the curriculum? Is it mandatory?

“The course is mandatory for students in the Mechanical Engineering and Production Engineering concentrations.”

“The course is mandatory.”

“It is mandatory.”

“The projects developed along the program are mandatory.”

“This is a weird question. The very fact of being mandatory is a contamination from an ancient vision of education. Why must it be mandatory? See, we are working in another direction. The idea is that there is a well-established core training in engineering that is transmitted through active learning techniques such as project-based learning. Thus, the student will exercise these skills without a drawing a lot of attention. And besides, a number of initiatives that complement and enable the student to deepen his knowledge, including other skills as related to scientific careers: special certificates, open elective courses for students and multidisciplinary subjects containing graduate students and undergraduate together; educational content integration with complementary activities; and integration of disciplines.”

“The projects are mandatory.”

“It is part of the activities required in the mandatory curriculum.”

“The experience is optional.”

“The course is part of the curriculum and thus it is mandatory for students.”

“It ends up being mandatory since it is integrated with the methodological aspects of disciplines whose goal is to make a cross-curriculum integration.”

What were the obstacles for the adoption of this experience in the program?

“There weren’t many obstacles. A relatively large team of instructors and graduate students was involved in the process of designing and offering the course. Both faculty and students were very open-minded and the results were better than expected!”

“The main problem was to convince our colleagues that serve on several committees involved in the approval of curriculum changes that hands-on activities were not only desirable but also important to improve the professional insertion of the recent graduates.”

“Lack of professionalism coming from the students since they tend to act dishonestly; lack of commitment from students; unethical behavior involving plagiarism and presenting projects that have already been presented in previous semesters.”

“The main thing is the very structure of the university. The institution is geared towards the traditional classroom teaching. The rules and physical structure is geared to this type of education. We are making many changes to accommodate the new practices, but it is a learning process that takes time.”

“Unfortunately, my university lives in an outmoded period and has no innovative method of teaching. The professors in general are all essentially researchers instead of educators and have no interest in giving a quality lecture. Few are those who use PjBL, which in my opinion is one of the best methods we have today to train engineers with quality.”

“Low faculty engagement and lack of time of the students.”

“More faculty involvement and office hours.”

“The challenges are related to: student attraction; the formalization of partnerships with companies to provide design challenges for students; obtaining resources to enable students to build their solutions, which require use of materials.”

“Excessive number of hours in traditional classroom activities. Lack of school infrastructure to support the implementation of projects. Lack of incentive for students to present project proposals.”

“Too much work in preparation for the activity.”

“The greatest difficulty is the instructor's profile, who must have the ability to work in a transdisciplinary way and have experience in real project situations.”

“Culture change is necessary among faculty and students.”

“One of the challenges was the need for an infrastructure with the capacity to support the projects, with the employment of professional and modern equipment, and technical personnel to provide support to students in order to carry out the activities safely. The allocation of resources from academic budget to execute the projects and the acquisition of materials needed for their development. It is very difficult to get corporate sponsorship and students do not have their own resources. It should be noted that with the limited time available for the activity along the semester, time management is crucial. So avoid wasting time in processes that do not add value is an important aspect to be considered.”

I.10. Other mechanisms and their obstacles

“Courses that bridge extracurricular activities and content (there are three subjects in the curriculum for this).”

“Special elective courses in the humanities and social sciences, such as course on social skills offered with the support of psychologists.”

“Use of innovation competitions and games in regular and compulsory subjects.”

“Prototyping laboratories, workshops and meetings for students to experience and develop practical projects.”

“Environmental design courses.”

“Experience with elective courses that bring together graduate and undergraduate students.”

“Tutorial teams, working with an inductive learning posture. It is used in classrooms, according to the instructor, and teamwork outside the regular courses.”

“Practical lectures and experiments. They are optional but require financial resources.”

“Integration of theory, projects and lab activities. They require the involvement of several instructors.”

“Intensification of laboratory practice with the use of instrumentation in order to collect temperature field data, illuminance and noise levels, etc., and contact with reality, to support practical work with initial project specifications. The teams are made up of three students each. It is mandatory and happens outside normal class hours. The main obstacle is the lack of financial resources, laboratory equipment and human resources.”