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## IMPLEMENTING A PRECIOUS PLASTIC PROJECT: PEDAGOGICAL AND SUSTAINABLE ASPECTS AT A UNIVERSITY MAKER SPACE

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**Abstract.** *In the framework of maker culture that promotes the collaborative creation and multidisciplinary projects of any kind, the Precious Plastic project created by Dave Hakkens, consists of a global community united with the purpose of fighting against the negative effects of plastic pollution. In order to do so, the projects of four plastic processing and recycling machines, called shredder, compression, injection, and extrusion machines, along with their construction manuals were shared online, free of charge and iterated through virtual platforms. Therefore the main goal of this work is to apply the principles of collaborative creation and sustainability to improve spaces dedicated to digital creations, through the experience of building the injection molding machine, and its insertion in the Laboratório Aberto de Brasília (LAB) in the Faculty of Technology at the University of Brasília, aiming to provide students greater access to alternative manufacturing processes, as well as to promote creative learning techniques for future pedagogical purposes.*

**Keywords:** *maker culture, DIY, injection molding, plastic recycling, engineering education*

### 1. INTRODUCTION

With the advent of a maker culture being strongly encouraged by Gershenfeld (2012) in his "how to create (almost) anything" work at the Massachusetts Institute of Technology (MIT), digital manufacturing labs, popularly known as FabLabs, have gained considerable ground in academic environments. According to Gershenfeld (2012), a "hands-on" learning model that promotes collaborative actions to solve multidisciplinary problems results in the empowerment of individuals in the creation and production of knowledge itself, so that they become active producers of ideas and solutions, and acquire more knowledge than if they were working individually. His success in classrooms comes as a result of students' free use of laboratories equipped with digital manufacturing machines such as 3D printers, laser cutting machines, CNC milling machines, and cutting plotters, for the execution of projects of different natures.

Beyond the designation of 'FabLabs', created by MIT, the maker spaces can generally be defined as spaces dedicated to digital creation and rapid prototyping, where people who want to get their ideas off the paper can work in a collaborative way in the molds of the maker culture to manufacture, learn, and evolve. In this context, the Precious Plastic project was created by Hakkens (2013), whose mission is to engage as many people as possible in the fight against the negative effects of plastic pollution through the free and online sharing of four recycling machines: shredder, extrusion, injection, and compression. His central idea is to teach people on how to build these machines, to compose a small plastic recycling center, and thus disseminate the concepts of the maker culture to promote sustainability in a fast and accessible way. All machines are designed to be built with basic and easy to find materials, and above all, they do not require large investments. Construction instructions and tutorials, as well as lists of materials and technical drawings, are available for download on the precious plastic virtual platform, where in addition to this information, web surfers and designers can participate in forums for the exchange of ideas and experiences. With that said, in the context of the Faculty of Technology of UnB, the dedicated space to the digital creation, or college maker space, consists in the Laboratório Aberto de Brasília (LAB), and its mission is to promote educational activities for training students in the execution of technological projects. Due to the fact that it's a laboratory that has no costs for the students, there is the real struggle of reconciling costs for raw material acquisition and production demand. Materials such as 3D filaments for printing are relatively costly and produce large amounts of plastic waste. Therefore, the present work aims to report the implementation experience of the Precious Plastic project at LAB, by building the injection molding machine, to promote pedagogical activities, while working with a maker culture towards plastic recycling and sustainability.

### 2. THEORY REFERENCE

With the popularization of maker spaces especially around the year 2012, countless schools, museums, libraries and community centers around the world like HeatSync Labs, Chicago Public Library, Kid Museum, The Crucible, FamiLab,

and Vocademy, joined the maker movement announcing the opening of dedicated spaces for digital manufacturing. The ease of creating and editing projects through the computer, and loading them into the command software of the digital manufacturing machines, made the pedagogical practice behind the maker culture applicable to both formal and informal sectors of technology. Although the ideas disseminated by this movement had their precursors in the last century, the new digital technologies, increasingly accessible in terms of cost and use, promote in a very efficient and democratic way the three pedagogical and theoretical pillars of this famous maker culture: Experimental education , constructivism, and critical pedagogy (Blikstein, 2013)

In terms of experimental education, theoreticians like Dewey (1902) argue that education should be more "practical" and "experimental", directly connected with real world objects; allied to this philosophy, the ideas defended by Freire (1974), in the consolidation and empowerment of individuals through education, are focused on a significant curricular construction, in which the designers are inspired by elements of their local culture, to solve problems. They must pass easily through the states of "consciousness of the real", to "consciousness of the possible", transposing the limiting situations in the search for new alternatives. According to Blikstein (2013) and Cavallo (2000), this whole process becomes both educational and empowering for the apprentice when he/she is strongly connected with significant problems of his/her reality. In the construction of knowledge, as also attested by Blikstein (2013), learning outcomes are extremely positive when students construct, make and publish their objects of study.

Even though these education concepts are not entirely new they started to gain focus once again due to MIT's subject entitled "How to create (almost) anything" promoted by Neil Gershenfeld to study the boundaries between computer science and physical science. In principle, the course was designed to teach a small group of students and researchers on how to use the tools developed by the Center of Bits and Atoms (CBA - MIT), the CNC machines. However, the department's expectation was exceeded by a growing demand among students who simply wanted to build things from digital manufacturing machines. As a result, creative and successfully executed projects were emerging more frequently such as interactive alarm clocks, touch-sensitive dresses, and so on, bringing out answers to questions concerning utility, importance, and potentiality of the digital manufacturing machines, as attested by Gershenfeld (2012): "(...) the "killer app" in digital fabrication, as in computing, is personalization, producing products for a market of one person." (Gershenfeld, 2012, pg. 47).

And so the term "maker" started to be used as a designation for people whose main motivation consists in manufacturing, not only what can be purchased, but what is not available for purchase. This means each item produced by a digital machine can be customized according to customer's/designer's preferences from a conventional computer.

Due to the success of the CBA subject from a practical and educational point of view, the National Science Foundation launched in partnership with MIT a project that would push the academic boundaries further: In addition to describing the work done with students and digital manufacturing machines, the CBA researchers, aiming to provide access to the tools and machines used, developed a "kit", worth around 50.000US\$, including a CNC laser cutter, a 3D printer and two large and small milling machines, also CNC's. All the machines were connected by a custom software, and the "kit" was called "FabLab" from Fabrication Laboratories. Through the increasing replication of these FabLab's in both commercial and community spaces, Gershenfeld (2012) reports their inclusion in a larger plan called "maker movement": the high-tech "Do It Your Self (DIY)" movement that democratizes access to modern ways of making things, and guides more people to join technological sciences careers. Much of the success of this democratization is linked to the ability of sharing projects with other laboratories. As an example, Gershenfeld (2012) tells the design experience of aerials, radios and wireless internet terminals coming from the Boston FabLab. The design was created in Boston, refined in a FabLab in Norway, tested in another lab in South Africa, implemented in Afghanistan and currently applied on a sustainable basis in Kenya (project developed at Boston's South End Technology Center). Importantly, none of these maker spaces separately had the critical mass of knowledge to completely design and produce all components. But by sharing project files online and locally producing some of the components, they were all able to implement it.

Some FabLabs assume the task of incubating other FabLabs, supporting them to be released more. In contrast, this agenda connects, through the Fab Foundation, all FabLab's in and out of the territory. This generates a return on specialized networking for supply materials as a way to fight global shipping and logistics challenges.

To promote innovation in the way people learn at FabLab's, Gershenfeld (2012) reports that the Fab Lab Network has launched the Fab Academy program, which has enabled children and adults, working in remote FabLabs, to progress and learn incredibly more than local educational opportunities could provide, to the point of having to pursue advanced studies in other states if they were to continue their work projects developed at these FabLabs. To avoid this brain drain, the Fab Academy has connected FabLab's locations to form a campus. Along with access to the machines and tools, the students and makers who attend there, are surrounded by colleagues and mentors to guide them. They participate in interactive video lessons and share online materials and instructions at websites (such as [www.instructables.com](http://www.instructables.com)). In this way, the combination of digital communication and digital fabrication effectively allows, in the words of Gershenfeld (2012), "the campus to come to the student", who may consecutively pass on the designs and / or manufacture them locally.

This Fab Academy initiative seeks to balance the decentralizing enthusiasm of the maker movement with the mentoring work, as the makers can go to any FabLab and learn to use the tools of their own interest.

In this sense, regarding learning in engineering colleges, all these philosophies and experiences are sustained by the creation and diffusion of digital manufacturing laboratories, where students can develop creative learning approaches, and rely on the freedom and autonomy for the creation and execution of multidisciplinary projects. It is possible to note that subjects such as material mechanics, machine design, technical / mechanical design, among others, which are revisited and explored at various moments of engineering training, can be enhanced through the use of maker spaces to contextualize content learning through methodologies such as Problem Based Learning (PBL). With the aid of machines such as 3D printers and plastic injection molding machines, the production of small components such as spacers, seals, washers, scale models, specimens, and even toys can be easily associated with the contents of each discipline. And especially now with the maker culture, those machines can be manufactured by students. For this reason, the Precious Plastic project, using this "DIY" trend for plastic recycle, finds a strong and significant application in our environment.

Following the principle of makers producing their own machines, initiatives like this one are totally based on the precepts of the maker culture. Generally saying, Precious Plastic is a project created in 2013 by the designer Dave Hakkens, which aims to convince and gather as many people as possible to combat plastic pollution. It's community has over 40,000 people from many different countries working toward a solution to end this type of pollution; where knowledge, tools and techniques are shared online for everyone to engage in this fight.

Hakkens (2013) states that the project can be understood as a plan to build plastic recycling machines, shared in an open source mode, for free, for anyone to download and build, on its own, a complete work space dedicated for plastic recycling. They are called DIY machines, and therefore, represent simplified machines based on existing high-cost industrial models, but produced with low cost materials that are easy to find in any country. In order to make the project as simple as possible, and therefore easier to share and replicate, Hakkens(2013) argues that providing the access to the information, enhances the creation of solutions and adaptations by the user, to introduce improvements in the process that best suits their reality.

To join the project, one has to simply visit the platform [www.preciousplastic.com](http://www.preciousplastic.com) and download the blueprints, CAD files and construction/operation tutorials of the machines. In this platform there are also the forums for questions and tips, as well as a virtual bazaar for selling parts and components manufactured around the world by the already tested and built machines. Any information about suppliers, building techniques, tips, tricks, substitute materials, and even ideas about what and how to produce, are available on the website.

Therefore, inside our context of the Laboratório Aberto de Brasília - LAB, the idea is to construct the injection machine proposed by the Precious Plastic project in order to: first, recycle the filament waste from the 3D prints, by using the plastic chips from printing supports, to feed the injection molding machine; second, to provide students another fabrication method alternative to 3D printing, to be used in academic activities, without the respective usage cost for the material; and third, implement sustainability techniques allied with the maker culture principles of collaboration and free knowledge sharing. Most importantly, the implementation of this project is not just about building/reproducing a single machine. It means the first part of a larger plan, involving more students, working to build the other Precious Plastic machines, to expand the range of manufacturing methods for reusing plastic waste.

## 2.1 Using alternative materials to make molds for a DIY injection machine

According to Kriesi, Bjelland and Steinert (2018), in their work *Fast and iterative prototyping for injection molding - the case study of rapidly prototyping*, the injection molding process is essential for the large-scale production of the most diverse plastic components. However, predicting and simulating the quality of these plastic products is an arduous task. Although computational methods are quite advanced in this matter, the mathematical models used are conservative, and they sometimes lead to the production of oversized parts. Moreover, prototyping parts already in their final materials is virtually impossible, once the injection molding process itself leads to high costs from mold making, a very time consuming and laborious task. Any design error can result in long waiting times for the mold correction and so the parts.

The work done by Kriesi, Bjelland and Steinert (2018) states that, by building a "DIY" injection molding machine, prototyping possibilities for injected parts were increased due to the opportunity of testing with a variety of mold materials. And the validation of the results, came from mechanical "three-point bending" test, and finite element simulations performed.

As in today's globalized manufacturing market, it is very important to keep up with consumer trends to overcome competitors, increasingly better and cheaper solutions are always the most demanded. It is in this scenario that injection molding is fully established as a method for mass production, especially for plastic parts production; regardless of the several challenges and risks related to prototyping, and the tendency to work with recycled plastic. More precisely, on the working front of industrial design, there is the phase where alternative solutions need to be tested, and explored as much as possible in terms of use to produce the best solution.

This testing process happens iteratively through prototypes used to determine the products use and application features. With that said, Kriesi, Bjelland and Steinert (2018) report that building a desktop-sized injection molding machine for off-scale operations was the key to mold testing: the molds were made from different low cost materials (compared to steel, from industrial molds), and their resultant injected products, tested and analyzed through mechanical three-point bending

test, and finite element simulation. The results showed that molds made from epoxy-coated wood, epoxy-coated HDPU foam, Aluminum (AA 6082-T6), Photosensitive polymer (VeroBlackPlus), and even compacted paper, can produce good quality objects, once the machine's parameters and material's feature are correctly adjusted and calculated.

## 2.2 Injection Molding Fundamentals

Injection molding is the process of melting and injecting a thermoplastic under high pressure, into the mold cavity, where it's left to solidify, and generate a solid from the internal geometry of that cavity. After a post injection cooling time, the solid part can be separated from the mold, which can be used over and over again. That is why designing a good mold consists into a difficult task. The injected products quality is determined by a variety of possible constraints and failures (such as design angles, rebounds, sink marks, shrinkage, etc.) directly linked to the molds physical characteristics. Machining a steel mold, as is customarily made for industrial applications, can easily cost hundreds of thousands of dollars, and in case of any errors discovered during the testing phase, the mold should be sent back to the manufacturer (usually in China). Despite of these challenges, injection molding remains a key process for mass-production of plastic objects. Even if the investments in mold making are relatively high, once ready, the molds can be used thousands of times in a row and therefore, embedded costs per product are reduced. One of the methods to predict an injected product behavior and features, consists in simulating the behavior of plastics (thermoplastics) during mold filling through finite element analysis. But according to Kriesi, Bjelland and Steinert (2018), these simulations do not correspond exactly with the experimental data. When using thermoplastics, the nonlinear behavior of the material makes it extremely complex to fully capture the mechanical behavior of the plastic part, given the loading conditions and restrictions. In this sense, including all the properties of a polymer in a computational model imposes other challenges, such as convergence problems, while at the same time, provides good approximations, which guide all product development. Thus, prototyping injection molded parts can help on multiple levels as industry typical draw-build-test cycles, help to improve design in a timely manner, even during the testing phase. A company capable of performing interactive user experience testing, within environments equipped with rapid prototyping machines, means that it can rapidly improve it's products based on the user's own experience, and not only meet his or her needs but surpass them.

## 3. METHODOLOGY

### 3.1 Aspects of plastic part's production and waste at Laboratório Aberto de Brasília - LAB

During May and June 2019, the LAB's production demand experienced a considerable increase due to the end of the academic semester, and the final projects of partner subjects. The weekly production of 3D printed plastic parts is estimated in almost 500g of discarded filament. To better assess the actual production capacity of the laboratory, the 3D-printing information, recording of the produced objects was proposed (obtained from the 3D printing/slicer software) of the produced objects, over a week, for the period of 4 weeks, exclusively using FDM-type printers. At the end of this period, with the printing software records (containing the amount of used material, the geometry for each part produced, etc.), and the weight in kilograms, of the plastic residuals for each week, it will be possible to account for how much filament is effectively disposed, and what this quantity will represent in terms of costs for the LAB. The idea is also to analyze how many of these parts can be produced by injection molding, and how many recycling-cycles they can endure inside the injection molding machine.

Although the 3D print orders are usually made for ABS and PLA (Polylactic Acid, another thermoplastic widely used for 3D printing), machine and mold calibration tests have been done with both, but only ABS will be considered for the analysis, since it's disposal requires better management compared to the biodegradable PLA, that does not induce problems with normal waste disposal.

So far, the collection of discarded material in the LAB was done on an experimental basis, to better define the mold manufacturing steps. Records with information about weekly produced parts will be counted from June 24 due to the high production demand.

Once ready, the machine will be part of the LAB recycling service, and the entire process of building, maintaining, collecting and sorting material will be taught to its users so they can be free to propose changes and adaptations, while able to experiment a technique alternative to 3D printing. And in the future, if the injected products present good quality results, the machine can join the current LAB's production for sales, without dealing with bureaucratic and financial issues, and promoting the space sustainability, in a fun, free, collective, and educational way.

### 3.2 Construction Methodology

The Precious Plastic project, through it's online platform [www.preciousplastic.com](http://www.preciousplastic.com), has made available along with the blueprints and material list, manufacturing tutorials for each of its machines, which are all exclusively built with materials easily found in scrap yards. Thus, the methodology developed here specifically consists in the construction of

the injection molding machine, following its tutorials in a way that is more adaptable to the Brazilian reality, using only the work spaces provided by the University of Brasilia, in partnership with the Laboratório Aberto de Brasilia - LAB, for the selective collection of material discarded from the 3D prints, and the production of some components.

In theory, the process to be performed by the plastic injection is relatively simple: initially, the shredded plastic material is inserted into the machine and heated slowly inside the injection cylinder, using band heaters. When the optimum melting point for each plastics material is reached, the mixture is pressed by a manually driven piston into a mold coupled to the injection nozzle.

In terms of necessary adaptations, the fact that the project was developed in Europe, brings some dimensions outside the Brazilian standard measure system. For this reason, the construction of the injection machine in our space counted on some structural changes. After completing the machine's structure and based on the experiments proposed by C Kriesi (2018), it was defined that the mold at first, would be produced with epoxy-coated plywood, instead of metal, as one of good low cost alternatives. The other one, consists in plywood coated with high temperature resistant spray paint. The used and tested recycled plastic material will initially be largely composed of ABS from the selective collection implemented in LAB.

As the present work is in its first version, the model chosen to be produced by plastic injection molding has the geometry of test specimens for polymeric materials, ensured by ISO 3167 - Tensile specimen for the FSW process.

After setting the right temperature control settings, as well as the ideal quantities of material to be injected for each mold, the next stage consists in the development and preparation of geometries to be used in engineering classes and workshops. As mentioned before, the initial phase is focused on the pedagogical contribution to the LAB from the injection molding construction and molding prototyping. The second one, if the produced injected parts present good quality, is to implement in the future one more fabrication process to the LAB's services. Many of the requested 3D prints present a possible production by an injection molding process. And therefore, using the LAB's CNC mill, to cut the molds geometry in soft materials, such as wood, foam, etc. it is possible to manufacture not only recycled plastic object, but their respective molds as well.

### 3.3 Validation and evaluation of the recycling service

Based on the work of Kriesi, Bjelland and Steinert (2018), the molds for the injection molding machine will be made from epoxy/spray paint coated plywood generated by laser cutting (courtesy *Brasilia FabLab*), and/or CNC machining.

Although the manufacturing techniques for this task permeate both the artisanal and technical fields, the method for evaluating the injection molding machine operation, and the recycling service itself, consists, at first, in the visual analysis of the injected parts regarding texture, brightness, and surface smoothness. The next one is to test under traction and bending the injected parts produced, and compare the results obtained with finite element simulation. From these two results, it is possible to perform a qualitative analysis of the proposed process. The finite element simulation represents an ideal polymeric body, without internal cavities, and conformation defects. The proximity of these results to those obtained by the mechanical tests will be the indicative of how close they are to the ideal geometry.

The tensile test consists of a destructive mechanical test, where the tested specimen is pulled to the fracture to provide its tensile strength limit. The standard for specimen geometry, machines, and conditions for this test is ASTM: D638 (*Standard Test Method for Tensile Properties of Plastics*). The flexural regime test is known as the three-point bending test, and provides values for the modulus of flexural elasticity, flexural stress, and stress-strain ratio. Its regulatory standard is ASTM D790 (*Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials*)

The results considered as the successful ones will be those for which the respective molds manufacturing techniques, present the object with better visual appearance, and better mechanical resistance; highlighting geometric tolerances, and better smoothness on the surfaces of the internal cavities.

## 4. RESULTS

Figure 1 below shows the final result for the injection machine built inside the Faculty of Technology of UnB. The time required for its complete construction was mainly influenced by the waiting time for the arrival of the electronic components purchased online. Once in possession of all materials, the components and tools, the time for assembly and complete finishing of the injection machine stays close to 3 working days, with 4 to 6 hours per day.

The tools required for the construction were grinder, mill, MIG weld, and bench drill, as specified by Hakkens in his injection machine construction tutorial.

Some considerations regarding the safety of the machine operations should be noticed. Since melting cylinder temperatures reach approximately 200°C, PPE (such as heat-resistant rubber gloves, the mask and goggles) is required, as during the thermoplastics melting process, such as ABS, the release of harmful toxins to health occurs. And therefore, the place where the machine will be applied must have natural or forced ventilation to ensure healthy conditions.

As for maintenance, the injection machine needs a frequent melt cylinder cleaning procedure before starting the actual

injection process in order to minimize the effects of mixing different thermoplastics. All this procedure should also be done with the PPE, due to the possible need to disassemble modules while they are hot for easy cleaning.



Figure 1: The DIY injection machine

#### 4.1 The proposed mold

Due to the delays imposed by the importation of the injection electronic components, the order for the epoxy resin has not been placed so far. Should problems occur regarding chemical importation, the option would be to test alternative coatings such as, NCM spray paint resistant up to 600°C.

With that said, the results from the first manufactured mold to be tested are shown in figures 2 and 3. Where the center cavity consists of specimen geometry, regulated by ASTM D638



Figure 2: The mold CAD design



Figure 3: The partial mold

The coupling between the mold and injection cylinder will be done by means of a nut welded to a steel plate. This one along with another opposing plate will form a three plate mold, and the middle plate will be the laser cut plywood cavity. The three components will be held together by four screws, one at each end of the assembly.

#### 4.2 The actual recycling status

Until the present state, after the complete injection machine's construction and calibration, measures regarding the destination, storage, and separation of the plastic waste material have already been implemented. The ABS chips used in the LAB prints are manually ground, separated and stored in properly cataloged containers. The instructions are available to students by means of pdf files by now. And the collection of weekly printing data have not yet been completely processed.

Figure 4 shows the result of the first injection attempt with ABS chips. The plastic mass was only extruded from the injection cylinder without the mold in order to verify the plastic melting process.



Figure 4: First ABS plastic recycle attempt.

In the future, after settled the "good quality" mold parameters and manufacturing techniques, the idea is to construct the recycling LAB's center, with the other Precious Plastic machines as part of its daily operation, following the schematic representation shown in the Figure 5. Point 1 represents the entrance of raw material to feed the 3D printers and CNC machines. The sub products (i.e. plastic waste) of these machines enter the recycling cycle at point 2. After shredded (point 3) the plastic chips are fused into filament or injected pieces, points 4 and 5, the idea is that the plastic obtained in those points will be fed back into point 1.

#### 4.3 The pedagogical proposal

The injection machine built for the LAB, has the following features:

- Maximum Volume =  $2,3 \cdot 10^{-4} m^3$

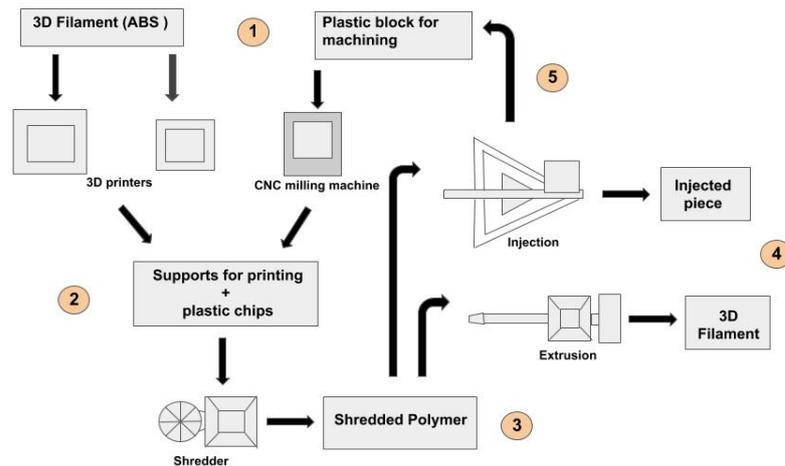


Figure 5: Schematic representation of the plastic's path into the LAB.

- Injection Pressure =  $868kPa$

Therefore, the insertion proposal of the injection molding machine in the engineering subject context will count on the development of the molds and geometries adapted to these parameters.

The first proposed pedagogical practice is devoted to the discipline of mechanical design: student groups will have to design molds to produce a geometry within the discipline content (such as small spacers, screws or other small mechanical elements). These will be produced by the LAB using alternative mold material (coated plywood, for example) in the CNC milling machine, and the results of the designs will be validated through visual aspects of their produced plastic injected objects, and demoulding process. The number of groups should not exceed 5, due to the capability of LAB's CNC milling machine to produce on demand. The maximum piece volume, is the maximum mold volume, which means the project volume must be equal or less than  $2,3 \cdot 10^{-4}m^3$ . With this activity, students are expected to develop notions about technical drawings, geometric tolerances, project execution time, manufacturing practice, and contrasts between expectation and reality. Aspects about surface finishes and possible recurrent defects may also be addressed.

Subjects such as material mechanics and mechanical system design can address aspects of mechanical testing of injected bodies seeking the stress-strain characteristics curves for thermoplastics.

Although for these two courses most of the content is based on the mechanical behavior of metals, the information about the behavior of polymers can be acquired and combined with the content of the discipline, as the plastics processing industry is as established and diverse as the metals industry.

These aspects lead to an increase in student learning, as they offer the opportunity to experience the various stages of manufacturing, problem solving, design and project management, that are part of the everyday engineering work. By encouraging pro-activity in the search for viable solutions, projects such as the injection machine serve to inspire students to use creativity in solving real problems. When one has at hand something that has been produced through the application of technical (and even sometimes artistic) knowledge, experience is the link between theory, practice and memory. Another positive perspective about this project is its viability in a scenario of contingency of public education costs. The difficulty to funding projects, machines, and equipment, and matching them to the demand of learning is real. The high cost of maintenance and repair of these, ends up preventing students from contacting technologies that are widely used in industries in general. Thus, one of the most important aspects of the injection lies in its ability to be repaired and improved by the students themselves, where even cleaning, repair and construction procedures can be approached from the perspective of industrial processes or design methodologies. Promoting access is the first step to engage and motivate people in science. When theory and practice meet to the same extent during the learning process, what changes, is the student's perspective on the usefulness and importance of what one is learning/teaching; how much it can be done with what we already know, and how far we can go by gaining even more knowledge. Is not exactly a methodology improvement, but a change in learning dynamics. Often, the contents are absorbed as absolute truths, and only at the theoretical level, undermining the student's critical sense of observing those teachings in situations not foreseen in books and exercises. As projects in the injection machine start to get executed, surely many questions will arise during the whole process. Which eventually leads the student to seek the essential information to advance, optimizing their learning process based on their involvement in a purpose.

Depending on the results generated by the mentioned activities, other subjects may be included to use the concepts of sustainability and characterization of polymers in the approach of their contents. But for now, it is expected that the practice of mold making and injection machine operation/maintenance will produce enough content for creative learning.

## 5. CONCLUSIONS

Regarding the application of the injection machine and its relevance to our maker space in the contextualization of disciplines, it can be used for the execution of projects proposed by the subjects, where the students can, through the methodologies of Problem Based Learning (PBL) develop mold geometry through CAD drawing software, manufacture it at LAB, reproduce the desired geometry from the material discarded in 3D prints, and validate mold manufacturing techniques, to improve the quality of injected products. For the sustainability of the space, the benefits related to the reuse of plastic waste can be perceived from the reduction of costs for the acquisition of raw material to be used in purely educational tasks, that is, processes in which the products will not be commercialized or mechanically tested; Moreover, in the following steps, other types of thermoplastics are expected to be tested, such as PLA, PP, PS, which are readily found in common single use plastics. The techniques of testing and identifying these polymers for the consequent temperature adjustment of the band heaters in the injection, can be disseminated by means of illustrative signs and charts, or even by small courses and workshops.

The results on LAB's actual plastic waste production, and the analysis on how much plastic the injection molding machine can process at a time, and how long does it takes, are not yet complete. In addition to these, the following parameters should still be raised to standardize the injection process:

- Ideal temperature for each thermoplastic;
- Injection Rate;
- Pressure time after injection;
- Cooling time for each mold type;

In the future, after defining these parameters for the good standardization of the injected specimens, the idea is to insert the injection molding manufacturing process to the LAB for the commercialization of parts/objects. These, which previously would only be produced by 3D printing, could be manufactured by plastic injection, resulting in a sustainable product with shorter manufacturing time.

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## 8. RESPONSABILITY NOTICE

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