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Challenges and practices of a university digital manufacturing laboratory in support of artistic practice[I]

Abstract *For the last ten years, digital manufacturing laboratories—initially meant for engineering and industrial design—have been proliferating and expanding their use to diverse fields in which experimental practice as a means of creation is a central element. While in some of these laboratories the access to their equipment is free, or, in a different way, they are private, others are exclusively dedicated to supporting the university activities. The goal of the present article is to highlight the importance of implementing the use of digital manufacturing laboratories in teaching, research, and extension activities in an academic artistic context, by presenting the specific case of ModelaFab, the Modeling and Digital Manufacturing Laboratory of the Department of Fine Arts of the School of Communications and Arts of the University of São Paulo (Escola de Comunicações e Artes da Universidade de São Paulo – ECA-USP). First, we present the challenges arising from the implementation of a university digital manufacturing laboratory; then, we discuss the establishment of ModelaFab, as well as its structure and the activities that have been taking place there until 2019.*

Keywords *Digital Manufacturing, Teaching, Research, Extension Activities, Visual Arts.*

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Desafios e práticas no âmbito de um laboratório universitário de fabricação digital em apoio a prática artística

Resumo Em um espaço de dez anos, laboratórios de fabricação digital – inicialmente dedicados a engenharia e desenho industrial – vêm se proliferando e ampliando sua abrangência para áreas diversas em que a prática experimental como meio para criação é elemento focal. Enquanto alguns destes laboratórios permitem o acesso livre a seus equipamentos ou, de modo diverso, são privados, outros são exclusivamente voltados para o suporte a atividades universitárias. O presente artigo tem por finalidade destacar a relevância da implantação de laboratórios de fabricação digital para o ensino, pesquisa e extensão, em contexto artístico acadêmico, com apresentação de caso específico do ModelaFab, Laboratório de Modelagem e Fabricação Digital do Departamento de Artes Plásticas da Escola de Comunicações e Artes da Universidade de São Paulo (ECA-USP). Em primeiro lugar, apresentaremos os desafios decorrentes da implementação de um laboratório universitário de fabricação digital; em segundo lugar, exporemos o processo de instalação do ModelaFab, sua estrutura e as atividades nele desenvolvidas até 2019.

Palavras chave Fabricação Digital, Ensino, Pesquisa, Extensão, Artes Visuais.

Desafíos y prácticas en un laboratorio universitario de fabricación digital en apoyo de la práctica artística

Resumen *En un espacio de diez años, los laboratorios de fabricación digital -inicialmente dedicados a la ingeniería y el diseño industrial- han ido proliferando y ampliando su alcance a diversas áreas en las que la práctica experimental como medio de creación es un elemento central. Mientras que algunos de estos laboratorios permiten el libre acceso a sus equipos o, al contrario, son privados, otros están dedicados exclusivamente a apoyar las actividades universitarias. Este artículo pretende destacar la relevancia de la implementación de laboratorios de fabricación digital para la enseñanza, investigación y extensión, en el contexto académico artístico, con la presentación del caso específico de ModelaFab, Laboratorio de Modelado y Fabricación Digital del Departamento de Bellas Artes de la Escuela de Comunicación y Artes de la Universidad de São Paulo (ECA-USP). En primer lugar, presentaremos los retos derivados de la puesta en marcha de un laboratorio universitario de fabricación digital; en segundo lugar, expondremos el proceso de instalación de ModelaFab, su estructura y las actividades desarrolladas en él hasta 2019.*

Palabras clave *Fabricación digital, Enseñanza, Investigación, Extensión, Artes visuales.*

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Challenges inherent in university digital manufacturing laboratories

Digital society functions based on the principles and innovations developed in research laboratories throughout the world. There has been a large proliferation of media labs and, according to Tanaka (2011), they can be classified as industrial laboratories, art laboratories, university laboratories, and laboratories incorporated in local communities. Tanaka points out that there is no singular definition for the laboratories connected to digital media, and he makes out that, with the rapid democratization of technology, the social relevance and purpose of the media laboratories make their focus change from a purely technological character to a more socially orientated one.

Such a diversity of spaces can also be found within digital manufacturing laboratories. Considering the specificities inherent in the activities developed in this type of laboratory, these places can also be referred to as FabLabs, MakerSpaces, HackerSpaces etc.; however, the pressing challenge of all these collaborative spaces is to encourage creativity and innovation through the sharing of information, knowledge, and experience.

Although they were initially used for fields such as engineering and industrial design[II] and geared primarily toward the development of prototypes, digital manufacturing laboratories can also be considered spaces for creative production connected to a wide variety of fields, such as arts, architecture, design, and engineering, among others. These spaces provide the opportunity to experiment with new materials, ideas, and methods during the act of designing and rendering a given object. In such labs, both digital and analog technologies are used for the training of new technical skills and the creation of new products.

In the case of digital manufacturing laboratories connected to universities, they serve as spaces where teaching, research, and extension activities take place. These activities are made possible via the exchange of knowledge between the laboratory team and their users.

The interest in the creative practice developed in these spaces can be attributed to the “maker” movement, which began outside the university system, and it was founded upon “Do-It-Yourself” (DIY) culture. The three basic principles of the maker movement are: a) the use of digital tools to creative design and prototype new products (digital DIY); b) the sharing of projects and on-line collaborations with other communities; and c) the shared use of standard files, allowing the submission of designs for manufacturing in commercial production services (Anderson, 2012, p. 21).

Recently, various researchers have depicted the DIY communities´ attitude as being anti-consumerist, rebellious, and creative, favoring a tendency toward producing instead of simply consuming things (Maldini, 2016, p. 142, from Kuznetsov and Paulos, 2010). According to Maldini, the development of the digital DIY movement has been accompanied by a broad ideological discourse, which has been visible principally in popular media, but which has also influenced academic production.

For example, according to Anderson (2016, p. 25), personalization and production in small batches is no longer impossible; they are, in fact, the future. Anderson (2012) has announced a "new industrial revolution", based, according to Maldini (2016, p. 142), on the possibility of replacing the traditional mass-production model with a complex and organic system in which users can create their own designs, as well as manufacture them on a domestic scale, and share them on-line.

However, Maldini (2016, p. 143) asserts that, even though the digital DIY model has certainly increased the agency of users and given them autonomy in relation to manufacturers—presumably resulting in material production much more focused on their preferences and individual needs —many other prospects emerge in this situation. Based on an ethnographic study that involved interviews with people who have used digital manufacturing tools to produce objects for their own use (in the last five years), the author has come to the following considerations: a) there has been no substitution of mass-produced objects by digital-DIY-produced objects; rather, a new type of product has been generated, increasing the accuracy and relevance of DIY; b) creators value and identify with the objects they produce; and c) this strong attachment to their designs, however, does not mean that the resulting materials are seen as irreplaceable (and, therefore, more durable); on the contrary, creators feel their objects can be easily replaceable.

Maldini (2016, p. 154) also states that the feelings described by the study participants regarding their experience seem to be intimately related to the feeling known as "flow," described by Mihaly Csikszentmihalyi (1991). By making things happen, instead of being directed by outside agents, people, in a certain way, feel in control of their lives. For Maldini, this is the real value of digital DIY: ultimately, it allows users to satisfy their needs autonomously, resulting in a diverse, "human-scale" material culture, in addition to providing feelings of pleasure and self-fulfillment resulting from the act of creation. However, even considering this positive impact, the author still points out that we should keep in mind the possible negative implications the popularity of this technology can have for the environment, as it implies a kind of production whose material is accessible and distributed easily (and increasingly so).[III]

On the other hand, considering the consequences referred to previously, within the universities, such labs can, according to Barrett et al. (2015), respond to a need to establish feedback between theory and practice, providing extra-curricular means for students to participate in more practical projects and to develop a wide range of skills. These authors assert that maker spaces go beyond the traditional workshop environment, offering access to rapid prototyping equipment and conceptual design spaces. They can also serve as a complement to courses (both undergraduate and graduate degrees, we believe), providing the benefits inherent in building physical models and establishing informal learning environments that are also open to the community.

As to the practice developed in digital manufacturing laboratories, the relevance of such spaces for education should be emphasized, as Blikstein explains so well (2013, p. 206-207). According to the author, this relevance is based on the assumption that education should be more experimental and connected to objects in the world. For Blikstein, such ideas are attributable to John Dewey originally, but they are also espoused by many other scholars and innovators like Dewey (1902), Freudenthal (1973), Fröbel and Hailmann (1901), Montessori (1964, 1965), and von Glasersfeld (1984).

On the same line, Blikstein (2013, p. 206-207) refers to Freire´s contribution, particularly the piece which criticizes the "banking education" in schools (Freire, 1974, p. 57) and the decontextualization of curricula (Freire, 1974). Blikstein also highlights Seymour Papert's notion of constructionism (1980), which built upon Piaget´s constructivism. Advocating experimental education, constructionism asserts that the construction of knowledge happens fluently in situations where students construct, make, and publicly share their objects. Thus, Blikstein notes that Papert's defense of the use of computers in education was far from rooted in technocentrism, but, rather, it should be understood from the idea of emancipatory tools that put the construction materials in the students´ hands. After all, those protean machines that allow students to design and construct are useful for many forms of work, expression, and construction. As Blikstein adds (2013, p. 207), the inherent, chameleon-like ability of technology to adapt allows the recognition and adoption of different learning styles and epistemologies, generating a convivial atmosphere in which students can concretize their ideas and designs with intense personal engagement.

However enchanting the possibilities of the continuum between design and production are (Kolarevic, 2003, p. 10), it is essential to be aware of the different scenarios (negative and positive) proposed by Blikstein (2013, p. 210-219), regarding the use of digital manufacturing in education. Finally, without disregarding the fact that Blikstein's ideas relate specifically to the primary and secondary school environment, we believe that it is possible to transpose the author´s principal challenges to the realm of the university digital manufacturing laboratory, given that the activities taking place there happen under the intense agency of the people involved. The scenarios to which Blikstein refers will be presented below in a succinct manner and, as an analogy and an approximation, they will be transposed to the context of a Visual Arts university course.

The first scenario regards the dangers of favoring the trivial use of equipment, as this can result in the product taking prominence over the process. This fact demands from educators the need to avoid rapid demonstration projects and to engage students in more complex ones.

Considering that there is no single and right way to respond to a given problem and that a solution requires exploratory practice, the second scenario refers to the potential of digital manufacturing laboratories to provide an environment for visceral design experiences. Such experiences can engender levels of both frustration and excitement that are not normally common to everyday university experience.

The third scenario corresponds to the power of interdisciplinary work developed in a digital manufacturing laboratory. The artificial boundaries between disciplines are completely reconfigured. For example, according to Blikstein, music and robotics could become closely related. Such richness would result in a more diverse and welcoming intellectual environment. Also, the professor would be much more of a facilitator.

The fourth scenario is related to contextualized learning in science, technology, engineering, and math (and, of course, arts too, and, specifically, computational geometry). In this scenario, students have the opportunity to come across different concepts in a highly meaningful, engaging, and contextualized manner.

Finally, the fifth and final challenge is related to the importance of intellectualizing and reevaluating familiar practices rather than substituting them. It presumes the incorporation and appreciation of students' practices, experiences, and repertoire. The malleability of the equipment and the pedagogical space in the laboratory allows the increasing and embracement of such practices, generating an environment that values many ways of doing things.

Therefore, understanding that the five implications and encumbrances mentioned by Blikstein (2013, p. 210-219) can be extended to a university digital manufacturing laboratory – given that both contexts, lower level schools and universities, despite their proper and necessary differences, are analogous in that they are learning environments – , it is thus our intention, in the pages that follow, to present ModelaFab, the Modeling and Digital Manufacturing Laboratory of the Department of Fine Arts of ECA-USP, highlighting the teaching, research, and extension activities that took place there between 2013 and 2019.

About ModelaFab

The Modeling and Digital Manufacturing Laboratory—ModelaFab, of the Department of Fine Arts of ECA-USP—began its activities in 2013. At that time, it was located in the Department of Fine Arts building. However, due to the inadequate physical space, its activities were quite limited, its use being restricted to the graphic representation courses of the Fine Arts disciplines. First, thanks to funds from the Pro-Equipment Program (Convênio Pró-Equipamentos)—CAPES Public Notice n. 25/2011—a laser cutter was bought for the lab. Next, also thanks to financial support from the Pro-Equipment Program, via CAPES Pro-Equipment Public Notice n. 024/2012, it was possible to buy other pieces of equipment, for 3D printing and digital milling. In August 2018, the Modeling and Digital Manufacturing Laboratory moved to the Espaço das Artes (EdA) building of the University of São Paulo, where there was adequate space for the installation of all the equipment.

ModelaFab is a space dedicated to the development of art and design projects with the use of digital manufacturing techniques. The development process for projects initially involves the production of digital models with the use of two-dimensional and three-dimensional drawing software, such as Inkscape, Illustrator, and AutoCAD for 2D structures, and Blender, 3ds Max, and Rhinoceros for 3D structures. These software integrate a step in the digital manufacturing process called Computer-Aided Design (CAD). The intangible objects and structures modeled and displayed by the computer can become physical objects and acquire other materialities, by the CAM (Computer-Aided Manufacturing) stage. For this CAD-CAM flux occurs, intermediate software in the communication between two- and three-dimensional drawings and machines (laser cutter, 3D printers and digital milling machine) are used.

So, to physically represent an object, it is generated a code in a language called G-code, used for numerical control programming. Therefore, the object coordinates are determined for the mechanical operation of the machines.

ModelaFab has three types of computerized numerical control technology with which it is possible to carry out projects through different processes (each project requires an evaluation to determine the best process and equipment to be used):

Subtractive Process: in this process, as the name suggests, material is removed in a method similar to traditional sculpting (Kolarevic, 2001, p. 271). The CNC milling machine is used in this process as it allows the sculpting of blocks of materials of different thicknesses.

There is a variety of milling machines with different formats and purposes. ModelaFab has one large milling machine (Figures 1a and 1b) that allows the use of a wide variety of materials[IV] in the production of art and design objects.

Figures 1a (detail), 1b (general view) **CNC milling machine model Raptor 1313. Modeling and Digital Manufacturing Laboratory (ModelaFab),** Espaço das Artes (EdA), University of São Paulo (USP), São Paulo. Source ModelaFab team.

2D Process: in this process, a numerically controlled cut is made in two dimensions. Machines like a water jet cutter, cutting plotter, and laser cutter are examples of pieces of equipment used in this process (Kolarevic, 2001, p. 269). ModelaFab has a Ruijie brand laser cutter (Figures 2a and 2b).

Figures 2a (detail), 2b (general view)
Ruijie laser cutter, model RJ-1060. Modeling and Digital Manufacturing Laboratory (ModelaFab), Espaço das Artes (EdA), University of São Paulo (USP), São Paulo.
Source ModelaFab team.

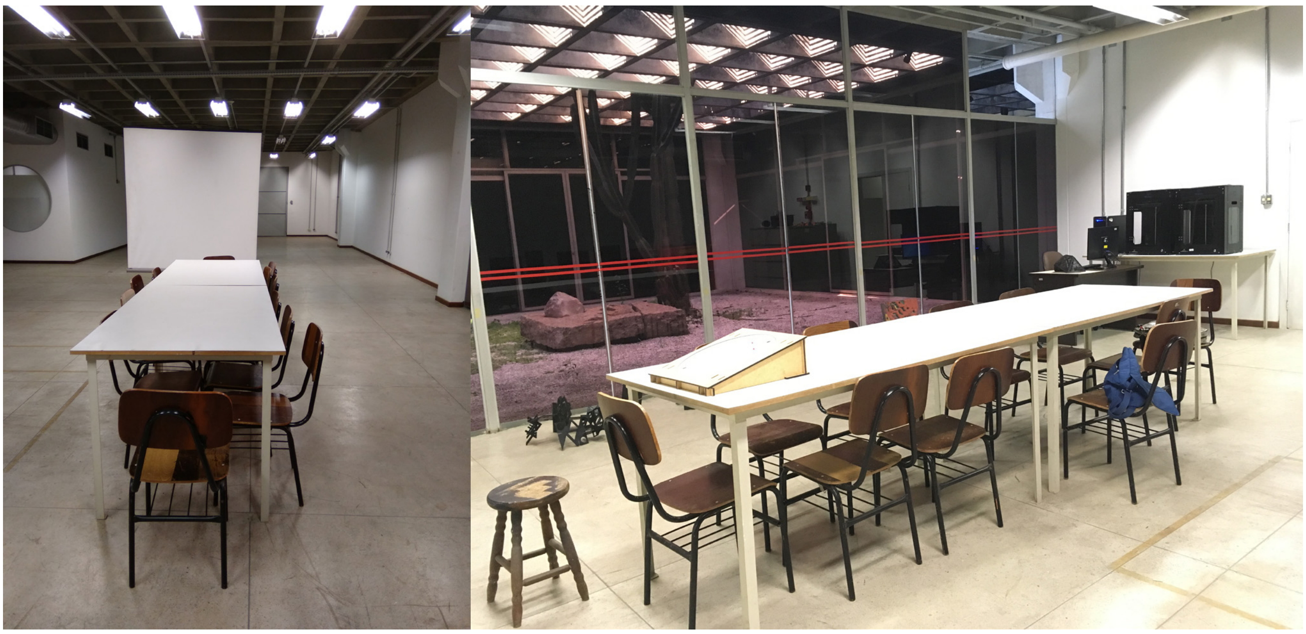
Additive Process: materials are added, layer by layer, to form an object. 3D printers are used in this process. Among the different types of 3D printing, the Fused Deposition Modeling (FDM) system, modeling by melting and depositing material, is the most common one. Options for materials can vary depending on the model of the printer; however, two types of plastic are used most commonly: acrylonitrile butadiene styrene (ABS), a resistant thermoplastic derived from petroleum (Micallef, 2015, p. 99); and polylactic acid (PLA), a biodegradable thermoplastic that ensures richness of detail (Micallef, 2015, p. 99). ModelaFab has three models of 3DCloner printers, two large and a small one (Figures 3a, 3b).

Figures 3a (detail), 3b (general view)
3DCloner printer ST model and one of the computers available in the space. Modeling and Digital Manufacturing Laboratory (ModelaFab), Espaço das Artes (EdA), University of São Paulo (USP), São Paulo.
Source ModelaFab team.

Structure of ModelaFab

ModelaFab possesses the previously mentioned machines: one CNC milling machine model Raptor 1313, one Ruijie laser cutter model RJ-1060, two 3DCloner printers ST model, and one 3DCloner printer DH model. It is also equipped with an Arduino kit as an electronic component. In terms of infrastructure, it has three computers with a variety of software installed (Inkscape, Illustrator, Blender, 3ds Max, and Arduino, among others), tables, and two closets to store tools, materials, and equipment.

The configuration of the Modeling and Digital Manufacturing Laboratory's physical space provides its operations with an organized dynamic. The lab team is composed of monitors (undergraduate students of the Department of Fine Arts of ECA-USP), supervisors, and coordinators (professors of CAP-ECA-USP). The activities performed by the ModelaFab team include the following: a) the development of support materials and displays to show the materials and properties of the machines, both of which help the team and users—students, professors, and external participants — understand how the available technologies work; b) the ModelaFab team is also responsible for the development of a visual communication identity to configure and organize the use of the lab space. In addition to the activities involving the laboratory's structure (Figures 4a and 4b), classes, workshops, and supervision of users´ projects are also offered by members of the lab teams. Thus, with the possibilities of use of the digital manufacturing in an artistic and academic environment, the lab aims at initiating a continuous movement of teaching, research, and extension activities. In the section to follow, we will demonstrate the results of the main activities that took place at ModelaFab between August 2018 and June 2019, after it was relocated to EdA.



Figures 4a (detail), 4b (general view) **Structure and organization of the laboratory. Tables and chairs available in the space. Modeling and Digital Manufacturing Laboratory (ModelaFab),** Espaço das Artes (EdA), University of São Paulo (USP), São Paulo.
Source Professors of the course.

Results of the ModelaFab activities

Teaching graduate courses

In August and September 2018, the course "Art and Digital Manufacturing Processes" (CAP-5029) was taught by professors Monica Tavares, Juliana Henno, and Gilbertto Prado. The course sought to investigate how digital manufacturing technology has been influencing the development of the creative process in the context of art. More specifically, it sought to promote critical analysis of how such digital systems can enhance the creation, with a view towards their use as an instrument and innovative mode of representation. Furthermore, the course aimed at creating a forum to discuss research topics regarding the convergence of art and digital manufacturing processes.

The course consisted of the following activities: lectures with group discussions about the assigned references, practical classes at ModelaFab, lectures by guest artists and researchers to share information about topics of the course, and seminars geared towards bringing knowledge that has problematized the relationship between art and digital production processes.

The course was justified given the substantial increase in the use of digital manufacturing systems in the realm of art, concretely in the development of creative practices mediated by the CAD/CAM system. The use of the CAD/CAM system has boosted the emergence of innovative creative solutions that claim a trend towards the manufacture of singular, customized objects. Within this category of creation, a pursuit of the "digital craft" process, in which craft is intrinsically allied with digital manufacturing systems, has stood out.

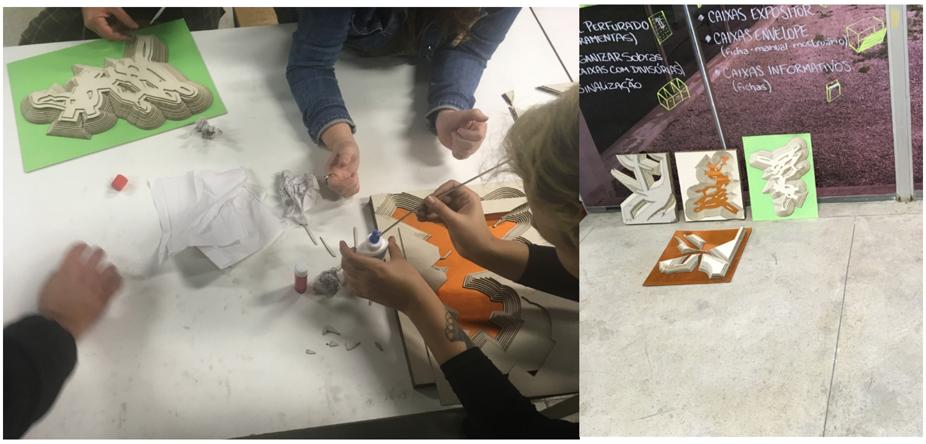
From the specific content in the convergence of art and digital manufacturing technology — the CAD/CAM flux and the creative process, digital simulation and manufacturing in the context of visual poetics, digital manufacturing systems, mass production vs. customized production, multiplicity, FabLabs, MakerSpaces, and HackerSpaces, digital craft, parametric and generative systems, complexity as an instrument of creation, stages of the production process from creation to manufacture — the course sought to empower artists and designers in the use of these technologies as an instrument of creation.

Among the practical activities carried out by graduate students were experiments that engaged them with the different technologies available in the Lab. The first activity was the development of a (non-digital) generative algorithm that synthesized the stages of construction of a shape. The basis of this activity was the grouping of laser-cut strips of ethylene vinyl acetate (EVA). Cuts were made on these strips in specific positions and used as a reference for coding the syntax that could generate the different student's algorithms. Each piece, thus configured, was replicated multiple times (Figures 5a and 5b) to produce arrangements of elements.

The second activity was based on the structures generated during the first activity. In this case, the students used the CAD tool to create new formal patterns. This second activity was established from a formal cutout in order to create a representation of the representation, with reference to the structures generated in the first exercise, and with a view to generating a surface, necessarily delimited. Each surface depicted gained successive scalings with a certain similarity ratio, thus ensuring the generation of similar shapes (those which possess the same homologous angles and proportional homologous segments) that were to be arranged one on top of the other. Each similar surface thus created was sectioned by the laser cutter and stacked to achieve a tridimensional effect (Figures 6a and 6b).

In order to experience the processes related to 3D modeling, in the third activity, participants used a 3D scanner to obtain the volumetry of their busts and then to edit them using surface treatment software, before performing 3D printing (Figure 7). 3D modeling in a virtual environment was also conducted, as participants were introduced to the TinkerCAD (Figure 8) software to create 3D shapes that would be unfolded in a two-dimensional plane. The resulting plane could be cut by the laser cutter, and, through folds and creases, recover the reference of the modelled figure.

Figures 5a (montage), 5b (finished structures) **Arrangements of elements made according to choices established by the participants through the use of shapes originally generated by the grouping of laser-cut strips of ethylene vinyl acetate (EVA).**
Source Professors of the course.



Figures 6a (montage), 6b (fnished structures) **Examples of the formal patterns generated by the stacking of similar shapes bonded together layer by layer.**
Source Professors of the course.

Figure 7 **3D printed busts.**
Source Professors of the course.

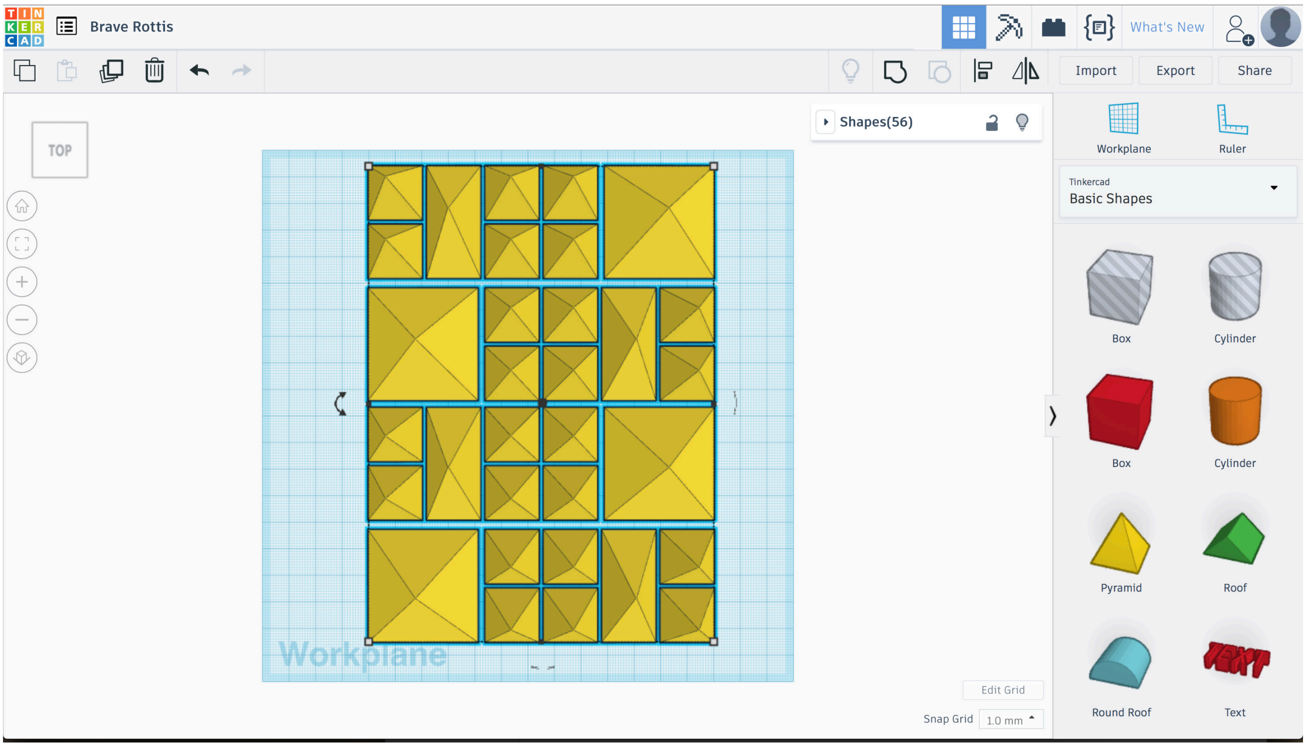


Figure 8 **Constructing a modular surface with the TinkerCAD software program.**
Source Professors of the course.

Teaching undergraduate courses

In the first semester of 2019, the course "Multimedia and Intermedia Practice II" (CAP-0280) was taught by professor Priscila Guerra. The goal of the course was to present and discuss the creative process of the artist with the possibility of expanding its potential through the use of digital manufacturing. Practical in nature, the course primarily focused on final projects guidance, and so the classes were dedicated to the development of projects, with stages for both the development of prototypes and the manufacture of final objects. Furthermore, it sought to demonstrate, theoretically and practically, the possibility of employing the poetics of recodification. More specifically, through the reuse of symbolic structures, it sought to encourage (re)combinations of processes, media, and images.

The course also included lectures introducing digital manufacturing and the processes of montage, collage, and bricolage (for each process, examples of artistic works produced with digital manufacturing were given).

As mentioned previously, the practical classes were mainly geared towards acquiring knowledge related to the development of projects involving the use of digital manufacturing. The focus was given to the laser cutter in order to explore in-depth solutions for 2D developing surface, fitting, and stacking exercises, meant to encourage the production of creative structures. Furthermore, the course included practical classes on other topics focused on the use of Inkscape, LaserCut, Blender, ClonerGen3D and ClonerMake3D software, and electronics and programming with Arduino (LED and potentiometer). These classes also supported the development of the students' projects.

The development of the projects was photographically documented, which allowed improvements in the development of creative processes and aided discussions during the lectures, ensuring feedback between theory and practice. In general, the projects were characterized by collections of conceptually coherent pieces that established relationships among themselves, they proposed combinations of different techniques and technologies, and they demonstrated fine workmanship.

It should be mentioned that during the prototype development stage, the students found themselves challenging the technologies (laser cutter and 3D printer) in the sense of the creation of complex structures, reinforced by their choice of materials. The series of trials and errors experienced by the students, particularly at this point of the course, evoked a dialogue with the second scenario of challenges to be considered regarding activities carried out in a university digital manufacturing laboratory, which was presented in the first section of this article.

Workshops

The first workshops offered by the ModelaFab team took place on the 22nd and 29th of April and on the 6th and 13th of May 2019, on Mondays, from 2 pm to 4 pm, resulting in a total of 8 hours of activities.

The first meeting, "Introduction to Digital Manufacturing", was theoretical and sought to introduce students to the equipment and machines in the laboratory, in addition to complementary technology and procedures. It covered the early days of digital fabrication laboratories, the processes involved (2D and 2.5D cut, additive and subtractive processes), and the dynamic of the system (CAD, CAM, and CNC). Then, the students were introduced to the space and the equipment available in the laboratory, along with examples of work by artists who used the demonstrated technologies in the creation of their pieces. Among the advantages of developing projects with digital manufacturing, those ones that were emphasized were reduced execution time, technical precision and precise finishing, and new ways of conceiving and carrying out projects, which entail new proposals for engaging the public.

The second meeting, "Stenciling with a Laser Cutter", aimed at demonstrating the possibilities for mixing artisan, mass, and digital media. The free software Inkscape was introduced. The use of free programs was a priority both in this meeting and in all the others. The participants[V] made stencil designs that were laser cut (Figure 9), and they had the opportunity to discuss adaptations to the designs (CAD). The operation of the CNC milling machine was also demonstrated during the second workshop – it was used to cut a 6-cm diameter circle. As it is more complex to use and its operation requires qualified professionals, no designs were proposed to be cut with this technology.

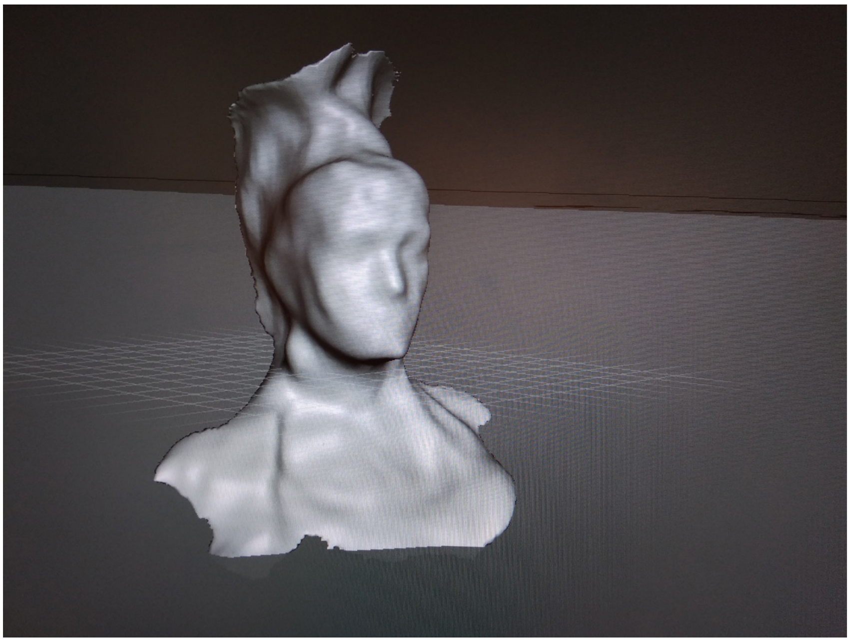
Figure 9 **Result of the "Stenciling with a Laser Cutter" meeting", held on 04/29/2019 from 2 to 4 pm. Modeling and Digital Manufacturing Laboratory (ModelaFab),** Espaço das Artes (EdA), University of São Paulo (USP), São Paulo.
Source Professors of the workshop.

In the third meeting, "3D Modeling with TinkerCAD", the free on-line program TinkerCAD was introduced as a simple and easy-to-learn interface for three-dimensional modeling, and it was proposed for the students to model their own 3D pieces. There was also further instruction regarding the topic of the second meeting with the use of kraft paper stencils, as seen in Figure 9.

In the fourth meeting, "3D Scanning and Printing", it was introduced the properties of the 3D printer, the materials used, the parameters available and their differences, and a model made by one of the participants was used to be printed during the workshop. Also, during this meeting, a three-dimensional scanning exercise was done with the Android smartphone app SCANN 3D, which allows one to map an image by taking a series of pictures and to process it into a three-dimensional format (Figures 10 and 11) that can be exported in a file format read by CAD and CAM programs (.STL).

Figure 10 **Processing of a sequence of images captured using the Android smartphone app SCANN 3D. Modeling and Digital Manufacturing Laboratory (ModelaFab),** Espaço das Artes (EdA), University of São Paulo (USP), São Paulo.
Source Professors of the workshop.

Figure 11 **Result of the three-dimensional processing of the images captured with the SCANN 3D app. Later the object was edited by using the Autodesk program Meshmixer. Modeling and Digital Manufacturing Laboratory (ModelaFab),** Espaço das Artes (EdA), University of São Paulo (USP), São Paulo.
Source Professors of the workshop.



The themes of the workshops were directed towards artistic fields, and the activities were distributed among the ModelaFab team. The results of this series of workshops were satisfactory, given the interest of the participants in the development of the activities, exploration of resources, and possibility of studying with/about digital manufacturing.[VI] The software chosen by the digital modeling team proved to be appropriate due to their ease of use for someone coming into contact with the technology presented for the first time.

Development of support material

The ModelaFab team has developed support material and displays showing the properties of the equipment. For the laser cutter display, a standard design was developed to be applied to all cutting materials (Figure 12). The aim is to present a structure that can be updated and handled by the users of the space to identify the materials that can be cut, such as papers, plastics, wood, and fabric. Alongside this, a spreadsheet has been developed showing the materials that can be cut, their properties, such as color and thickness, in addition to the power and speed settings for cutting and engraving a line or area.

The materials have been shown to be adequate references for the classes of the Department of Fine Arts of ECA-USP in the laboratory space, and the same can be said of the first series of workshops offered in the months of April and May of 2019.

Figure 12 D**isplay of materials for the laser cutter. Modeling and Digital Manufacturing Laboratory (ModelaFab),** Espaço das Artes (EdA), University of São Paulo (USP), São Paulo. Source Professors of the workshop.

Visual identity and communication

The logo of ModelaFab was developed using the Illustrator program, as were the signs for the machines, general notices with rules for using the space, and QR codes for accessing the rule book and manuals for the laser cutter, CNC milling machine, and 3D printers. The visual communication and identity material were taped to surfaces around the environment (Figure 13). An e-mail account especially for the laboratory was also created with the address <modelafabdigitais@gmail.com>. This account was created to help the team organize the activities at ModelaFab, and to establish contact with users who wish to enroll in workshops, schedule project supervision, ask questions, and obtain information.

A template was created for a project registration document to be completed by users who wish to use the laboratory. The projects are analyzed and, if they are approved, the projects are scheduled for monitoring by the supervisors and monitors of ModelaFab in their execution.

Moreover, the rule book[VII] for using the space must be previously read and followed by the users. It contains ModelaFab´s mission, the rules for using the space, equipment, materials, documentation of completed projects, credit, the team members´ names, and a list of materials for use on the laser cutter (permitted and non-permitted).

Figure 13 **Stickers with the logo, e-mail address, general notices, manuals, and rules of the laboratory placed on doors, walls, and equipment. Modeling and Digital Manufacturing Laboratory (ModelaFab),** Espaço das Artes (EdA), University of São Paulo (USP), São Paulo.
Source Professors of the workshop.

Final Considerations

With regard to the activities at ModelaFab, it turns out that: a) when it comes to teaching, the aims have been to integrate theory and practice in digital manufacturing in a continual manner that focuses on the flux between the design and the manufacture phases; b) with respect to research, without disregarding the flux referred to previously, it has been a goal to raise awareness of specific modes of production that take advantage of the technological resources of ModelaFab with a view towards enhancing the performance of artistic research, dynamizing and expanding the artistic practice and reflection on creative processes; c) with regard to extension activities, the goal is to ensure the dissemination of digital-manufacturing-related-technology knowledge that was acquired through teaching and research. This last activity has already been implemented via workshops and limited to the community of the Department of Fine Arts of ECA-USP. However, there are plans to expand it with presentations and short courses open to the USP community and high schools, so that the lab complies with its pedagogical and social role in a more extensive manner.

Finally, it is worth highlighting that the ModelaFab team must always be attentive to the five challenges referred to by Blikstein (2013) regarding the actions involved in operating a digital manufacturing laboratory: a) trivial use of the equipment; b) levels of engagement — from frustration to excitement — stimulated by the results obtained during the development of projects; c) the potential of interdisciplinary work as an avenue for expanding solutions; d) contextualized learning in science, technology, engineering, math, arts and computational geometry in order to ensure comprehensiveness of contexts; and e) incorporation of the specific demands from the users, valuing their own repertoires and poetics. Overcoming and dealing with these challenges is a constant that permeates the innovative and challenging artistic activities that take place in a digital manufacturing lab.

I. This article is a review, in English of the text "Desafios e práticas no âmbito de um laboratório universitário de fabricação digital em apoio a prática artística", published at 18th International Art, Science, and Technology Meeting, 2019, Lisbon. #18.ART: Da admirável ordem das coisas: arte, emoção e tecnologia / # 18.ART: Of the admirable order of things: art, emotion and technology. Lisbon: Faculdade de Belas Artes (FBAUL) (Portugal) / Media Lab Brasil, 2019. v. 18. p. 350-371.

II. According to Henno (2016, p.75), while the mechanical engineering field has been producing metallic engine parts for the aerospace and automotive industries, the fields of civil engineering and architecture have been producing entire houses using digital manufacturing. Another field that is benefitting from digital manufacturing is dentistry, with the creation of custom dental crowns for the mouth structure. Medicine can also be added to the list, as digital manufacturing has been making a big impact with the production of implants, prostheses, and medications.

III. Due to concerns about the environment, a change in focus from "manufacturing" to "repairing" has been proposed within the expanded DIY movement (Bidoret, 2014). In this regard, the image of the maker as an individual who "makes everything" would be updated to one of a "fixer" or "remaker", as such an individual would reutilize manufactured objects and products by modifying, recontextualizing, and combining them.

IV. Some examples of materials used are medium-density fiberwood, plywood, and Styrofoam, among others.

V. The first sequence of the workshops offered by the ModelaFab team had 15 participants enrolled, comprising students and professors of CAP-ECA-USP and PPGAV ECA-USP.

VI. In general, users have shown interest in exploring the possibilities of the technology at ModelaFab by proposing projects for the team supervisors to be carried out in the ModelaFab environment.

VII. The ModelaFab Rule Book (2019) contains information regarding the "rules for using the space", in a topic with the same name, and it establishes in subsections that: "In hierarchical order, priority for the use of ModelaFab is as follows: a) projects of CAP-ECA-USP and PPGAV ECA-USP students enrolled in courses taught at ModelaFab; b) projects of CAP-ECA-USP and PPGAV ECA-USP students who are at the end of their courses; c) projects of CAP-ECA-USP and PPGAV ECA-USP students connected to current courses; d) projects of CAP-ECA-USP and PPGAV ECA-USP professors and research groups; and e) CAP-ECA-USP and PPGAV ECA--USP students´ projects that are related to ModelaFab´s respective areas of research."

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