Developing maker-centered learning programs to promote critical thinking about technology and design for emergent futures

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Abstract

The scope of the paper is to analyse and reflect on the educational approaches and frameworks implemented in the 20-21 academic year of the Master in design for Emergent Futures (MDEF) and its integration with the rapid prototyping course of Fab Academy alongside their design curriculum agenda. The paper outlines the learning theories applied in the design and implementation of the methodology as well as the resources required, instructors' roles, instructional tools and support. Furthermore, it examines the potential benefits of implementing maker-centered programs in design-oriented programs and vice versa. It proceeds to summarize the problems and challenges of such implementation and reflects on the learning outcomes of this experimental methodology. Finally, it provides insights by discussing a selection of student projects focusing on the reciprocal relationship between digital fabrication practices and the MDEF master's design studio concepts.

Keywords

peer learning, education, digital fabrication, self-led research, emergent technology, multidisciplinary learning environments, design thinking.

1 Introduction

The MDEF Master program is a complex learning environment integrating, in its educational curriculum, different concepts and topics relating to emergent technologies. Topics from synthetic biology, digital fabrication, machine learning and design theory are all incorporated into one coherent course.

This master aims to provide the strategic vision and tools for designers, sociologists, economists and computer scientists to become agents of change in multiple professional environments. The program focuses on the design of interventions in the form of products, platforms and deployments that aim to produce new emergent futures through analyzing the current challenges in society and industry. (MDEF 2019-2020 – EMERGENT FUTURES, n.d.)

During the course, the students are encouraged to create a network of projects that exceed the boundaries of the academic space and engage communities and organizations addressing societal problems in the form of design interventions. Projects are not limited to the development of artifacts and prototypes that represent single solutions, but incorporate a combination of methodologies, interventions and designed objects under an umbrella of strategic, future thinking and design activism.

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Students arrive at the program with different cultural and professional backgrounds, that instate the diverse areas of investigation in which they will initially focus their research. A core aim is to empower students with hands-on prototyping in the Fab Lab environment, unlocking technological 'black boxes' to create a deeper understanding of technology in designing for emergent futures. In that regard, technology does not represent the solution, but rather a powerful tool to enhance the process of creating change (Soomro, 2021).

The challenge methodology framework consists of two fundamental curriculum paths: individual reflection tasks for each weekly topic and an intensive monthly maker-sprint week referred to as a challenge. Students work in small groups to develop week-long projects applying accumulated knowledge and skills from the previous Fab Academy weekly topics with concepts related to MDEF and their research projects, aiming to bridge the gap between the two courses.

In this paper, we will analyze the implementation of the challenge methodology and argue that design and digital fabrication courses can equally benefit from one another to foster a deeper understanding of technology and more critical and meaningful use of its tools and practices. This model differs from Stanford's design thinking model that relates to a well-established conceptual framework in which the development of a solution leads to a concrete product (Tschimmel,2012) and broadens the scope of direct technological education frameworks merged with non-pre-established design agendas.

This hypothesis will be focused on the academic year 2020-2021 through a range of probe-based projects developed during the four micro-challenges.

2 Research Scope

Prior to the definition of the paper's scope, the following subchapter presents a guide to the educational models that this research combines. This is necessary in order to understand the foundational framework of the Micro-challenge methodology. The Fab Academy program has provided an educational guidance track framework for the digital fabrication course of MDEF that is deployed over the second and third terms. The adapted course is designed to assist students in dealing with the demands of rapid prototyping and design.

2.1 Fab Academy Curriculum

Fab Academy program is a distributed course taught by the Fab Foundation, inspired by the "How to make almost anything" course of the Massachusetts Institute of Technology (MIT). It presents a unique educational model. Instead of being centralized with students attending one campus, or decentralized, with students attending an online class remotely, Fab Academy is based on a networked model. Each student attends a physical lab, referred to as a node, where he has peers, mentors, and access to machines. All these nodes are connected to one global network: this is what we call Distributed Education. As part of distributed learning, faculty and students can engage in more interaction, and collaborate on learning. (Oblinger, et al.,2001) Students get to interact with their local peers, but also with a vast global community of students and tutors from every corner of the network.

Fab Academy is a six-month crash course in rapid prototyping. Nineteen transversal topics are addressed, at a weekly pace, summing up into a final project at the end of the course, combining a wide variety of topics covered during the semester. It is not a project-based course, but rather a combination of technical skills expressed in one final project.

This advanced digital fabrication instruction is provided through a unique, hands-on curriculum and where students get access to technological tools and rapid prototyping resources as a fast lane exposure to the latest praxis and state-of-the-art techniques related to digital fabrication. The distributed educational model of the course allows for the development of a set of soft skills relating to spiral project prototyping, including creativity, collaborative work and problem-solving (Alimisis,2013) as it offers a peer-to-peer review and project mentoring by other instructors and students worldwide.

2.2 Design Interventions

During the MDEF master's program, students are expected to propose small-scale design interventions as part of their thesis development. The focus of the interventions is to approach large-scale societal problems that cannot be solved with single moon-shot solutions. Hence, the student's projects consist of a network of design actions, artifacts, platforms and prototypes that aim to address complex issues from a multifaceted perspective.

A variety of instructional methodologies are used throughout the design studios to help students reflect on their purpose as designers and establish their research paths. The multidisciplinary nature of the students as well as the structure of the first term is very influential in terms of cultivating various areas of interest. During the first term, the students are exposed to various thematic with topics ranging from biology and agriculture to machine learning and physical computing electronics to not only broaden their scope beyond their pre-established interests but exceed their preconceived notions and discover new research possibilities. "As a tangible artifact, not an abstract description that requires interpretation" (Beaudouin-Lafon, 2002)

The role of the design studio, which runs in parallel to the different weekly courses, is to aid students to filter all this new information and provide them with the tools to build their own design identity. Through a series of activities and reflection exercises, they are encouraged to focus on an area that they are most passionate about creating change.

As soon as the students have identified their areas of interest, they must start working on creating *interventions,* either individually or in collaboration with other classmates. An "intervention" in MDEF, as defined by the studio's lead professor Oscar Tomico (ELISAVA, School of Design of Barcelona), is *a design action situated in context that involves the community object of study.* Hence, situating the projects in real life context and collaborating with communities that relate to the research areas are the key assessment criteria for the design studio.

Therefore, throughout the year, students are expected to design and develop tools in forms of platforms, workshops, communicative or educational artifacts and prototypes that support or even inspire these interventions.

2.3 Micro-Challenge model

During the first two academic years of the MDEF Master's program (2018-2019 and 2019-2020), an adapted version of the Fab Academy course was transversely integrated into it, following the weekly cycle of the original Fab Academy course as well as the content of the assignments but reduced in its scope. The course structure and concepts, as well as assessment criteria, were closer to the Fab Academy educational goals and principles, focusing more on the learning-by-doing approach rather than on the conceptual outputs of the assignments as per other courses along the MDEF program.

As a result, the MDEF design studio and the Fab-Academy adapted version course felt alienated from one another, as per multiple students' feedback at the end of the program. Even though the content was interesting and potentially useful, the typology of pre-defined exercises presented to them, made the students feel they were lacking the time or opportunity to apply it to their current thesis-project in order to evolve their prototypes according to the knowledge gained and diminishing the capabilities that the range of technologies provided them (Blikstein, 2013).

Therefore, the challenge methodology was primarily conceived as an answer to this problem in an effort to bridge the gap between the two courses and create an integrated and meaningful learning experience for the students. An initial assumption in this context is the need to integrate digital fabrication technologies and rapid prototyping workflows in the master's curriculum. This is considered a crucial part for the students, in order to gain a better understanding of the intrinsic complexities that new technologies might impose on our current realities and the ways in which these realities can influence the future. In return, the master's critical perspective on technology would enrich the "learn by doing" methodology and provide insight into rethinking maker-centered learning experiences in a way that digital fabrication becomes a vehicle and resource for addressing personal or complex societal issues. (Smith, Iversen & Hjorth, 2022)

The main intention of the challenge is to amplify the impact of the design interventions by empowering the students with the knowledge and technical skills to create artifacts that help them investigate and communicate their ideas to their community of practice. In this context, rapid prototyping frameworks provide a means for making design ideas tangible. The projects developed during the challenge are not expected to present singular solutions, but to be part of a wider network of actions and interventions that aim to address the wicked societal problems that the students have been investigating through their design projects. This use of digital prototyping processes fosters development of competencies across a variety of fields such as science, technology, engineering and mathematics commonly stated as STEM competences. Providing an understanding of these digital technologies, supports their ability to interact with their current digital world, giving the opportunity to create their own understanding of it as participatory citizens. *(see Schelhowe, 2012 as cited by Smith et al.2015)*

The challenge is a project development tool as much as a learning methodology, based on the hypothesis that the process of learning by creating something that the students are passionate about increases the level of engagement and enhances their cognitive abilities. Although the challenge methodology has been implemented in the last two consecutive academic years of the MDEF program, we decided to focus on the first one as we have had more time to analyze the projects and reflect on the application of the challenge methodology. Furthermore, the MDEF course evolves and changes slightly every year, and therefore we would have to treat each year as a separate case study in its totality.

3 Methodology

Following the Fab Academy global schedule, the challenges combine four weekly cycles into one intense project-based fabrication sprint. Therefore, the objective is to combine the skills and knowledge acquired throughout the weeks prior to the challenge in order to ideate a small project that is connected to their personal interests and individual or collective interventions. The students have to use the technology and equipment available and focus on the specific skills they have already acquired during the past weeks. This is set as a primary goal to foster the students' capacity to design and conceptualize their projects with the tools and skills they might have available, without limiting the possibilities of what they could achieve. In addition, the challenges align with the MDEF design studio in an effort to connect each challenge topic to the current status of the design interventions of the students. As mentioned before, the intention is to weave the two courses together in order to enhance both for the benefit of the students' projects. The design studio provides a critical context in relation to the technologies developed during Fab Academy, and in return the Fab Academy course yields the skills and knowledge to help physicalize these concepts.

3.1 Challenge Instructional Design (Tools and Platforms)

Each challenge is initiated with an ideation and brainstorming session, where the students are asked to form small groups of either two or three according to their personal interests. For the ideation process, the instructors have prepared a collaborative Miro board with brainstorming templates for each group. The first template is designed to facilitate students to find intersections between their personal areas of interests and their individual projects. Then they proceed to the *project ideation* or first project iteration template where they can include references, sketches and start prototyping ideas in a digital fashion.

The use of Miro has multiple advantages for both students and instructors. Since the past two years, most of the educational programs have shifted to online or hybrid models, collaborative platforms like Miro provide the opportunity for students to work remotely in groups or in a hybrid format, but also to gather their ideas simultaneously in a communal digital space and therefore get inspired from each other's work. (Gerodimou et al., n.d.) The instructors are equally benefited as they can easily access and monitor the progress of the projects and use the boards that feature all the student's work and ideas as a documentation tool for further educational research.

3.2 Challenge Agenda

On the first day, the students are introduced to the challenge brief and are given time to brainstorm on the projects. In the middle of the session, they are asked to present their initial ideas mostly focusing on explaining the common grounds that they detected through the intersection of their personal interests and share some first ideas on how they could approach the project, knowing beforehand the tools and skills they have developed throughout the previous weeks.

This part is important and therefore significantly emphasized in this methodology. The intention of the challenge is to approach digital fabrication and technology in a way that is meaningful and critical for the learner. The technological tools are not the goal, but rather the means for creating integrated projects through the challenge. Hence, time and consideration must be dedicated to the ideation process, for the groups to reflect on meaningful connections that benefit and motivate all team members. After the ideation session is concluded, the students continue to work on the projects while the instructors are available for feedback. In this early stage, the assistance is mostly focused on project planning and conceptualization. Since the time is limited, proper organization and early prototyping is key for the successful development of the challenge.

On the second day students are requested to expose their intentions and project management plan to the rest of the class. This is enforced so that the students gain insights from each other and faculty on whether their initial project statement is in line with the challenge criteria. A second control session is conducted by the faculty at midday to assess any prototyping flaws.

The third day is mostly focused on production, having only one evaluation session, mostly focused on debugging or revising deviations from the initial idea due to problems encountered or time constraints.

The fourth day is mostly spent with one-on-one tutoring in order to finalize the prototypes and assess the presentation's key points. During the week, students are provided with constant fabrication support from the lab experts on machine usage as a guided instruction rather than a fabrication on demand facility. The intention is for the students to familiarize themselves with the fabrication processes in view of eventually becoming autonomous with the tools and machines.

On the last day, the challenge results in a joint presentation from all the groups. It is not necessary for students to present their finalized prototypes, but instead they should explain their design process, concept in relation to their research and reflect on their key learnings and problems encountered. In addition to receiving daily feedback throughout the week, during the final presentation, students can receive comments from a panel of invited faculty related to their subjects.

3.3 Assessment criteria and Deliverables

The assessment criteria of the challenge are defined in alignment with those of the design studio in order to establish a meaningful reciprocal relationship between the two. The challenge briefs, as aforementioned, also correspond to the current status of the design studio and consequently some of the assessment criteria change as the course progresses.

The key points of the assessment, as presented to the students, are the correlation between the challenge project and their individual investigations as well as the possibility of the prototypes to inspire or facilitate design interventions.

Additionally, the assessment criteria correspond with those of the Fab Academy course in terms of the documentation and replicability principles. For each challenge, the groups are asked to create a GitHub repository where they collaboratively document the whole process and development of the project. A detailed evaluation spreadsheet (Figure-3.3.1) of the assessment criteria is shared with the students in advance, which is accessible throughout the year. This way the students can track their progress, understand the strong and weak points of their documentation and proactively ask questions regarding the evaluation criteria.

The overall deliverables of each challenge include a completed repository that covers all the points expressed in the spreadsheet, as well as an individual post on each student's personal website reflecting on key learnings and personal contribution to the challenge. On the final day, the students are asked to present through the repository rather than create a separate presentation.

The evaluation detailed criteria are demonstrated below, as presented in the spreadsheet that is shared with the students.

25%	**INDIVIDUAL POST**
o	Write a post out of personal experiences
o	Explain your contribution to the project
o	Reflect about learning outcomes
o	Add link to the challenge section and repo
30%	**ACADEMIC LEVEL** ***Level of the project (quality and complexity of the designed prototype/code/artifacts)***
o	Linked to your individual pages
	Initial idea / Concept of the Project (aligned to research areas)
o	Propose (What is supposed to do or not to do)
o	Shown how your team planned and executed the project
o	System diagram (illustration explaining function, parts, and relations)
o	Integrated Design (How you designed it - relation between elements)
	Honest Design (use of technology in a meaningful way) Relation to the topics
	Be creative (find solutions with materials and technology you have)
	Explore design boundaries (based on your expertise)
o	Listed future development opportunity for this project
30%	**REPLICABILITY** ***Level of clarity and detail of the documentation material (photos, video, text, etc)***
o	How did you fabricate it (fabrication processes and materials)
o	Design & Fabrication files (open source or open format)
o	BOM (Build of Materials)
	Iteration Process (spiral development)
o	Described problems and how the team solved them
o	Photographies of the end artifacts
10%	**ATTITUDE** ***Involvement, Motivation level, proactive behaviors***
o	Attendance to classes
	Proactive behaviors to find answers during the challenge
o	Help others student's projects
o	Participation in feedbacks sessions
	Dealing with uncertainty
	Don't be afraid to make mistakes (going out of your comfort zone)
5%	**EXPLOSION**
	Explode
	Green = 1
	Orange = 0.8
	Red = 0

Fig: 3.3.1 - Evaluation criteria spreadsheet

Each topic holds a percentage of the final grade, and each requirement is evaluated on a scale of 0 to 2: 0 (red) meaning that the student has not submitted, 2 (orange) that a certain part of the requested documentation is missing, and 1 (green) that the basic criteria are met. The green colour is not indicative of the quality of the documentation, but rather signifies that the task is completed. The grade is defined later amongst all the instructors and faculties, considering additional assessment criteria.

INDIVIDUAL POST									
Write a post out of personal questions	1	0	1	2	2	0	1	2	0
Explain your contribution to the project	0	0	2	0	0	0	0	0	0
Reflect your learning goals	2	2	2	2	2	0	2	2	0
Add link to the challenge section and repo	0	0	1	0	0	0	0	2	0
ACADEMIC LEVEL *Level of the project (quality and complexity of the designed prototype/code/artifacts)*									
Linked to your individual pages	1	0	1	0	0	1	0	1	0
Initial idea / Concept of the Project (aligned to research areas)	1	1	1	1	2	1	1	0	2
Propose (What is supposed to do or not to do)	1	1	1	1	1	1	1	1	0
Shown how your team planned and executed the project	0	2	2	2	2	0	1	0	2
System diagram (illustration explaining function, parts, and relations)	2	2	1	1	2	2	1	2	2
Integrated Design (How you designed it - relation between elements)	0	2	1	1	2	0	1	0	1
Honest Design (use of technology in a meaningful way) Relation to the topics	1	1	1	1	1	2	1	1	1
Be creative (find solutions with materials and technology you have)	1	1	1	1	1	2	1	1	2
Explore design boundaries (based on your expertice)	2	1	1	2	1	0	1	0	2
Listed future development opportunity for this project	1	0	1	1	0	0	1	0	0
REPLICABILITY *Level of clarity and detail of the documentation material (photos, video, text, etc)*									
How did you fabricate it (fabrication processes and materials)	1	2	1	2	2	2	2	0	0
Design & Fabrication files (open source or open format)	1	1	1	2	0	0	0	0	0
BOM (Build of Materials)	1	0	1	0	0	0	0	0	0
Iteration Process (spiral development)	1	2	1	1	1	0	2	0	0
Described problems and how the team solved them	1	0	1	1	2	0	0	0	0
Photographies of the end artifacts	1	2	1	1	1	1	1	2	2
ATTITUDE *Involvement, Motivation level, proactive behaviors*									
Attendance to classes	1	1	1	1	1	1	1	1	2
Proactive behaviours to find answers during the challenge	2	1	1	2	2	0	1	1	0
Help others student's projects	0								0
Participation in feedbacks sessions	1	1	1	1	1	1	1	1	0
Dealing with uncertainty	2	2	1	2	1	0	1	1	1
Don't be afraid to make mistakes (going out of your confort zone)	1	1	1	2	1	2	1	1	1
EXPLOTION									

Fig: 3.3.2 - Evaluation documentation spreadsheet

3.4 Case Studies (Student´s projects examples)

We have selected four student projects for each of the four challenges conducted during the academic year of 2020-2021. Additionally, we have included a fifth project that has been deployed throughout all four challenges. Each project encapsulates the main objectives of each challenge's goals and methodology, which is enabling students to create meaningful projects in relation to the technological tools taught over the previous weeks and the capacity to combine them with their design interventions that are being developed concurrently in the design studio.

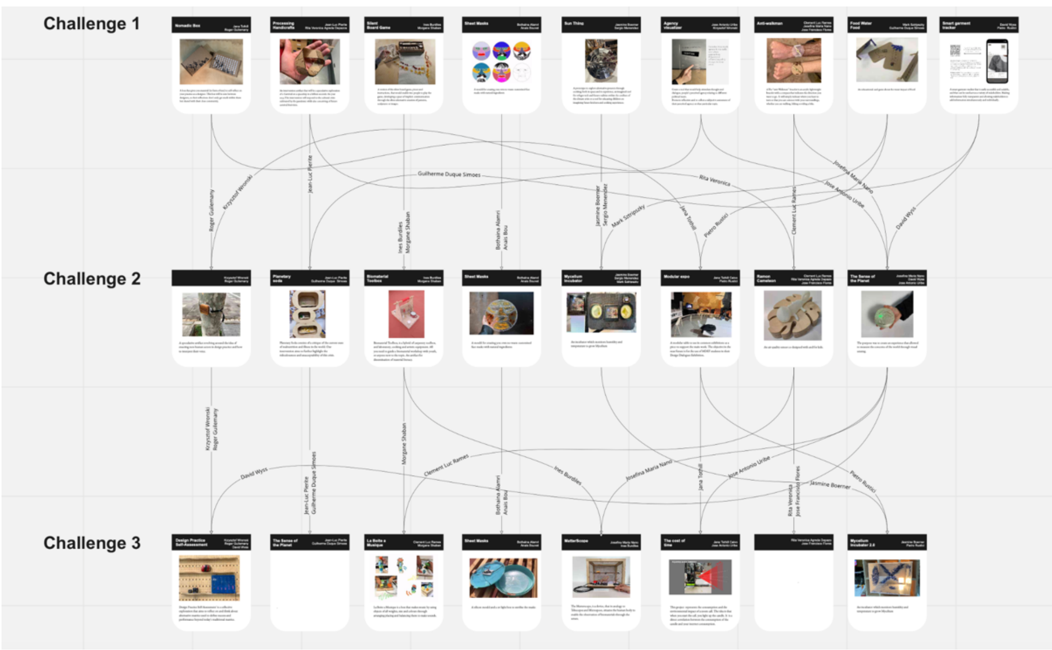

Fig: 3.4.1 - Challenges outputs interrelation

Case Study challenge 1: "The silent board Game" [20]

- ***Topics***: Principles and Practices, Computer aided Design and Computer Controlled Cutting, Electronics production(optional)
- ***Challenge brief:*** "Design and make something that can help the process of designing/creating/thinking/collaborating with others".
- ***Students***: Ines Burdiles, Morgane Shaban

The two students were working on individual design projects throughout the year, but due to the challenge, they found a common ground to explore both of their interests. Ines was focused on biomaterial exploration and the emotional impact of materials, and Morgane was interested in how children's agency can be empowered through play. Therefore, they decided to develop a version of the silent board game[1] "that *would enable two people to play the game, developing a space of implicit communication through the silent alternative creation of patterns, sculptures or images*" (Habraken & Gross, 1987).

The group designed and fabricated the game with plywood, fabric and acrylic using the laser cutting machine for different purposes. They created a press-fit box to contain the pieces from plywood, engraved the instructions of the game on canvas fabric that was integrated into the design of the box and used the acrylic to cut out the pieces of the game and its negative as a mould in order to create more pieces from biomaterials. Since both students were passionate about sustainability, an important part of the fabrication was to take advantage of the materials used to minimize waste during the fabrication process.

Their project was successful in terms of the objectives of the challenge, as they developed a prototype that was aligned with their research interests and additionally enabled them to collaborate with others and enrich their design interventions. The game was both a functioning prototype and a tool to communicate their projects to their communities-objects of study. In this case, the challenge worked as a project development tool for the students, as it allowed them to advance their individual research and inspired further interventions and collaborations with communities.

Fig: 3.4.2 – The Silent Board Game

[20] "The Silent Game is about implicit understanding among design participants through making patterns and conjecturing patterns in making forms. The game involves two kinds of acts: inventing patterns and guessing patterns. The game needs at least two players. Players take turns inventing patterns for the other(s) to guess, and guessing the patterns made by other players. Patterns involve selections of pieces and spatial relations among the pieces and are expressed only by placing pieces in the site. A player is assumed to understand the patterns if s/he can make moves to continue the configuration without objections from the other player(s). Patterns remain implicit throughout the game, and no verbal or any other kind of explicit communication is allowed. Therefore, the game is silent. (Habraken & Gross, 1987)

Case Study challenge 2: "Pascal, the Chameleon"

- ***Topics***: 3d scanning and Printing, Electronics Design, Computer Controlled machining, Embedded programming (optional)
- ***Challenge brief:*** "Develop an artifact that allows you to explain your project to others" or interact with others so that they understand your research project."
- ***Students***: Rita Veronica Amparo Agreda de Pazo, Clément Luc Rames, José Francisco Flores Carreño

Developed during the second challenge, the chameleon is an air quality sensor co-designed with and for kids. In this case the student's interests were quite diverse, but all equally represented in the project. José and Clément were interested in spatial justice, co-design and participation methodologies for citizens engagement and Veronica was interested in education focused mostly on women and children.

In their project repository, the students describe the chameleon as a communication and educational artifact. Pascal changes colour as a function of the ambient air quality and is therefore able to demonstrate environmental data in a way that is more accessible to children. This way, complex topics like pollution in cities, public health, climate emergence as well as technological concepts (sensors, etc) can be introduced playfully. Additionally, the way the team designed the artifact involved co-creation methods with the community object of study. Veronica's daughter crafted the chameleon's shape out of playdough and then the team created the digital model by 3d scanning, taking advantage of the technologies included in the challenge. The base containing the electronics is fabricated with CNC and the electronics are visible from below for the kids to interact with the technology even at a subconscious level.

In this case, two of the students were more advanced in terms of technical skills, which allowed them to create a high-quality functioning prototype. However, this fact had little influence on the assessment criteria. What was more significant in this case was the participatory design approach, the successful alignment of their individual interests as well as the use of the prototype in real context, as they subsequently used the artifact in educational workshops with children.

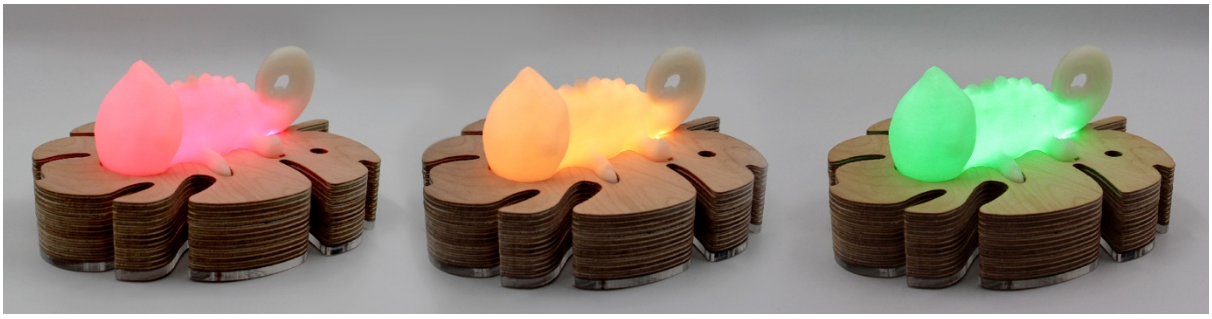

Fig: 3.4.3 – Pascal: colour indications according to air quality

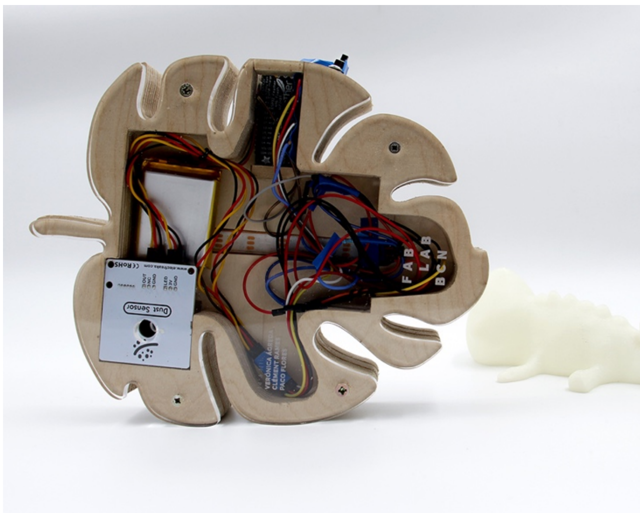

Fig: 3.4.4 – Pascal: Hardware Integration

Case Study challenge 3: "Design Practice Self - Assessment"

- ***Topics***: Input devices, moulding and casting, output devices, networking and communications
- Challenge brief: "Design and make a tool or strategy that in combination with your artifacts help you measure the impact of your interventions"
- Students: Roger Guilemany, David Wyss, Krzysztof Wronski

The students' research projects, in this case, had a more theoretical background aiming to critically examine and rethink the design practice under the prism of posthumanism and interspecies collaboration. Inspired by the challenge brief that was to design something that measures the impact of an intervention, the students decided to work on a self-assessment artifact that would provoke designers to critically reflect on their design practice and its impact. As described in the repository of the student's documentation, the "Design Practice Self-Assessment" is a collaborative exploration of alternative metrics for measuring success and performance beyond today's traditional ones. With the intention of transcending the limits of conventional formats, this project explores ways to encourage designers to think about posthumanism and its impact on industry, people, social systems and cultural values.

The device consists of five columns, each representing one assessment topic relating to posthumanist practices. Each topic-column is measured on a scale from 1-10 by pressing the button dedicated to each column. The front panel is designed to create openings for the buttons and light arrays to display the data. The user can add multiple projects by pressing the new button and eventually see the average of all the projects measured by pressing the update button. As a result, the designer can gain an overview of their practice over time based on criteria defined in the beginning.

This project is an interesting example of physicalizing an abstract and theoretical concept through a device/ artifact, while at the same time connecting to both the individual projects and the challenge brief. Another important aspect has to do with the fabrication processes chosen by the students in relation to the topic. The group decided to fabricate the panels with recycled plastic, as they considered that using virgin materials would contradict their critical reflections on equitable and sustainable design practices. In this case, digital fabrication becomes part of the narrative and an equally crucial part of the design process, rather than just a means to an end.

Fig: 3.4.5 – Design Practice Self-Assessment Final Prototype

Case Study challenge 4: "Magic Twister"

- ***Topics***: interface and application programming, wildcard week, applications and implications, invention / intellectual property and income
- ***Challenge brief:*** "Integrated prototype that helps your MDE Fest's intervention and combines the range of units covered"

- ***Students***: Alejandra Tothill Calvo, Roger Guilemany, Pietro Rustici, Clément Luc Rames

The fourth and last challenge was the least demanding in terms of fabrication. As the students approached the end of the course the intention was to focus on their final thesis and interventions and therefore the challenge was designed to assist with that process without adding more tasks that might not be valuable for all student's projects. Hence, they were encouraged to be more autonomous and to reflect on what technologies would be useful when developing their final prototypes instead of being restricted to using specific tools.

Consequently, the main brief provided to the students was to develop a prototype that would help with their final design interventions using any of the units covered throughout the year, while also developing a long-term dissemination strategy and a way of sharing/communicating their project in order to reach communities and increase impact.

The Magic Twister project is, therefore, an online exhibition through a website developed by the students, in view of sharing the resulting pieces and reflections gathered throughout their master research. Their idea was to create a virtual universe of 3d objects that would allow users to explore them and their related information in an interactive and engaging way. Two of the students in this group, who had been working together throughout the master's program, had collaborated on the first challenge in which they created a box that was used to distribute and collect the objects (Fig: 3.4.7) to their community object of study, in this case local designers. It is, therefore, interesting to see how the challenges can both inspire interventions and as the course progresses support and help students communicate the results of these interventions to a wider audience

Fig: 3.4.7 – Nomadic Box physical objects

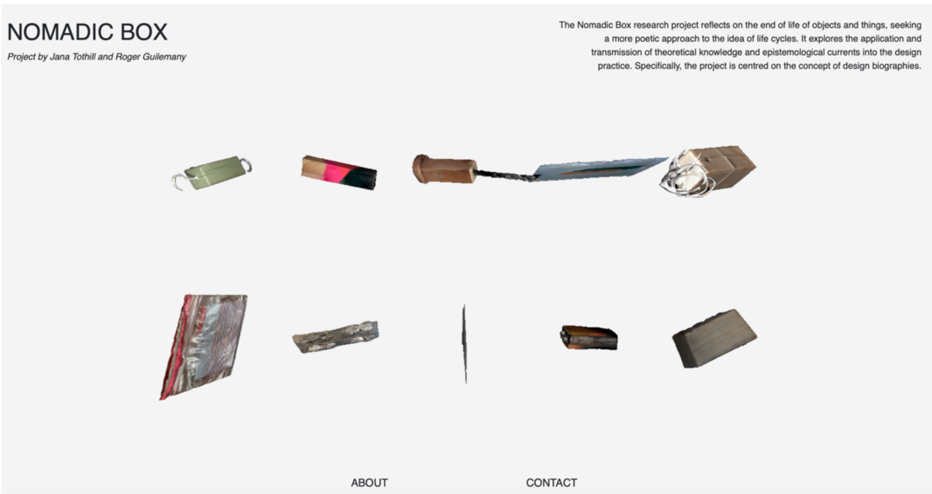

Fig: 3.4.8 – Nomadic Box online exhibition (Website Screenshot)

Challenges 1,2,3,4: Face Masks

- **Topics:** (all the above-mentioned)

- **Students:** Anais Bouvet and Botaina Rafaa A Alamri

In this case, the two students collaborated for all the challenges. Their areas of interest revolved around sustainability, the environmental impact of production waste and alternative materials. Focusing primarily on the cosmetic industry and the waste produced by one-use face masks, they decided to prototype a mould for creating do-it-yourself (DIY) customized face masks with natural ingredients.

This project is a great example of how the four challenges could work as a continuous exercise in order to evolve the same idea with different digital fabrication methods. Apart from using the technologies in correlation with their design projects, the group was able to get a deeper understanding of how each fabrication method could be beneficial for their purpose and the ways in which they could enrich their prototype with the use of different tools. It is important to mention that neither of the two students had extensive prior experience with digital fabrication.

For the first challenge the fabrication methods were limited to Principles and Practices, Computer aided Design and Computer Controlled Cutting. Therefore, the group created the first mold by laser cutting acrylic, as it had to be waterproof in order to be able to pour the bio-based recipes. The technology presented some limitations, as they could not create smoother edges that would help with demoulding the masks.

Fig: 3.4.9– Face Mask Mould: 1st Challenge Prototype

Therefore, during the second challenge that included CNC (numeric controlled cutting) they were able to optimize their design by making rounded edges. As the students mentioned in their presentations at the end of the second challenge, this was a valuable learning outcome as they were now able to understand the limitations and possibilities of the different manufacturing methods and could therefore be more proactive when designing or prototyping in the future. They also used 3d scanning to scan their classmate's faces in order to investigate how they could personalize the size and shape of the moulds and printed one of the scanned models in order to test the size of the masks.

Fig: 3.4.10– Face Mask Mould: 2nd Challenge Prototype

During the third challenge which included electronic hardware and coding, the team decided to create a sterilizer box for the silicon moulds of the face masks, taking as a reference the sterilization phone boxes that use UV light LEDs to kill bacteria on electronic devices. The design of the box required a UV LED, an Arduino board and an ESP32, and a relay. In this case, the challenge worked as a learning opportunity. While the object itself wasn't essential to the project's development, it motivated the group to tackle complex topics they didn't have prior knowledge of.

Fig: 3.4.11– Face Mask Sterilization box: 3rd Challenge Prototype

For the fourth and last challenge, the main objective, as explained in the previous case study, was to reflect on a long-term dissemination plan and explain the strategy they would use to share their project with potential users. Therefore, the team decided to work on a website that would eventually function as a platform to share open-sourced recipes in view of creating a community around natural face masks and sustainable cosmetics.

3.5 Problems and Challenges

As aforementioned, MDEF master students come from different disciplines with a wide range of skills and expertise. Most of the students are not proficient in digital fabrication, and only a small portion has prior knowledge of more complex topics like electronics and coding. Thus, the instructional team must provide substantial technical support to ensure that the challenge is a fertile learning ground and not overwhelming and intimidating. Moreover, due to the short time frame of the challenge and the group work modality of the course, some students who were less experienced with the topics felt as though they didn't have enough time to become independent with the technologies, as they had to rely on their more experienced classmates in order to complete the project on time.

It was also clear as the course progressed that not all the challenges had the same importance or were equally beneficial to the students. Specifically, on the last challenge, students lacked engagement as they were more focused on finalizing their final studio deliverables. Additionally, as the end of the course approaches and the projects are mostly defined, it was evident that the challenge was more beneficial to certain types of projects that were more focused on technology or needed to fabricate artifacts for their final interventions.

Furthermore, the more complex the topics became regarding technological skills, the more difficult it was for the students to foresee prototyping issues and manage the workload. Particularly, students that lacked experience, for example with coding and electronics, were less proactive and struggled to ground their ideas in relation to what was possible in the short timeframe provided. Nonetheless, these students seem to gain valuable insights on project management and the importance of adapting fast according to one's capabilities and limitations.

4 Conclusions and Contributions

Several insights regarding rapid prototyping learning approaches have been derived from the research performed so far pertaining to the practice-based education design challenges model. Rapid prototyping on focused and restricted topics (enforcing the use of a specific set of digital prototyping tools) have pointed to an increase in creativity and the development of project management skills. Because MDEF students' projects might shift throughout the year and different collaborations might be formed, the challenge could be just a brief expression of an interest that might be disconnected from the final project. In that case, the challenge works as an exploration tool where the students can engage with certain topics and ideas and filter what is or isn't important for their individual projects.

In every challenge, students were given constraints regarding the technologies and tools they should use, in order to not become overwhelmed by the lab's wide range of capabilities. This allowed them to focus more on the ideation process and in certain cases get inspired by one specific manufacturing process that they might not have engaged with otherwise. The short timeframe provided forced students to concretize and therefore physicalize their abstract project ideas, as well as make quick design decisions and dive quickly into an iterative prototyping process. All of the above might have otherwise required more time or remained only in the ideation phase due to overlapping with the other courses' deliverables.

Furthermore, the research team has detected novel research paths in relation to the micro-challenge methodology that have to do with the interchange of knowledge, skills, and design sensibilities between the students, amongst all four challenges. The students had to work together in different groups and develop various projects based on the intersections of their diverse interests, backgrounds, and skills. As a result, each team member had a unique contribution in terms of mentality, knowledge, and capabilities. Students were actively learning from each other and were inspired by their classmates' unique perspectives and distinct approaches to design and prototyping. Often, more technical profiles aimed to collaborate with classmates that were more creative or theoretical and vice versa. According to the students, this enabled them to develop stronger concepts and better prototypes. Additionally, the mandatory group-work format of the challenge methodology nourished collaborations that were maintained throughout the program. Through the ideation process, by focusing on detecting intersections between their areas of interest, some students discovered surprising commonalities that inspired them to collaborate on design interventions after the completion of the challenge. The research team aims to further explore this topic by mapping the student's trajectories, throughout the challenges, to assess how this transversal interaction influences their final projects and learning development.

It is important to note that the case studies discussed here only provide a small explanatory probe, similar to other outcomes of the courses. Due to the research methodology set out at the beginning of previous academic terms, insights have been gained from all the case studies and workshops that have taken place.

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