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3D Printing for Social Innovation: analysis of case studies from a Design perspective to define guidelines

Impressão 3D para Inovação Social: análise de estudos de caso sob a ótica do Design *para a definição de diretrizes*

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ABSTRACT

This work is derived from research that establishes the relationship between Additive Manufacturing (AM) and Social Innovation, from Design perspective, and aims to propose guidelines for inserting 3D Printing in socially beneficial projects/businesses, especially in interior communities. It is characterized as applied in nature, with a qualitative approach, exploratory in objectives terms and bibliographical. Its procedures include case studies, these being multiple, selected for generating 3D printed products and causing social impact in a given context, which are presented and analyzed, and research documentary. As preliminary results, the advancement of AM Industry was verified, the increase in 3D printed prototypes, the increase in demands regarding co-design, Design presence in the cases analyzed and the emphasis on disadvantaged contexts.

Keywords: Design. Social Innovation. 3D Printing. Additive manufacturing.

RESUMO

O presente trabalho é derivado de uma pesquisa que estabelece a relação entre Manufatura Aditiva (AM) e Inovação Social, sob a perspectiva do Design*, e objetivou propor diretrizes para inserir a impressão 3D em projetos/negócios socialmente benéficos, especialmente em comunidades interioranas. É caracterizada como de natureza aplicada, de abordagem qualitativa, exploratória quanto aos objetivos e bibliográfica. Seus procedimentos incluem estudos de caso, sendo estes múltiplos, selecionados por gerarem produtos impressos em 3D e causarem impacto social em determinado contexto, que são apresentados e analisados, bem como pesquisa documental. Como resultados preliminares, verificou-se o avanço da indústria AM, a crescente de protótipos impressos em 3D, o aumento de demandas referentes ao* codesign*, a presença do* Design *nos casos analisados e a ênfase em contextos desfavorecidos.*

Palavras-chave: Design*. Inovação social. Impressão 3D. Manufatura aditiva.*

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INTRODUCTION

The world has been plagued by social problems such as hunger, violence, inequality, inadequate housing, water scarcity, and lack of basic sanitation, among others. Despite being widely reported, these issues often do not receive the necessary attention. In this context, it is essential to promote practices that aim for the common good, combining knowledge and skills.

The United Nations (UN) estimated that, in the first half of 2023, 360 million people worldwide needed humanitarian aid — 30% more compared to the same period the previous year — which equates to one in every 22 inhabitants of the planet. The UN also highlighted that the causes of this increase include unresolved conflicts, global economic problems exacerbated by COVID-19, and the impact of the Russian invasion of Ukraine (UN, 2023).

In this context, Social Innovation emerges to generate new ideas (products, services, and models) developed and implemented to satisfy social needs and create new relationships or collaborations. It addresses the urgent demands of society by influencing the dynamics of collective interactions. Therefore, it aims to improve human well-being (Hahn; Andor, 2013).

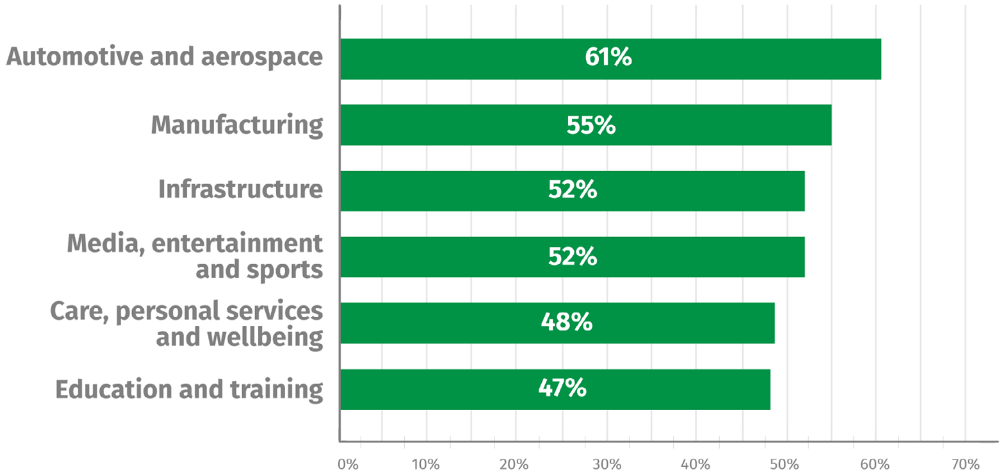
From this perspective, designer and educator Victor Papanek (1971) is known as a pioneer of the thought advocating environmental and social responsibility. He asserted that designers must make their skills accessible to the world and work to solve community problems. In contemporary times, Manzini (2017) relates Social Innovation to Technological Innovation, noting that this collaboration helps identify new solutions to specific problems. This union has transformed infrastructure, production, and consumption systems.

That said, one of the technologies gaining notoriety is 3D printing. This production process, operated by a computer, adds material in layers and is part of the new technologies capable of causing global transformations. It is emerging and revolutionary, with the potential to alter the last two centuries of design and manufacturing approaches, leading to economic, geopolitical, demographic, social, environmental, and security consequences (Campbell *et al*., 2011).

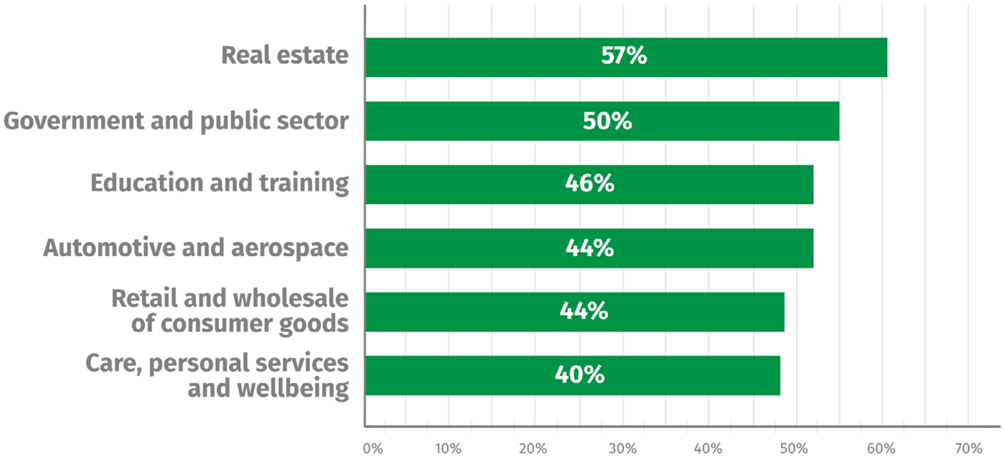
According to The Future of Jobs Report by the World Economic Forum in 2020, 51% of companies worldwide could be using 3D printing by 2025. The 2023 edition indicates that the sectors expected to adopt 3D printing the most by 2027 are: automotive and aerospace (61%), manufacturing (55%), infrastructure (52%), media, entertainment, and sports (52%), care, personal services, and well-being (48%), and education and training (47%) (Figure 1).

The sectors most impacted in terms of jobs will be: real estate (57%), government and public sector (50%), education and training (46%), automotive and aerospace (44%), consumer goods retail and wholesale (44%), and care, personal services, and well-being (40%) (World Economic Forum, 2023) (Figure 2).

The Additive Manufacturing (AM) market value surged from 3.1 billion to approximately 18 billion between 2013 and 2022 (Figure 3). The 2023 Wohlers Associates report highlights this growth, noting the involvement of more than 400 organizations from ten industry sectors. These organizations consequently impact various groups of people and address a wide range of needs.



Source: Adapted from World Economic Forum (2023).
Figure 1. Sectors with highest adoption of 3D Printing [2023–2027].

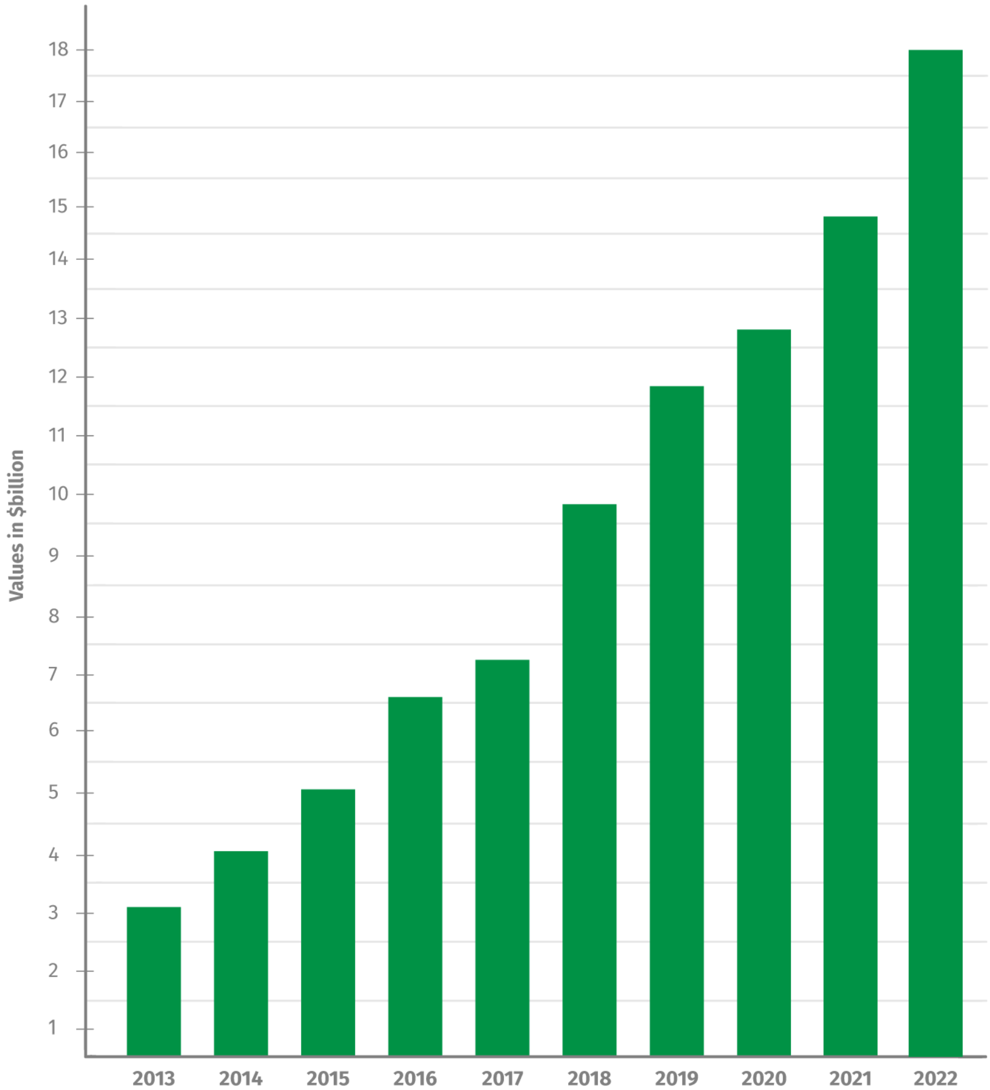


Source: Adapted from World Economic Forum (2023).
Figure 2. Sectors most impacted by 3D printing on jobs [2023–2027].

In the field of Design, 3D printing has revolutionized the industry, particularly in prototyping. This phase involves representing the selected solution and checking control points and fundamental issues. The physical models produced through 3D printing can closely resemble the final product in terms of detail, fit, and finish (Prado; Sogabe, 2022). Moreover, 3D printing is now also capable of producing fully finished objects.

Given the presented panorama, 3D printing can be an important technological vector for Social Innovation. It can be used to assist communities disadvantaged by various problems, thereby addressing their urgent needs.

Thus, this research is applied in nature, utilizing a qualitative, exploratory approach. It involves bibliographical methods and procedures, including case studies with multiple cases presented and analyzed. These cases are selected based on their generation of 3D-printed products and their social impact in a specific context, supplemented by documentary research.



Source: adapted from Wohlers Associates (2023).
Figure 3. Market value of the Additive Manufacturing Industry.

SOCIAL INNOVATION

Social Innovation is a term that was first used in the early 1970s, in an academic publication by Taylor (1970) focusing on learning from people at risk. Later in the same year, Gabor (1970) published a study addressing social innovations aimed at territorial development, emphasizing the local nature of these initiatives.

From this perspective, the concept of Social Innovation is related to changes in how individuals or communities address their own problems or create opportunities (Manzini, 2008).

Social Innovation can be divided into six stages, which range from the formation of ideas to the impact they produce. These stages do not necessarily follow a linear sequence, as some innovations may focus directly on “practice” or “scaling,” and feedback cycles can occur throughout the stages. The stages are: requests, inspirations, and diagnoses; proposals and ideas; prototyping and pilots; sustainability; scaling and diffusion; and systemic change (Murray; Caulier-Grice; Mulgan, 2010).

Considering the local context, Bacon, Mulgan, and Woodcraft (2008) propose a model for integrating innovation into communities, which involves three axes: authority, organizational capacity, and value (Figure 4).

Source: Adapted from Bacon, Mulgan, and Woodcraft (2008).
Figure 4. Strategic model for local Social Innovation.

ADDITIVE MANUFACTURE/THREE DIMENSIONAL PRINTING

The principle of manufacturing by adding material, known as AM or 3D printing, emerged at the end of the 1980s. This process involves the gradual addition of material in layers, based on data from a computational 3D geometric model of the object (Carvalho; Volpato, 2017).

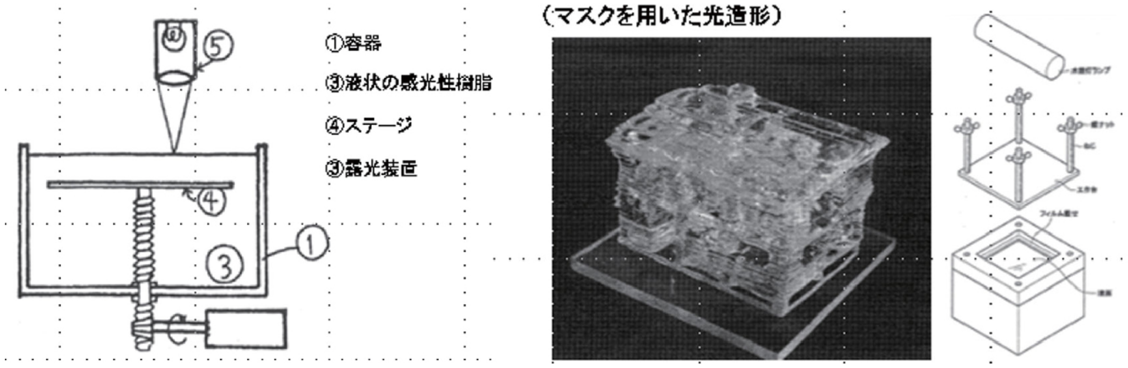
The patent application for a rapid prototyping system by Japanese doctor Hideo Kodama, from the Nagoya Municipal Institute of Industrial Research, in May 1980, marks the beginning of AM equipment. The technology was described as a "vat of photopolymer material (a type of resin), exposed to UV light, which makes the part rigid and produces layer-by-layer models" (Figure 5). However, the registration was not successful (Lonjon, 2017).

Currently, the stages of this productive environment, as described by Carvalho and Volpato (2017), are:

- three-dimensional modeling;
- conversion of the 3D geometric model to a format suitable for AM;

- process planning for layer-by-layer production: slicing and delimiting support structures and material deposition techniques;
- manufacturing the object using AM equipment (3D printer);
- post-processing.

Figure 6 illustrates each of the steps.



Source: Institute of Electronics, Information and Communication Engineers (2014).
Figure 5. Photopolymer vat with ultraviolet light exposure.

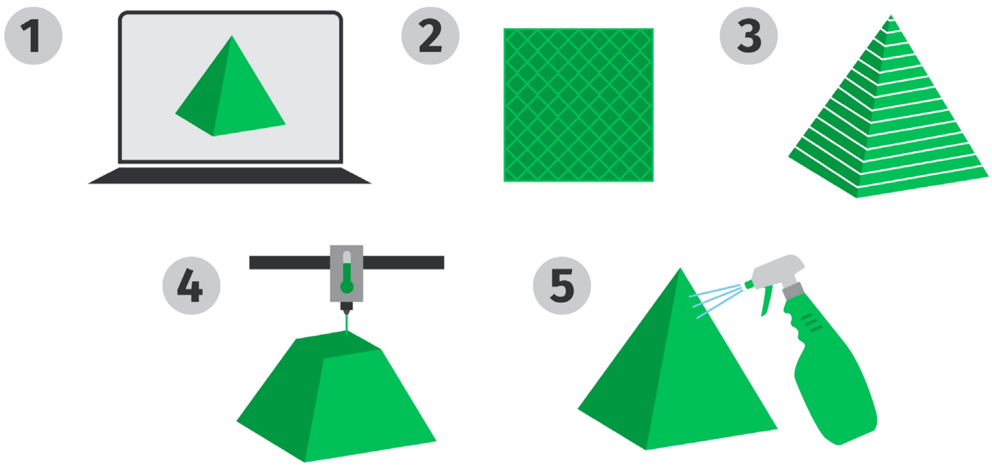


Figure 6. Stages of 3D Printing.

DESIGN FOR SOCIAL AND TECHNOLOGICAL INNOVATION

Design focused on Social Innovation is not a new discipline. It leverages skills and capabilities in various combinations to promote and support socially positive actions, facilitating, sustaining, and guiding paths of social change aimed at sustainability (Manzini, 2017).

In this field of Design, the objective is to develop products, services, processes, and policies that more effectively meet the needs of social groups. The focus is on solutions that enhance the use of existing but underutilized resources (Niemeyer, 2017). It is important to highlight the scope and relevance of Design beyond products and services, as it can also foster new processes and influence the political sphere.

In terms of approach, co-design is commonly adopted to guide socially innovative projects. Designers act as facilitators and members of multidisciplinary teams, involving various stakeholders such as recipients, investors, whether from public or private sectors, communities, and others (Niemeyer, 2017).

It is also worth noting that innovations reflect and originate from various activities and technological capabilities, including experiments, creative models, and solutions based on Engineering, Design, and Research and Development (R&D). Technological Innovation, defined as process and product innovation, that is, new features implemented by production sectors — through research or investments — enhances the efficiency of the production system (Leal; Figueiredo, 2021), which may be related to Design.

In this context, design is viewed as an activity within the broad field of Technological Innovation. It is involved in the stages of product development, addressing aspects such as use, utility, function, production, and formal/aesthetic quality (Hsuan-An, 2017). Design contributes to improving techniques, reducing resource use, and creating new possibilities for developing products and services, among other benefits.

When examining the relationship between the two types of innovation, it is noted that Social Innovation often relies on technology as a key vector, while Technological Innovation has the potential to create social impact by reaching various segments of society. In this way, both types of innovation can collaborate to rethink systems and devices, moving away from marketing logic and focusing on benefiting society.

Case studies

To investigate and demonstrate the use of AM in projects promoting Social Innovation, case studies were employed. This research method involves collecting and analyzing information about individuals, families, groups, or communities. It examines various aspects of life with an emphasis on rigor, objectivity, originality, and coherence as fundamental requirements (Prodanov; Freitas, 2013).

The selection was based on several pre-established criteria, including: generating social impact, producing tangible products through 3D printing, operating globally regardless of the area, and having been active for at least three years. For the search, only reliable sources were considered, such as official project pages on the internet and scientific articles found in institutional repositories or journals. The search terms used were: "3D Printing and Social Innovation" and "*Impressão 3D e Inovação Social*."

Five cases were selected, prioritizing diversity in geographic, social, and cultural contexts, with each case representing a different country and segment. Additionally, the cases address urgent needs of the communities involved, aligning with the future objectives of the research.

The cases were structured into the following topics (Torres, 2016):

- Context: definition of the condition in which the community was found during the initial phase of the project's team intervention, which later points out strategies to address identified problems;
- Actors (stakeholders): Identification of the agents involved in the innovative process;
- Description of the development: Detailing the stages of the adopted process, encompassing the codesign approach, methods, and tools used;
- Results: Presentation of the project's outcomes, which were delivered and implemented for the benefit of the community;
- Impact: Verification and measurement, when possible, of the impact caused by implementing the results, demonstrating the transformation in the local reality. This understanding of the benefits brought about by Social Impact Design contributes to its appreciation by the population.

Case 1: AcuaLab Filter

Background

The AcuaLab filter is a project by FabLab Nariño, a digital manufacturing laboratory located in the coastal community of Nariño, Colombia, which has around 1.6 million inhabitants according to the 2018 Census (Gobernación de Nariño, 2020). The project aims to treat water from sources that are difficult to access, assisting in finding potable water in the Pacific region. It promotes cocreation and collective participation in the development of prototypes and customized manufacturing tailored to the specific context or need (Sec.Tic, 2018).

Actors

FabLab Nariño was established by the Secretariat of Information Technology, Communications, Innovation, and Open Government (Sec.Tic) of the Government of Nariño. It is an open space that provides free services, including monitoring and advice on digital manufacturing, supporting projects, enterprises, and social needs (Sec.Tic, 2018) (Figure 7).

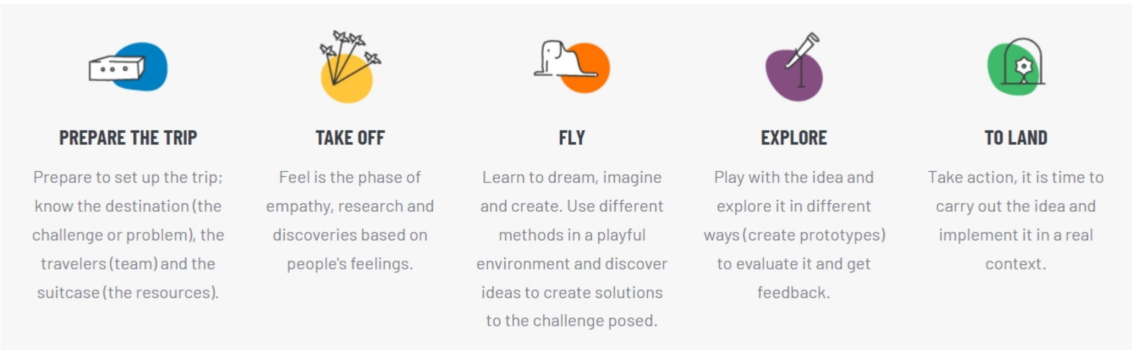
The laboratory provides society with access to emerging technologies in a sustainable manner through training, collaboration, and the development of AM projects. It also operates on an itinerant basis to extend its reach and enhance participation in local regions (Sec.Tic, 2018).

Development description

Designed for user-specific manufacturing, the AcuaLab personal filter aims to empower communities through maker and Do It Yourself (DIY) trends. These trends involve users making, repairing, or altering objects themselves, using specific techniques and tools for each case. The filter was developed using the Feeling method, an open-source social technology originating in Latin America. This method is divided into five phases: "Prepare for the Trip," "Take Off," "Fly," "Explore," and "Land" (Feeling, 2023).

The description of each of them is presented in Figure 8.

Source: Social Innovation Center (2019).
Figure 7. AcuaLab Filter Manufacturing Workshop



Source: Feeling (2023).
Figure 8. Steps of the Feeling Method.

Results

The developed product is divided into parts (FabLab Nariño, 2019) (Figure 9):

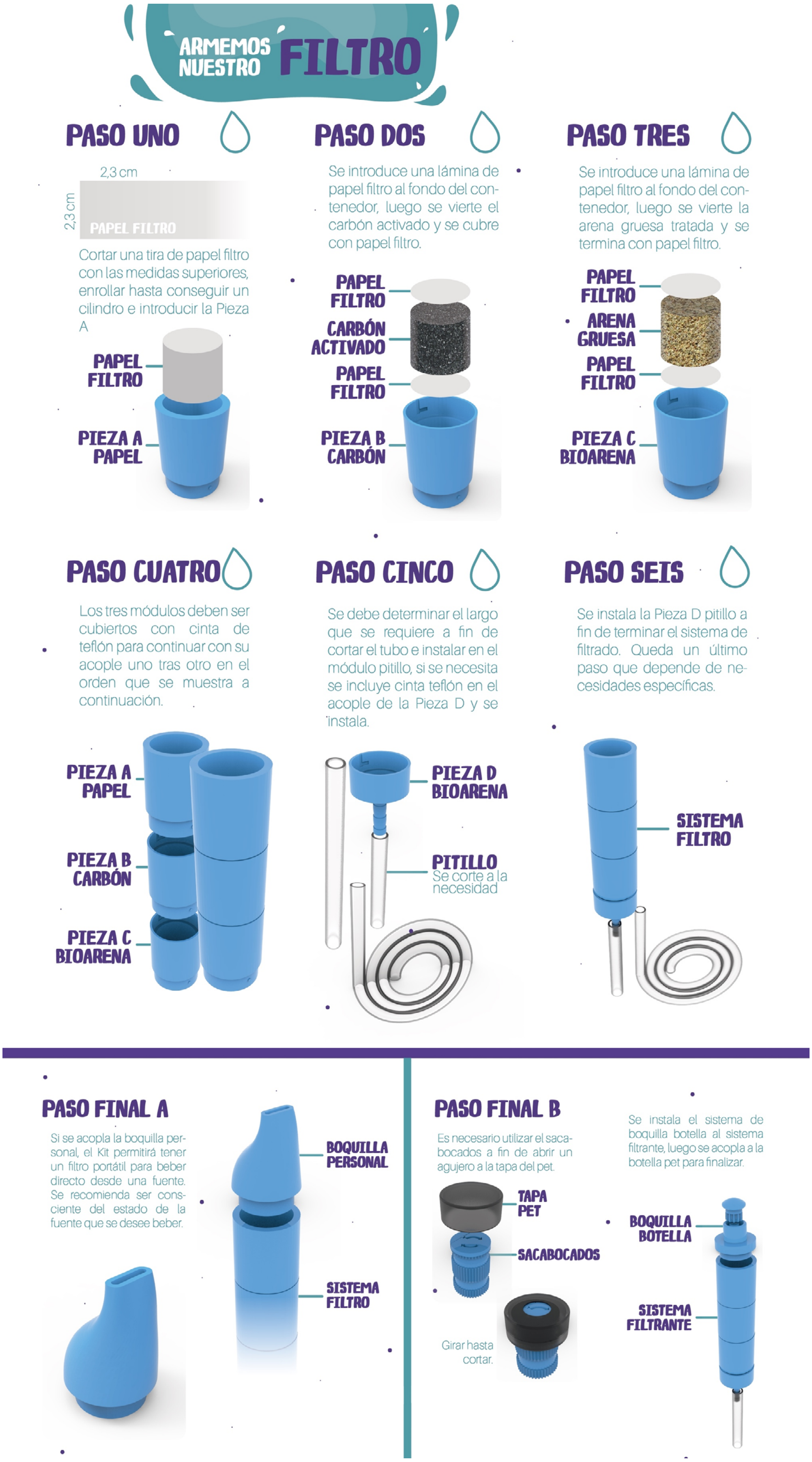
- Spout: allows the use of the filter in polyethylene terephthalate (PET) containers, giving a new use to plastic that would otherwise be discarded, and provides a personal water container;
- Part A: assembled with a paper filter to retain impurities and particles, with the cylindrical part distinguishing it from the others;
- Part B: contains activated carbon filter, a particulate material encapsulated within the container, and should be accompanied by two paper filters, one above and one below;
- Part C: contains treated sand filter that is encapsulated and should be accompanied by two paper filters, one above and one below;

Source: FabLab Nariño (2019).
Figure 9. Parts of the AcuaLab Filter.

- Part D: it is a straw, the end of the filter, designed to be connected to a type of hose, facilitating the product's access to the water source.

And, for the filter to be used, the following steps must be followed (FabLab Nariño, 2019) (Figure 10):

- Step 1: cut a strip of filter paper to the appropriate size (2.3x2.3cm), roll it into a cylinder, and insert it into Part A;
- Step 2: place a sheet of filter paper at the bottom of the container, pour in the activated charcoal, and add another sheet of filter paper on top of it;
- Step 3: place a sheet of filter paper at the bottom of the container, pour in treated coarse sand, and add another sheet of filter paper on top of it;
- Step 4: cover pieces A, B, and C with Teflon tape and assemble them following the alphabetical order;
- Step 5: determine the necessary length to cut the tube and install it into Piece D, and if needed, use Teflon tape;
- Step 6: attach Piece D to complete the filtration system;



Source: FabLab Nariño (2019).

Figure 10. Steps for Assembling the AcuaLab Filter.

- Final Step A: if the personal spout is attached, drink the water directly from a source, paying attention to its condition;
- Final Step B: use the punch to make an opening in the PET bottle cap, turning it until it cuts through. Attach the spout to the other filter pieces and insert it into the bottle to complete the assembly.

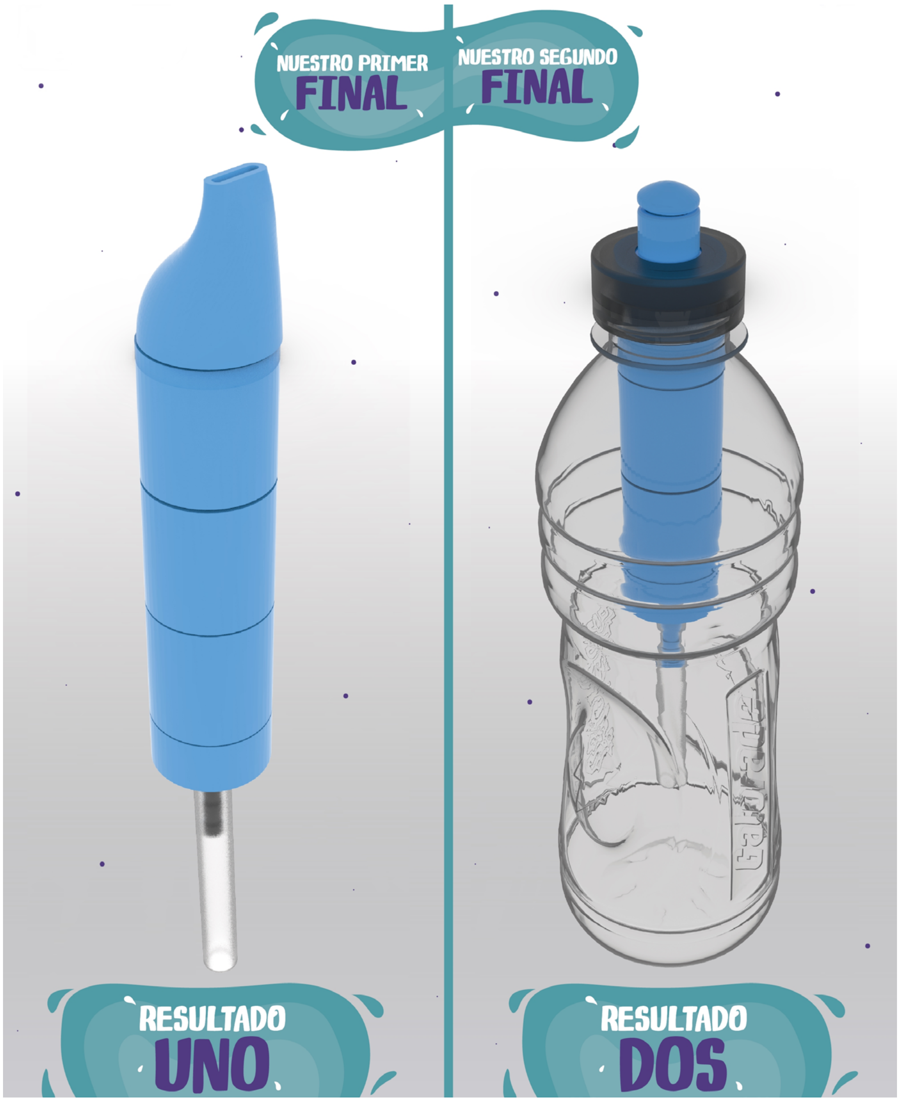
The filter can be produced in two formats, as shown in Figure 11.

The assembled filter and its components can be seen in Figure 12.

To use it, hold the filter with your hands and suck the water from a container or source, as shown in Figure 13.

Impact

Providing clean water in unhealthy contexts and granting the community autonomy to manufacture the filter, the AcuaLab project has already achieved the following results (Cátedra Futuro, 2019):



Source: FabLab Nariño (2019).
Figure 11. Options for the AcuaLab Filter Results.

Source: Social Innovation Center (2019).
Figure 12. Details of the AcuaLab Filter.

Source: Social Innovation Center (2019).
Figure 13. Use of the AcuaLab Filter.

- 7 visited municipalities: Roberto Payán, La Tola, Guachucal, Guaitarilla, Sandoná, Buesaco, and Obonuco (Pasto);
- 12 maker training workshops;
- 210 people benefited;
- More than 300 filters assembled by the communities.

Case 2: Field Ready

Background

Field Ready is a group of non-governmental, non-profit organizations with partners around the world, including regions such as Syria, the South Pacific, Türkiye, and the Philippines (Field Ready, 2023).

Syria is experiencing a massive humanitarian catastrophe due to armed conflicts that have resulted in over 570,000 deaths. Currently, 16 million people need assistance, over 7 million are displaced within the country, and nearly 6 million are refugees. Consequently, many Syrians lack basic necessities such as food, shelter, and clothing (Field Ready, 2023).

The South Pacific, comprising various island nations, is susceptible to violent storms, volcanoes, tsunamis, and earthquakes. Despite strong local preparedness and response efforts, the long-term impact and consequences of these natural disasters can be severe (Field Ready, 2023).

Turkey continues to deal with the devastation from the deadly earthquake in early 2023, in addition to ongoing conflicts in the region. In the Philippines, climate disasters — cyclones, floods, landslides, and droughts — destroy homes, jeopardize health, exacerbate economic difficulties, and increase poverty. The country's geographical complexities make emergency response actions challenging and costly (Field Ready, 2023).

Actors

The organization's team consists of humanitarian workers and technologists who are experts in their fields, possessing the necessary qualifications and experience (Field Ready, 2023).

Development description

The Field Ready way of working is organized into five stages (Field Ready, 2023):

1. Assess: see, listen, and understand — comprehension of the situation and people involved, with great empathy, in a collaborative effort aimed at practical and sustainable solutions;
2. Design: idealize and develop concepts — focus on technology and the benefits of proper use, utilizing a process with interactions;
3. Make: manufacture useful things — rapid involvement of people with experience and appropriate technology to meet needs in various sectors and challenges, moving from the specific to the general;
4. Share: test, distribute, and train others — sharing repaired or manufactured items and knowledge from extensive experience through training and other forms of education;
5. Lead: replicate where needed — serve as a role model for others, taking into account being a pioneer in this type of approach.

Figure 14 illustrates the complete process.

Results

Among the extensive catalog of products developed, several made using 3D printing can be highlighted (Field Ready, 2020):

- Atena Duoband Yagi (Figure 15): custom part for the antenna structure that captures radio waves, radar, or Wi-Fi, facilitating its assembly;

Source: Field Ready (2023).
Figure 14. Field Ready's Work Stages.

Source: Field Ready (2020).
Figure 15. Duoband Yagi Antenna.

- Ground Stake (Figure 16): it is driven into the ground for securing tents, shelters, and canopies;
- Bag Hook IV (Figure 17): designed for hanging intravenous bags;
- Otoscope (Figure 18): device for examining the external ear canal and the eardrum;
- Adherence Piece (Figure 19): designed to tighten threaded snouts on a water inlet hose for a compressor.

Impact

By enabling the production of items locally and teaching methods to groups, positive effects include (Field Ready, 2023):

- 90% reduction in the price of some essential humanitarian supplies to save lives;
- speed in delivery, reducing the time to hours instead of weeks or months, as usually happens with traditional aid logistics;

Source: Field Ready (2020).
Figure 16. Ground Stake.

Source: Field Ready (2020).
Figure 17. Bag hook IV.

Source: Field Ready (2020).
Figure 18. Otoscope.

Source: Field Ready (2020).
Figure 19. Grip tool.

- increased community resilience and preparedness by enabling local production and other means of recovery;
- training a large number of people and open, widespread sharing of projects, knowledge, and approaches.

Case 3: Proximity Designs

Context

Considered a country with a high rate of poverty, Myanmar has around 6 million inhabitants, a large proportion of whom work in agriculture, with rice production accounting for 60% of the agricultural areas (Proximity Designs, 2023).

Due to scarce resources and limited technological advances, acquiring agricultural equipment is challenging in this Southeast Asian country. In response, Proximity Designs implemented 3D printing to create prototypes for engineering projects (Proximity Designs, 2023).

Actors

Proximity Designs was founded by Jim Taylor and Debbie Aung Din in 2004 with the aim of creating a social business to support needy families in rural Mianmar. They recognized the significant needs of farmers who were not receiving assistance from the government or private sectors (Proximity Designs, 2023).

Currently, the social enterprise has four core areas, each managed by a dedicated team (Proximity Designs, 2023):

- agricultural technology: approximately 130 people;
- agronomic services: 225 members, including agronomists, soil scientists, farmers, and technologists;
- agricultural finance: more than 450 members;
- design (Labs): 10 designers.

Development description

To address Mianmar's challenges, the Design Thinking method is employed, emphasizing creativity and empathy. The team of designers, engineers, and researchers works locally to listen to people, create prototypes, and obtain direct feedback (Proximity Designs, 2023) (Figure 20).

The products are designed in a personalized manner using software designs and undergo rigorous testing with prototypes to simulate use on rough terrain. These prototypes are then sent to users for evaluation (Proximity Designs, 2023).

After confirming viability, the teams responsible for manufacturing and assembly begin production using advanced technology, computer-aided design (CAD) software, and 3D printers. They consider important factors such as accessibility, usability, and durability (Proximity Designs, 2023).

Results

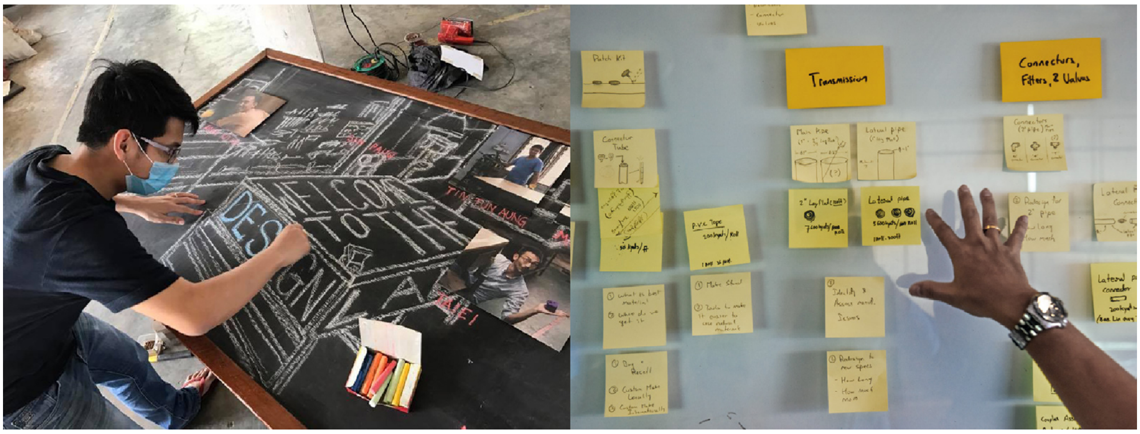
By introducing 3D printing in the prototyping phase, the production time for specific parts used in machines was reduced from weeks or months to just days. Printed items help test assembly, improve designs, and avoid ordering aluminum parts from abroad, thus reducing costs (Clarke, 2017).

Some of the printed pieces include (Harimoto, 2016):

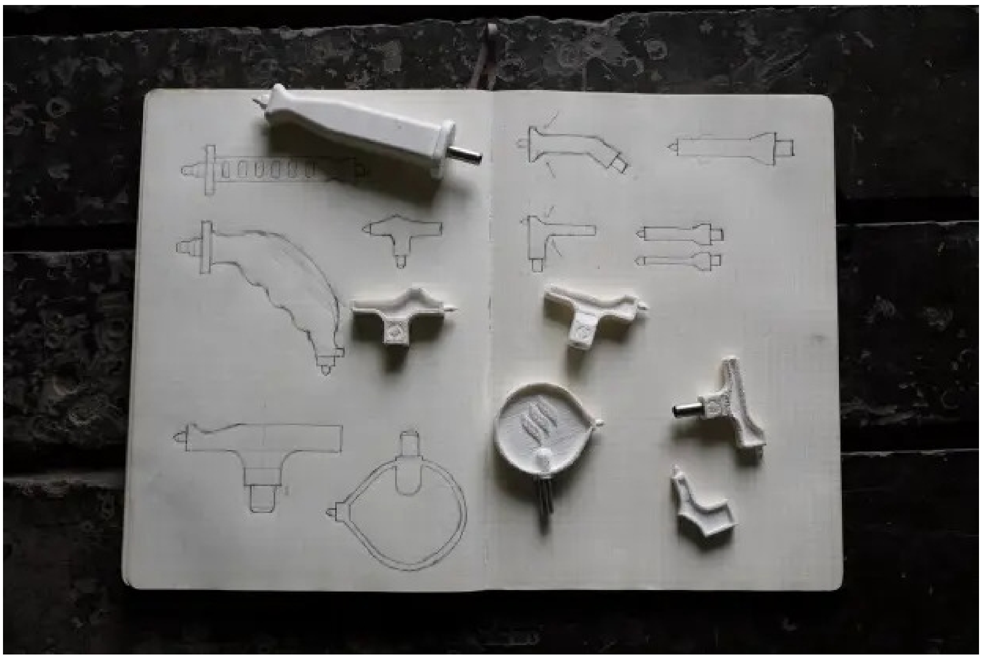
- sprinkler components (Figure 21);
- water pump components (Figure 21);
- spacer rings (Figure 22).

Impact

The scope and scale of Proximity Designs' impact can be demonstrated by the following numbers (Proximity Designs, 2023):



Source: Proximity Designs (2023).
Figure 20. Design tools from Proximity Designs.



Source: Harimoto (2016).
Figure 21. 3D-printed prototypes for Proximity Designs.

Source: Harimoto (2016).
Figure 22. 3D-printed spacer rings for Proximity Designs.

- Scale: over 250,000 agricultural clients benefited annually, approximately more than 1,300,000 families;
- Reach: 17,000 villages, 227 municipalities, about 75% of the agricultural population;
- Average: $275 annual net gain per farmer's income;
- Efficiency: six times (net profit gain/delivery cost);
- Cumulative impact: $725,000,000 over the last 19 years;
- Sustainability: 20% of the budget is from earned revenue, with a 98% repayment rate on agricultural loans.

Case 4: 3D Africa

Context

Due to the lack of an established industrial sector, most inhabitants of the African continent rely on imports, which involve high costs, for items such as machine parts, consumables, household goods, tools, and construction materials (3D Africa, 2023).

3D printing offers a viable option for manufacturing products domestically, eliminating the need for factories and requiring minimal machinery, reduced labor, and low capital. The direct and indirect savings can help individuals escape poverty (3D Africa, 2023).

Actors

3D Africa is an education and training program from the Youth for Technology Foundation (YTF) focused on 3D printing. It integrates product sales with business/career creation. The leaders of its segments come from various parts of the world and have experience in academic, philanthropic, public, and private sectors. This includes engineers, doctors, CAD modelers, and administrators (3D Africa, 2023).

The program also collaborates with partner companies/institutions that provide support through volunteer employees, student internships, financing, mentors, financial resources, speakers, and online participation (3D Africa, 2023).

Development description

3D Africa's education system targets high school and university students, job seekers, women, and young entrepreneurs. All programs combine an online curriculum (Massive Open Online Course — MOOC) with in-person training (3D Africa, 2023).

The contents cover technical and commercial aspects of 3D printing, organized as follows (3D Africa, 2023):

- learning software, hardware, and digital modeling programs;
- team laboratory work, focusing on planning, invention, innovation, presentation and review of 3D printing models intended for real-world solutions;
- mentorship for developing online entrepreneurship opportunities with 3D-printed products;
- work in a maker space for individual projects or entrepreneurial business creation.

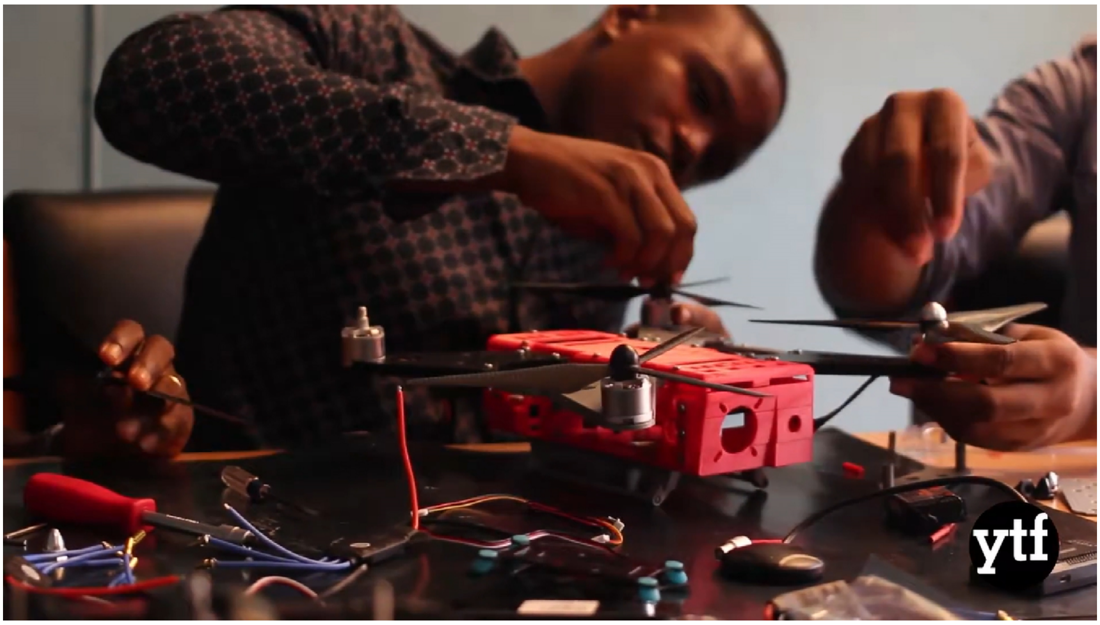
Results

The program has already amassed several successful cases, including (3D Africa, 2023):

- Afrocentric Afrique (Akwa Ibom, Nigeria): owned by Maureen, offers the creation of furniture, beads, bags, interior decoration, and fabrics with prints related to African culture. They have added 3D-printed jewelry to their catalog, designed and printed custom for each client, ranging from individuals to hotels, restaurants, and construction companies (Figure 23);
- 3D Printing Center (Lagos, Nigeria): focused on entrepreneurs, founded and coordinated by Tochukwu, who created a booth to attract Nigerian students to reading. This project earned her a nomination for the American Society of Mechanical Engineers (ASME) Social Innovation Award in the capital of Kenya (Figure 24);
- Drone (Nigeria): developed by Emmanuel, an engineer who learned about the program at his school and, after completing the training, saw new opportunities with the application of 3D printing (Figure 25).

Source: 3D Africa (2023).
Figure 23. Owner and products of Afrocentric Afrique.

Source: 3D Africa (2023).
Figure 24. 3D Printing Center in Nigeria.



Source: Youth for Technology Foundation (2016).
Figure 25. 3D-printed drone.

Impact

According to data from the Youth for Technology Foundation (YTF, 2015), the educational program has already reached 500 young people, girls and women entrepreneurs in Nigeria, Kenya and the United States, indicating other income options and employment possibilities.

Therefore, marginalized and vulnerable young people gain access to learning and work in the digital era by connecting new and traditional technologies to sustainable means of survival, initial revenue streams, and significant business growth (YTF, 2015).

Case 5: Face Shields (UH - UEL)

Context

The COVID-19 pandemic has presented numerous challenges for public hospitals worldwide, including issues related to protecting healthcare professionals and a shortage of essential equipment such as ventilators, aspiration probes, bacterial filters, nasal swabs, etc. (Corsini; Dammicco; Moultrie, 2021).

In this case, the project was conducted at the University Hospital of Londrina (HU) of the State University of Londrina (UEL) in Paraná, Brazil. It is administratively linked to the Rectory and academically to the Health Sciences Center, recognized by the Ministry of Education (MEC) and the Ministry of Health (MS) (Interministerial Ordinance MEC/MS No. 1.213 of 05/30/2014). The hospital is the second largest public hospital in the state and serves as a reference center for medium and high complexity, part of the Brazilian Unified Health System (*Sistema Único de Saúde* – SUS). It has 307 beds and serves around 250 municipalities in Paraná and more than a hundred cities in neighboring states. Additionally, it functions as a teaching hospital and a research facility for both *Stricto sensu* and *Lato sensu* studies (Sampaio; Luiz, 2021).

To address issues related to obtaining Personal Protective Equipment (PPE), such as the importation process, higher costs from national suppliers due to insufficient inputs to meet high demand, and the lack of adaptability and flexibility of solutions for the given context, the initiative employs digital manufacturing, specifically 3D printing, to produce face shields. This approach has been implemented in various locations worldwide (Sampaio; Luiz, 2021).

Actors

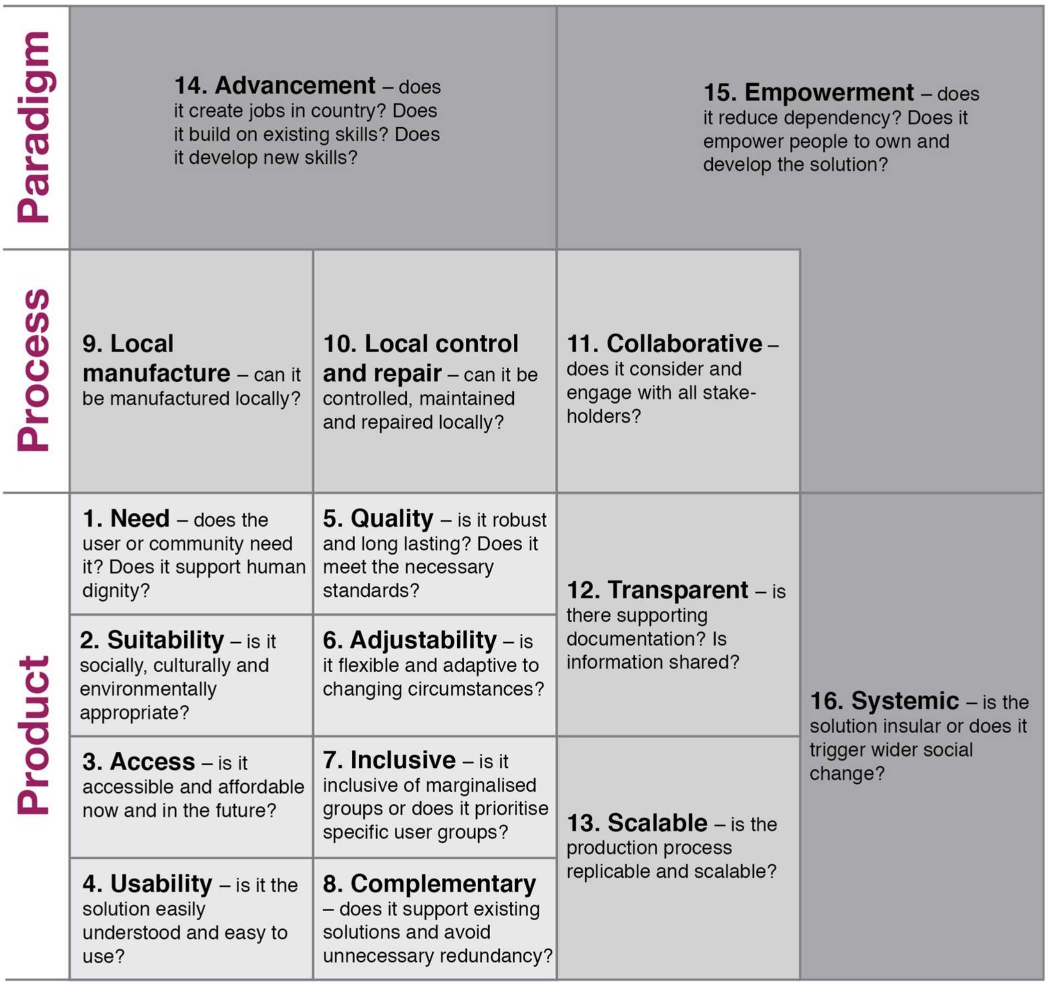
To produce face shields for the UEL UH, a collaborative group of approximately 40 people, along with several companies in the city of Londrina, Paraná, was formed (Sampaio; Luiz, 2021) (Figure 26).

Source: Sampaio and Luiz (2021).
Figure 26. Project team for the production of face shields.

Development description

The steps followed the Design for Social Sustainability (DfSS) method, proposed by Corsini and Moultrie (2019). This method is designed to support humanitarian and development projects that utilize digital manufacturing, aiming to enhance initial decision-making and conduct a final assessment of the sustainability of the products.

The framework (Figure 27) is composed of three levels of evaluation, each with its own aspects: product (1. need, 2. suitability, 3. access, 4. usability, 5. quality, 6. adjustability, 7. inclusivity, 8. complementarity, 12. transparency, 13. Scalability, and 16. systemicity); process (9. local production, 10. local control and repair, and 11. Collaboration); and paradigm (14. advancement and 15. empowerment) (Corsini; Moultrie, 2019).



Source: Corsini and Moultrie (2019).
Figure 27. Framework of Design for Social Sustainability (DfSS).

At the product level, the face shields addressed four aspects satisfactorily (13,6,6, and 7), five aspects were covered partially (2, 4, 12, and 13), and only one aspect was addressed unsatisfactorily (16). At the process level, all aspects were covered satisfactorily. At the paradigm level, one aspect was covered partially (15) while the other was unsatisfactory (14) (Sampaio; Luiz, 2021).

Results

The equipment features a 3D-printed support that holds a transparent, flexible sheet of PET plastic. This configuration acts as a microbiological barrier, offering protection to healthcare professionals from contamination while treating infected patients (Figure 28). Production occurred between April and May 2020, resulting in approximately 2,000 masks being supplied to UH/UEL (Sampaio; Luiz, 2021).

Source: Sampaio and Luiz (2021).
Figure 28. 3D printer used and support for the face shields.

As a result of this initiative, there was the creation and implementation of a digital manufacturing and innovation center, Fab.i HU, at the University Hospital of Londrina, Paraná. This interdisciplinary environment focuses on research, development, production, and supply of personalized hospital solutions and equipment tailored for various professionals and sectors within the hospital. It aims to enhance service effectiveness and efficiency, while reducing dependence on external suppliers (Sampaio; Luiz, 2021).

Impact

Among the benefits of introducing 3D printing is the significant reduction in the cost of locally manufactured equipment, which can reach about 35% of the sales price of imported products. This underscores the economic and technical viability of 3D printing in public healthcare environments (Sampaio; Luiz, 2021).

CROSS-CASE ANALYSIS

After detailing the selected cases and examining their aspects, a comparative analysis is conducted to identify similarities and patterns, as well as differences. This analysis aimed to validate and refine the points found in the literature review.

When analyzing the case studies, it is possible to observe how design tools are utilized in the development of projects and how these tools influence their storytelling.

Following Torres' proposal (2016), the analysis followed the topics below:

- Phases: 1) immersion/analysis, 2) opportunities and challenges, 3) idea generation + creative lab, 4) prototype and testing + evaluation and feedback, 5) delivery and implementation + action plan, 6) impact/growth and scaling;
- Management style: participatory, valuing the effective involvement of all project stakeholders; experimental, focusing on prototyping and testing stages; and centralized, involving direct and centralized collaboration from government bodies, companies, institutions, etc.;

- Results profile: product-centered system/transformation, product-service, and socio-technical solution system;
- Approach: local-global, implementing in the local reality with the potential to increase impact by reaching other parts of the world; systemic, where all elements of the system have equal weight and importance in providing a specific service; artisanal, encompassing manual manufacturing techniques; and functional adaptation, adapting an existing solution for implementation in a new context.

AcuaLab addresses all stages from immersion to impact/growth, though it remains localized. The management style is both participatory, involving community action at various stages, and centralized, with direct involvement from the Government of Nariño. The outcome is a product-focused transformation: a filter that provides clean water in contaminated environments, reflecting both local and global approaches.

Field Ready encompasses all phases and employs participatory management, involving agents from various fields. It results in a product-service centered on humanitarian aid, with a local-global approach.

Proximity Designs also encompasses all phases, utilizing experimental management focused on prototypes and field tests in agriculture, resulting in a product-centered system with a systemic approach.

3D Africa includes five phases: immersion/analysis, opportunities and challenges, idea generation + creative laboratory, prototyping and testing + evaluation and feedback, and delivery and implementation + action plan. It is participatory, primarily involving students and entrepreneurs, and centered on product-service solutions, as products arise from the education system, and it is systemic.

The Face Shields case (UH/UEL) encompasses four phases: immersion/analysis, opportunities and challenges, delivery and implementation + action plan, and impact/growth and scaling. It is centered on collaboration among companies, universities, and hospitals, resulting in a product-centric transformation that addresses a major health crisis. The approach includes functional adaptation, adjusting the manufacturing of an existing product to improve access and reduce costs.

The entire analysis is summarized in Figure 29.

FINAL CONSIDERATIONS

Using the collected data, an overview was developed to understand and demonstrate how 3D printing can drive social innovation, even with limited resources, particularly financial. The potential of this technology and its contributions to the field of Design were highlighted, emphasizing the importance of analyzing cases to reinforce concepts and generate insights for future stages.

The studies led to several findings: the exponential advancement of the AM industry; the growing incorporation of 3D printing in prototyping stages of Design projects; an increase in demands related to codesign; the presence of design in the development stages of the analyzed cases; and a focus on disadvantaged contexts in the presented projects.

	PHASES	MANAGEMENT STYLE	RESULT PROFILE	APPROACH
ACUALAB	All	Participative/ Centralized	Product-Centered Transformation	Local-global
	Only 4	Centralized	Product-Centered Transformation	Functional Adaptation
FIELD READY	All	Participative	Product-Service	Local-global
proximity	All	Experimental	Product-Centered System	Systemic
3DAfrica	Only 5	Participative/ Centralized	Product-Service	Systemic

Figure 29. Classification resulting from the case studies analysis.

To continue the research, the steps and some tools of the Human-Centered Design (HCD) method will be followed — a design process aimed to generate new solutions on a global scale, covering products, services, environments, organizations, and modes of interaction. It is segmented into three lenses: Desirability, Practicability, and Feasibility, and three phases: Hear, Create, and Deliver (IDEO, 2015).

The expected results include outlining guidelines for the necessary capabilities for implementation, covering both technical and social factors, specifically aimed at socially beneficial projects/businesses in rural areas. Additionally, the goal was to verify these guidelines in practice by developing a 3D-printed product and evaluating the social impact generated in a community in the interior of Paraíba, Brazil.

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