



**HAL**  
open science

## The use of Design Thinking in the innovation of artificial connected reefs

Justine Michel, Manon Arnaud, Adrien Roudaut, Albane Tenneson, Lucie Mace, April Schnaffner, Mame Cheikh Sow, Nicolas Chaton, Nader Wehbe, Paul-Emeric Roger, et al.

### ► To cite this version:

Justine Michel, Manon Arnaud, Adrien Roudaut, Albane Tenneson, Lucie Mace, et al.. The use of Design Thinking in the innovation of artificial connected reefs. *Computer Aided Chemical Engineering*, 52, Elsevier, pp.1933-1938, 2023, <10.1016/B978-0-443-15274-0.50307-3>. <hal-04351851>

**HAL Id: hal-04351851**

**<https://hal.science/hal-04351851v1>**

Submitted on 18 Dec 2023

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

# The use of Design Thinking in the innovation of artificial connected reefs

Justine Michel<sup>a</sup>, Manon Arnaud<sup>a</sup>, Adrien Roudaut<sup>a</sup>, Albane Tenneson<sup>a</sup>, Lucie Mace<sup>a</sup>, April Schnaffner<sup>a</sup>, Mame Cheikh Sow<sup>a</sup>, Nicolas Chaton<sup>a</sup>, Nader Wehbe<sup>a</sup>, Paul-Emeric Roger<sup>b</sup>, Anne Asensio<sup>b</sup>, Arnaud Coutu<sup>a</sup>

<sup>a</sup>Institut Polytechnique UniLaSalle, Rue Pierre Waguet, 60000 Beauvais, France

<sup>b</sup>Dassault Systèmes, 10 Rue Marcel Dassault, 78140 Vélizy-Villacoublay, France  
arnaud.coutu@unilasalle.fr

## Abstract

The climate changes that have occurred in recent years are modifying the characteristics of the environment. Seas and oceans swallow, each year, a part of the CO<sub>2</sub> we emit, acidifying it in consequence (*Francour and al., 2006*). To respond to this environmental alert the Dassault Systèmes Foundation launched a call for projects to UniLaSalle students to help protecting the oceans and reduce the anthropic impact. Using the Design Thinking method, the students developed solutions that links the working methods of designers and engineers. This method is a perfectly adapted approach to answer this type of problem because designers work for human beings, while engineers work for the nature. It was use in order to well understand the perimeter of the project. Its exercises allow you to ask questions about the general appearance of a project while keeping in mind how humans and/or the environment can impact it or be impacted.

**Keywords:** Artificial Reef, Design Thinking, Fluid simulation, Innovation, Modelling.

## 1. Introduction

The Dassault Systèmes Foundation had invited UniLaSalle students to participate to a call for projects. Their goal was to bring together Design and Engineering in order to mix, within the framework of science, different ways of thinking. To do that, the Foundation asked students to create a scientific project with the aim of protecting the oceans and offered them a training in Design Thinking to organize their ideas in a new way.

Climate change, which currently affects 45% of threatened marine species, is not the only stressor threatening the marine environment. It is the fifth most important factor after overfishing, transport, urban development and pollution (Wait, 2022). Therefore, it is imperative to start to focus on the preservation of the ecosystem.

During this project, Design Thinking allowed the team to highlight the importance of public awareness and the progress of research. In order to deal with this problem, the student chose to develop a project based on the creation of artificial reefs connected to sensors in order to follow the progress of the environment in which they are located. The goal was to create a database that could be used to create animations in museums or to support researchers working on specific marine environments. Step by step, the main idea switch from the development of artificial coral reefs to intelligent 'reefed' mooring posts. This change expanded the study area to regions of high anthropogenic stress and promoted the presence of fauna and flora in ports (Luff et al., 2019). On this file, it will be explained the processes of design thinking, modulization and simulation that permitted this reconversion.

## 2. Methodology

### 2.1. The Design Thinking process

« Most people mistakenly think that design is about appearance (...)  
That's not how we define design. (...) Design is how it works»  
- Steve Jobs in 2003

This approach, based on people, was oriented towards innovation in order to create innovative services or products. The particularity of this approach is the modification of the working method (Usabilis, 2018) by asking the right questions at the beginning of the project in order to guide its development into the right direction.

During the creation phase of the project, three workshops had been set up by the Design Studio in order to guide UniLaSalle students through the learning and use of Design Thinking. This approach made it possible to co-create projects and to determine future problems and needs by following a precise thought process (Figure 1). In this context, the supervisor prepared exercises on a remote collaboration space called Miro. This tool consists of a whiteboard that allows you to work and share your ideas with images, post-its, mind maps, tables, text boxes, and other tools.

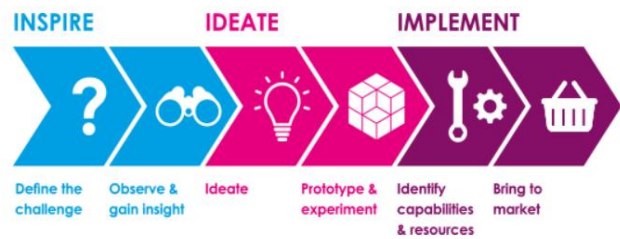
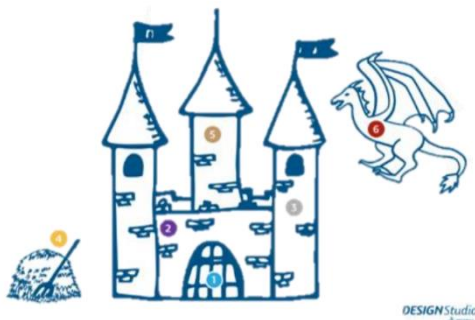


Figure 1: Three steps to simplify the process (Usabilis, 2018)

Design Thinking exercises allow to ask questions about the general aspect of a project while keeping in mind how humans and/or the environment can impact it or be impacted. These are lighthearted questions that specify each parameter of the project, thus allowing the team to grasp most of the difficulties it will encounter in the future (Figure 2). They follow a pattern that always involves: actors, priorities, problems and proposed solutions.



- The group work on the determination of the specific part of the opportunity with the helps of the analogy of a fortress:**
- 1 **The Drawbridge:** The digital innovation possibilities.
  - 2 **The Walls:** The biggest legacy we'll have to handle.
  - 3 **The Towers:** Actors who can help to leverage the project.
  - 4 **The Market:** External data and information needed to trigger the project.
  - 5 **The Dungeon:** The core mission of the opportunity.
  - 6 **The Dragon:** What can make us fail? (Competitors, business context...)

Figure 2: Exercise questions of the fortress realized by the Design Studio

To complete these exercises, the engineering students answered the questions using post-its. This method allowed everyone to express themselves and to understand the opinions of others in order to discuss the problems of the project.

Following this step, each group made a pitch explaining their project. Three meetings were held in order to answer new questions:

- What is the problem? Context, understanding of human problems, environmental impact, opportunities and trade-offs?
- What solution is proposed? To do what? At what cost? What is needed to implement it? What will be tested to verify its relevance?

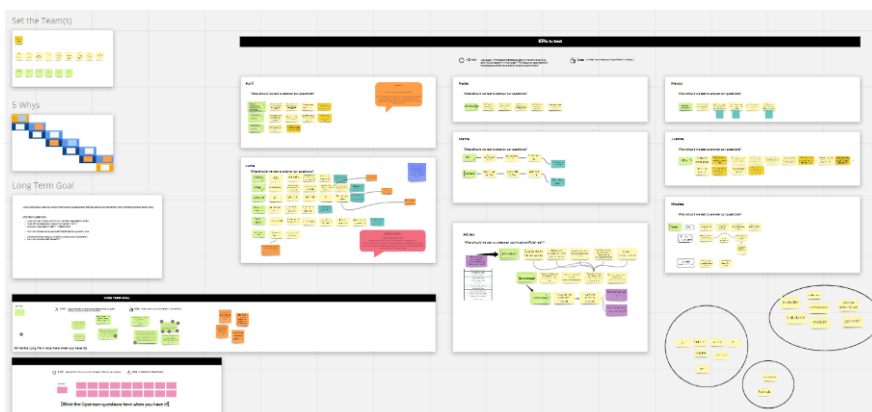


Figure 3: Example of Design Thinking work done on Miro

These pitches were used to distinguish which project would be about to be developed for an internship. The chosen subject had been the one that is presented on this paper: the "intelligent artificial reef". Therefore, the 4 members that imagined this solution constituted a team of students coming from different specialities (biology, environment, mechanics and geology) in order to develop it.

In order to create a group spirit and to communicate everyone's ideas, the new team had a formation of Design Thinking with the Design Studio supervisor. This period allowed students to bond during the important choices of the project by taking votes. Each student had post-its that they could place on whatever their choice was. The 3 choices with the most votes were then put aside to make a second round. The main objective was to make everyone agree with the development of the project by letting them discuss and debate (Figure 3).

This period also gave the students personal goals and a problem to solve. From this stage on, the students worked semi-autonomously as a small research office would. The Design Studio accompanied the group conducting weekly meetings on Friday mornings, for 30 minutes to 1 hour, to monitor the project and advise its members. These meetings began early and ended on the day of the Fondation Dassault Systèmes visit, at the end of the internship. The framing of these meetings allowed the team to refocus in this research in order to avoid misdirection and not waste time. Moreover, these project reviews allowed students to use Design Thinking by reflex, they no longer need to consult each other before a meeting because everyone follows the role of the others and knows where the project is at.

## 2.2. Digital designs and simulations

The Ocean ReGen team worked on the creation of an artificial reef and "reefed" mooring post, both composed of sensors to monitor the physico-chemical and biological criteria of the marine environment (sound, image, turbidity, temperature, pollution and population tracking). The sensors that make up the electrical system of both solutions could be modified according to the user's needs by slightly modifying the proposed system.

To carry out this project, the students used Dassault Systèmes solutions such as the 3DEXPERIENCE platform. This platform is a collaborative environment that allows the creation of innovative products using virtual experiences. It also provides a real-time view of project activity through its 3DDashboards (Figure 4), which connect people, ideas and data.

This collaborative environment also allows the use of some Dassault Systèmes software, including Catia, Creative Experience and Drafting. The most important is the Catia software. It allowed students to model their reefs and moorings spots in 3D. These models were then used in the Drafting application to create constructions plans for each shape and then in Creative Experience to make virtual enhancement videos. In addition, these models were imported into XFlow, a fluid simulation software, also produced by Dassault Systèmes, but not included into the 3DEXPERIENCE platform. In order to optimize to the maximum their creation, numerous 3D models had been produced.

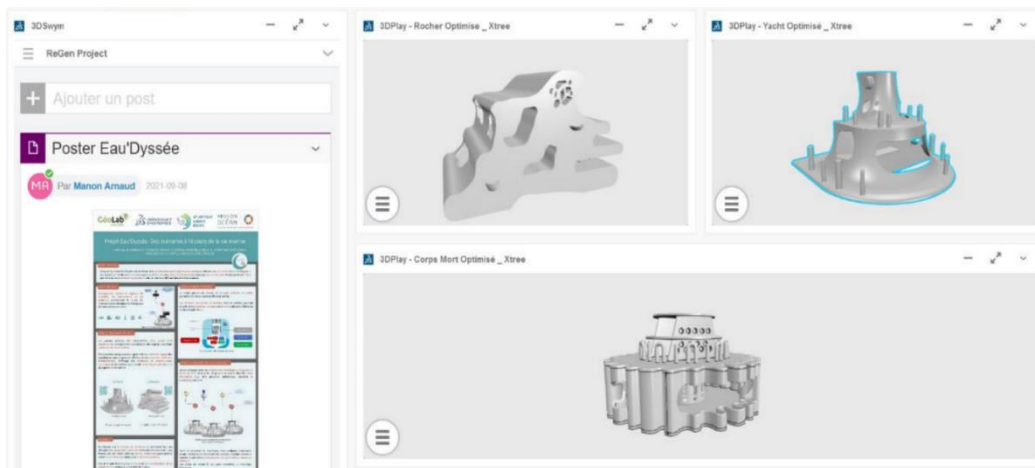


Figure 4: Example of a 3D Dashboard presenting the 3D models of the reefs made

XFlow permitted to choose the most appropriate shape for the team's needs by following some criteria... In order to attract as many species and entities as possible, reefs and moorings must had a complex shape (Charbonnel et al., 2001) and had to own shadow zones, turbidity, an upward current and a dead zone (where the current is weak or non-existent) within or behind the structure.

Ocean ReGen students contacted 6 scientists working in the domain of artificial reefs in order to have opinions on their achievements and to have new proposals. A total of 15 hours of exchanges were realized with those scientists including 6 hours spent with Atlantique Landes Récifs (ALR). Following those exchanges, ALR became a partner that proposed to prototype the mechanical part. Those realized with the MIO (Mediterranean Institute of Oceanography), GIS Posidonie, Ifremer and Xtree allowed to review the priorities and the organization of the project. Those meetings helped the students to choose the ideal location, the shape and the materials of the reef.

### 3. Analysis

#### 3.1. Project development through collaboration between Design & Engineering

The confrontation between Design & Engineering allowed the emergence of many ideas. The initial concept developed by the selected team proposed the implementation of an intelligent artificial coral reef. However, following the collective reflexion activities orchestrated by the Design Studio, the training of the different Dassault Systèmes tools and the exchanges with professionals such as Ifremer, ALR, the MIO... the project underwent many changes.

A final visit to the Fondation Dassault Systèmes permitted the Ocean ReGen project team to propose two different scenarios for the implementation of reefs. First of all, the aspect of artificial coral reefs had disappeared. Indeed, the project had split into two parts, one of which allows the implementation of an intelligent artificial reef and the other one of a reefed mooring post, also intelligent. An artificial reef would be a structure that would be voluntarily immersed in water to help the biomass to develop. A traditional mooring post is a massive concrete platform that is immersed. This structure, connected to a chain and a buoy, allows the anchoring of boats in order to avoid the ravages caused by anchors on the sea floor. The difference with the reefed mooring post would come from the shape of the structure. Unlike a massive block, the goal is to complexify its shape to create a mini reef while keeping the basic utility of a traditional mooring post. This idea came from exchanges with researchers who worked on the Port-Cros reefs immersed in 1985. Their feedback and advices guided the choices made by the group of students regarding the shape of their structures and their location.

On the other hand, the weekly design meetings also helped to guide the choice of sensors for the intelligent system while linking them to the human. To do this, the student had to answer why and to whom? In others terms: Why use these sensors and for whom would they be useful? The chosen ones are hydrophones, cameras, a tracking system, turbidity, temperature and pollution sensors. (Table 1)

Sensors		for whom?
Hydrophones	<ul style="list-style-type: none"> <li>Lack of knowledge about marine sounds.</li> <li>Identify day/night organisms.</li> <li>Locating disturbing anthropogenic sounds.</li> <li>Monitoring against illegal fishing ...</li> </ul>	<p><b>Museums:</b> diffusion of videos and aquatic sounds to show marine life to the general public</p>
Video cameras	<ul style="list-style-type: none"> <li>Ecological monitoring of species.</li> <li>Surveillance against illegal fishing.</li> <li>Information on the transparency of the water and the possibility of diving.</li> </ul>	<p><b>Researchers:</b> ecological monitoring of the environment and scientific discoveries</p>
Turbidity sensors	<ul style="list-style-type: none"> <li>Detection of turbidity anomalies and thus detect certain pollutions.</li> <li>Information on the transparency of the water and the possibility of diving.</li> </ul>	<p><b>Authorities:</b> coastal surveillance for the protection of marine organisms by fighting against illegal fishing</p>
Temperature sensors	<ul style="list-style-type: none"> <li>Information on ocean warming.</li> <li>Understand the impact of temperatures on marine organisms.</li> </ul>	<p><b>Swimming monitoring:</b> turbidity and pollution levels can be used to prohibit swimming and protect the public.</p>
Capteurs de pollution	<ul style="list-style-type: none"> <li>Monitoring of pollution levels in ports and bays.</li> <li>Monitoring the impact of pollution on marine populations</li> </ul>	
Tracing system	<ul style="list-style-type: none"> <li>Ecological monitoring of fish species (interaction and movements).</li> </ul>	

Table 1: Table of sensors use

In order to illustrate the process a little better... After a meeting with Atlantique Landes Récifs, the association expressed a need for cameras in order to obtain information on the environment around the area where their reefs are located. The usefulness would allow to know the level of transparency of the water thanks to the recordings video in order to be able to organize their diving missions. Public awareness was one of the main missions of the Ocean ReGen team. For this purpose, the data from the tracking systems, the sounds recorded by the hydrophones as well as the images from the cameras could be transmitted and used by museums or schools. The same is true for the data collected by the temperature and pollution sensors. Moreover, those sensors would also help the scientific progress and the development of nature.

Human being knows little about marine sounds. It would have the possibility to increase the amount of data concerning the degradation of the biomass and the impact of the implantation of the structures that the ReGen Project team proposed.

The Design Studio's methods were reused many times by the team members. When it came to gathering everyone's ideas, Miro was the main tool used to create, deliberate and choose the best idea. This was helpful when it came to choosing the shape of the logo, the slogan phrase and the project name. The same was true for the choice of the reef shapes and mooring post. Dozens of 3D models were made and only 3 were chosen.

### 3.2. Students' feedback on the collaboration between Design & Engineering

This experience was filled with questioning, misdirection and success. The Design Thinking process allowed the group of students to see and revisit their ideas, project progress, and goals many times. Originally, the students aimed to incorporate salinity and oxygen sensors into the system in addition to temperature and turbidity... However, after a meeting with the deputy director of the MIO (Mediterranean Institute of Oceanology), instead he advised them to implement hydrophones. This technology is not very developed nowadays and marine sounds are still not well known in the scientific world. The same is true for cameras. After discussions with ALR, the usefulness of incorporating them into the system would be beneficial to them. Consequently, after having worked for several weeks on the installation of the wrong sensor device, the mechanical pole had to radically reorient its research.

The team of 9 students managed to be quick in their decision making allowing the project to develop quickly. This was possible thanks to their motivation, the advice of external professionals and the Design Thinking methods taught by the Design Studio at the beginning of their internship. The team became more cohesive and was able to focus on the task at hand.

Design Thinking allows different domains to mix and move forward together. Indeed, this method allows to build a project link by link, by considering future problems. This way of thinking is the very source of research. Generally, the students particularly appreciated the use of Design Thinking and planned of using it for their future research projects.

## 4. Conclusion and perspectives

Finally, the use of Design Thinking helped to direct and organize the project. The collaboration with the designers allowed the engineering students to learn a new approach to project management and the objectives of innovation. Thanks to it, the students were able to propose two scenarios that meet the needs of the environment and humans. Their work on the reefs already allow the 3D printing of the chosen shape thanks to the different construction plans made. As for the electrical system, it still needs improvements to be immersed and functional.

In order to finalize the project, UniLaSalle was considering organizing a new summer internship. This internship would focus on the development of the electronic part and would aim to realize a prototype of the reef and its intelligent system. The current team continues the exchanges with the various contacted organizations... The exchanges with ALR aimed to confirm their collaboration with the GeoLab. If this were to happen, ALR would help ReGen members with the prototyping of the electrical part and would implement it on its reefs in the Atlantic. The students were also keeping in touch with Xtree, in hopes of getting them to print the modeled reefs.

## Acknowledgments

The authors gratefully thank the Design Studio, the educational research platform Le GéoLab and La Fondation Dassault Systèmes for the support provided for this work. The authors want to thank also Maxime Denis and Julien Duquennoy for their precious help.

## References

E. Charbonnel, D. ODY, L. LE DIREAC'H, 2001, Effet de la complexification de l'architecture des récifs artificiels du Parc National de Port-Cros (Méditerranée, France) sur les peuplements ichtyologiques | Parc national de Port-Cros et Porquerolles, date of consultation : 14/11/2022. <http://www.portcros-parcnational.fr/fr/rapports-scientifiques/effet-de-la-complexification-de-larchitecture-des-recifs-artificiels-du-parc>.

- P. Francour, J.-F. Magréau, P.-A. Mannoni, J.-M. Cottalorda, J. Gratiot, 2006, Ancrages écologiques permanents. Guide d'Aide à la Gestion des Aires Marines Protégées. Université de Nice-Sophia Antipolis & Parc National de Port-Cros, Nice : 68
- A.L. Luff, E.V. Seehan, M. Parry, N.D. Higgs, 2019, A simple mooring modification reduces impacts on seagrass meadows, date of consultation: 30/11/2022. <https://www.nature.com/articles/s41598-019-55425-y>
- Usabilis., 2018, Design Thinking Définition. Date of consultation : 10/11/2022. <https://www.usabilis.com/quest-ce-que-le-design-thinking>.
- L. Wait, 2022, Unchecked global emissions on track to initiate mass extinction of marine life. In : Princeton University, date of consultation : 30/11/2022. <https://www.princeton.edu/news/2022/04/28/unchecked-global-emissions-track-initiate-mass-extinction-marine-life>.