Democratizing biology through DIY Interactive Popular Science

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Abstracts

The complexity of the tridimensional genome has much information to unpack. Bridging some of this information with a tangible object and interface can ease this process, acting as popular science. How can we make an interactive and tangible instance of scientific complexity to support this quest?
The proposed answer is by codifying the genome in a physical interactive space and allowing an active interface for the audience with total agency among the genetic code. A DIY system is proposed to democratize this interactive popular science process. This project has been developed following the Fab Academy training in FabLabBcn within a research network of molecular biologists, ChromDesign, closely working with CNAG (National Center for Genomic Analysis).

Keywords

Digital Fabrication, Experience Design, Interaction Design, Electronics, Kinetic Art, Popular Science, Science Communication, Transdisciplinarity

Introduction

Our organism is as complex as fascinating, behaving as a high-tech machine, including multiple levels, layers, and scales. Many parts work incessantly to make our body work and fix bugs, forcing it to constantly update pieces so tiny that we might not be aware of their nature most of the time [1]. The nature of microscales still has many unknowns caused by the lack of resolution to see at these levels beyond statistical simulations, as happens with the human genome [2]. As technology evolves, scientists will be able to discover the wonders of the tiny new worlds by observing new, unexpected, or long-awaited layers.

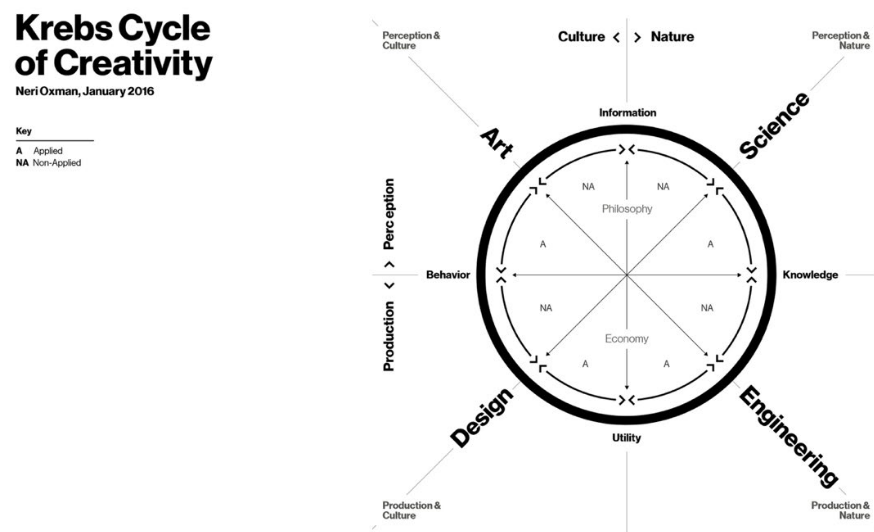


Figure 1. Neri Oxman, The Krebs Cycle of Creativity (KCC), 2016

In the meantime, non-biologists may struggle to understand some of these concepts as those are very abstract and don't have great visual representations [3]. New efforts to bring scientific knowledge and democratize science communication might be necessary for a transformative view of a place where general audiences usually encounter an understanding of scientific topics, science museums, and science centers [4].
New spaces and experiences are blooming to bring science and artistic practices closer together.

Consequently, we see that platforms other than the established ones are changing hierarchies in science and science communication [5]. Michael John Gorman highlights Neri Oxman as a critical actor for change. Neri Oxman works in a lab, displays work at MOMA, and has her own Netflix documentary. These actions and context break down some conventions about what scientists do and how they disseminate their work. Having her research work displayed in an exhibition space gives us a direct window into Oxman's lab. To this day, Oxman might be the closest thing biology has to a visible figure taking science to society. Neri Oxman's vision beyond individual disciplines can be framed as seen in Figure 1; there are four exploration domains: art, science, design, and nature, that present an antidisciplinary perspective [6]. Oxman, inspired by cellular metabolism, proposed the Krebs Cycle of creativity to describe how creative energy moves and transforms: engineers receive the knowledge produced by science; designers use utilities created by engineers; artists perceive behavioral changes made by designers; and new scientific inquiries are inspired by artists delving into new perceptions of the world [7]

As an experience designer and creative technologist, I explore the intersection between science, design, and technology and how this connects to society. Even though Neri Oxman seems to be the have-it-all example, society usually explores its curiosity toward science in science museums and other institutions, not museums like MOMA. Science museums today are still legacies of private curiosity cabinets that collectors built during the Renaissance. Nowadays, exhibitions pretend to be interactive displays of educational fun. Even so, Michael John Gorman calls for the transformation of science museums and centers to dynamize creativity and collaborative networks, bringing visitors together with scientists, artists, designers, and policymakers [8].

Unsurprisingly, much experimentation is needed to row toward a new paradigm for science communication. However, there is still a place for finding a more active role for societal impact in terms of science communication. Understanding the scope of interaction and experiences, plus looking at the intersectional nature and value of design, art, science, and technology, is pivotal to developing interactive popular science. This paper presents an experiment to define a DIY system to democratize interactive popular science by detailing its process and evaluating its outcomes. The following context defines the scope and requirements that provide the starting point.

Context

ChromDesign Horizon 2020 Project
ChromDesign is an EU-funded Marie-Sklodowska Curie Action (MSCA) Innovative Training Network (ITN) presented as a transdisciplinary hub for innovation and progress in the field of chromatin biology. The author of this paper represents one of the 13 researchers part of the research scheme with one particularity, being the only nonlife sciences researcher of the network.

The paper's experiment takes place within the ChromDesign research project, which aims to take the complexity of molecular biology to society. Interactive experiences are common in science museums for explaining scientific phenomena. The scope is to create an innovative interactive prototype employing digital fabrication as a way to offer a creative commons solution that can be created and replicated afterward.

Fab Academy Journey
In this particular experiment, the digital fabrication process used an existing framework for prototype development, the Fab Academy intensive course. According to the Fab Academy website (https://fabacademy.org): "Fab Academy is an intensive five-month program that teaches students to envision, design, and prototype projects using digital fabrication tools and machines. It is a multi-disciplinary and hands-on learning experience that empowers students to learn by doing and inspires them to make stuff locally to become active participants in sustainable cities and communities".

This framework is key for acquiring new knowledge in digital fabrication while setting a deadline for a functional prototype to be evaluated and shared with society at the end.

Method

Design thinking is defined as an intentional process to transform challenges in a non-linear, human-centered, collaborative, optimistic, and experimental way [9].

One can use many different design thinking processes, tailoring them to different needs [10]. The experiment will follow a simple design thinking process structure [11,12]: Emphasize, Define, Ideate, Prototype, and Test, as shown in Figure 2.

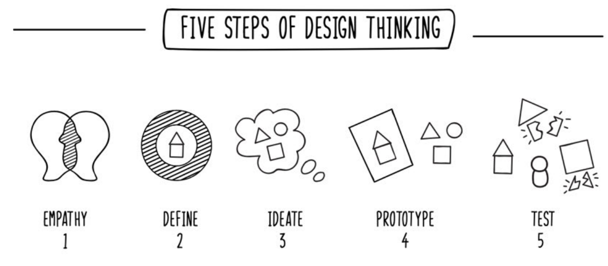
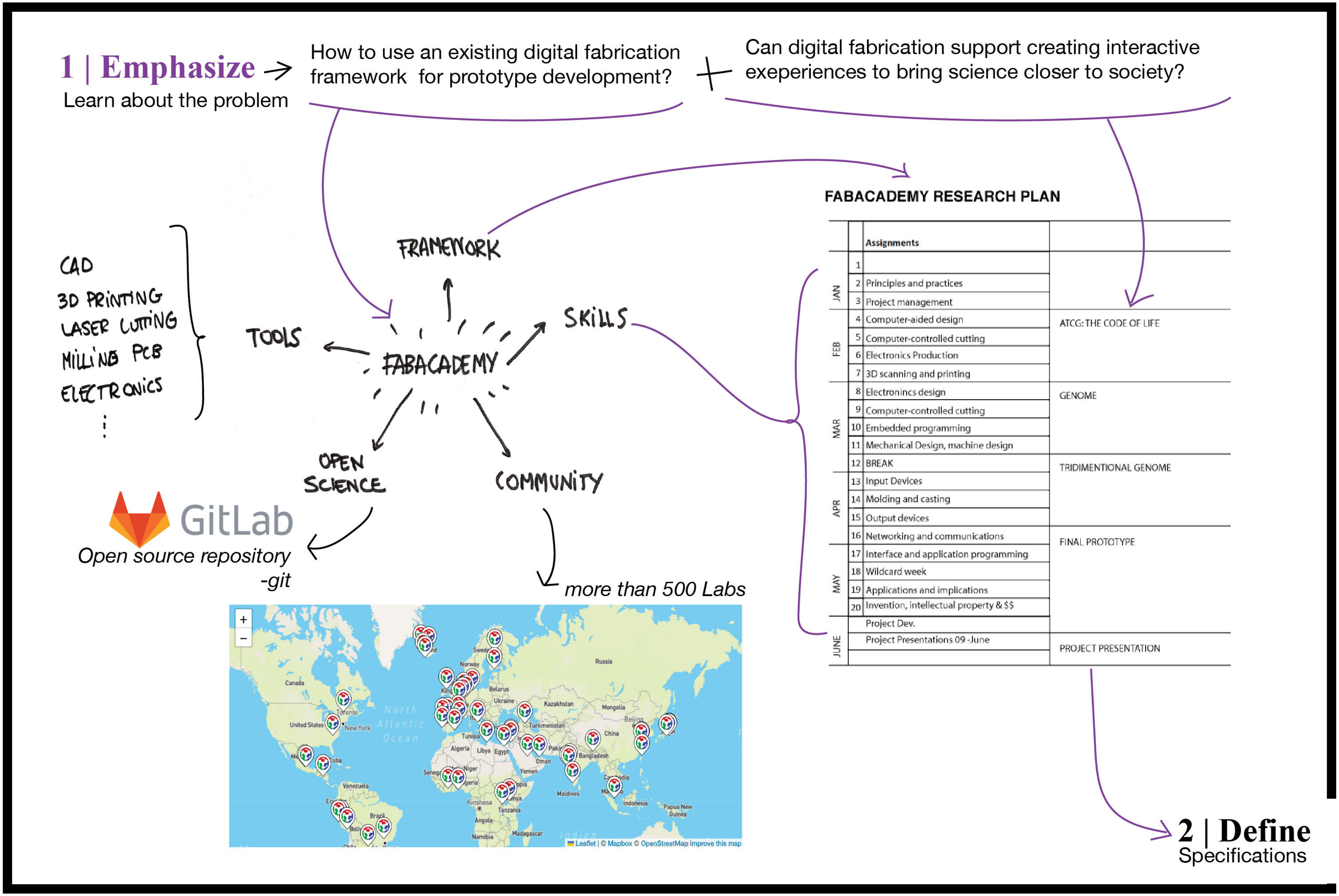


Figure 2 The Steps of Design Thinking. Original diagram by Carla Molins-Pitarch included in Iterate: Ten Lessons in Design

In the pages that follow, each part of the process has a dedicated illustrated space to unravel the development through visual storytelling. Standard design methodologies support all the design and prototyping processes [13] to create tangible outcomes as a design research deliverable [14]. After the development, the prototype will be put out for evaluation to frame and define the next steps for future results.



FABACADEMY RESEARCH PLAN

		Assignments	
JAN	1		
	2	Principles and practices	
	3	Project management	
FEB	4	Computer-aided design	ATCG: THE CODE OF LIFE
	5	Computer-controlled cutting	
	6	Electronics Production	
	7	3D scanning and printing	
MAR	8	Electronincs design	GENOME
	9	Computer-controlled cutting	
	10	Embedded programming	
	11	Mechanical Design, machine design	
	12	BREAK	TRIDIMENTIONAL GENOME
APR	13	Input Devices	
	14	Molding and casting	
	15	Output devices	
	16	Networking and communications	FINAL PROTOTYPE
MAY	17	Interface and application programming	
	18	Wildcard week	
	19	Applications and implications	
	20	Invention, intellectual property & $$	
JUNE		Project Dev.	
		Project Presentations 09 -June	PROJECT PRESENTATION

Figure 3 Emphasize phase process development by the author.

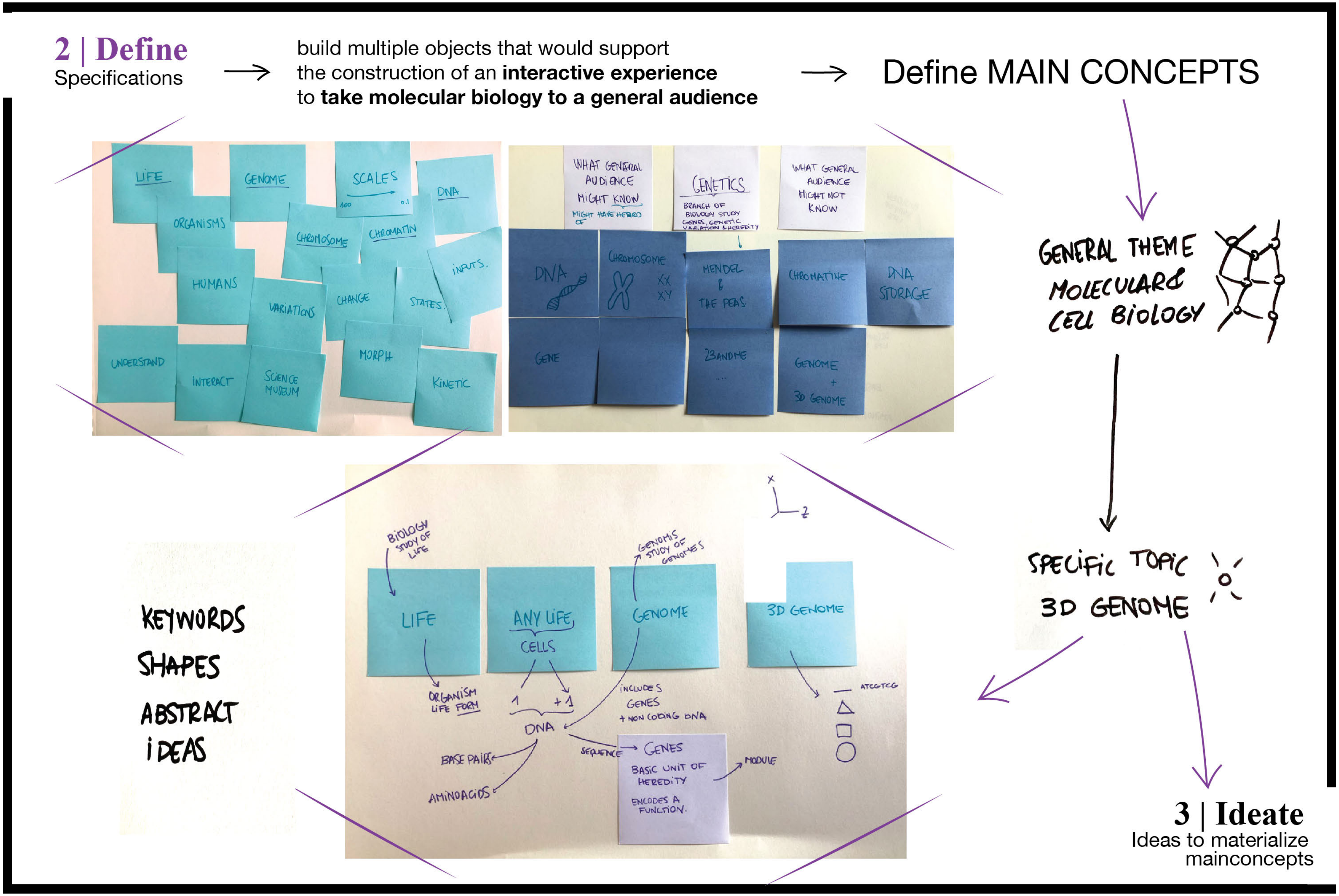


Figure 4 Define phase development by the author.

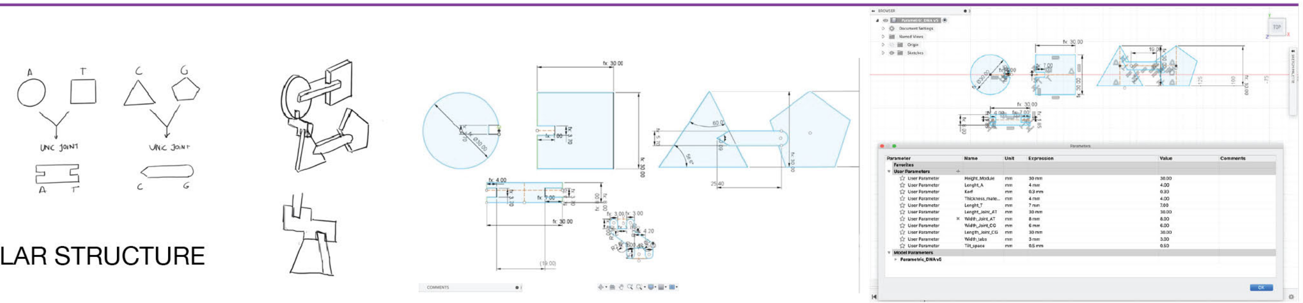
3 | Ideate

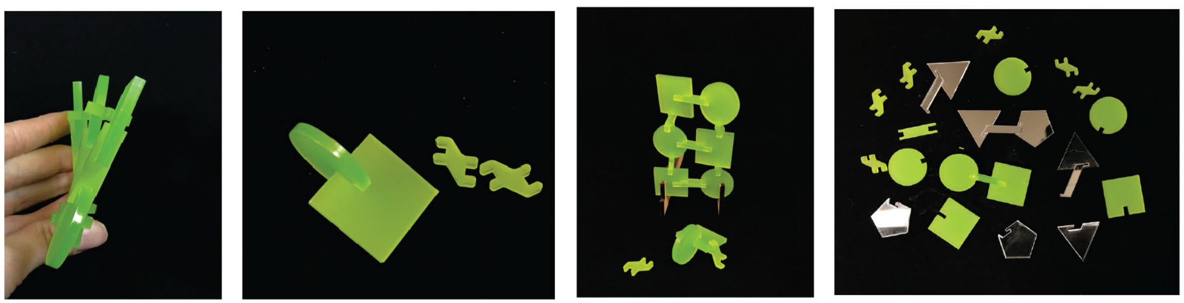
Ideas to materialize main concepts → each week { 1 technique, 1 question, 1 output } → Learn digital fabrication + come up with final form

CAD

How could I design parametric modules that would only fit the possible letter combinations (AT / CG)?

ATCG PARAMETRIC MODULAR STRUCTURE





Laser Cutter

Could laser-cutting techniques help me build a modular, stackable DNA construction kit?

CODE OF LIFE CONSTRUCTION KIT

3D print

Could 3D printing help to create custom connectors for the DNA construction kit?

CODE OF LIFE CONSTRUCTION KIT REVISITED

Figure 5 Ideate Phase Development Part 1 by the author.

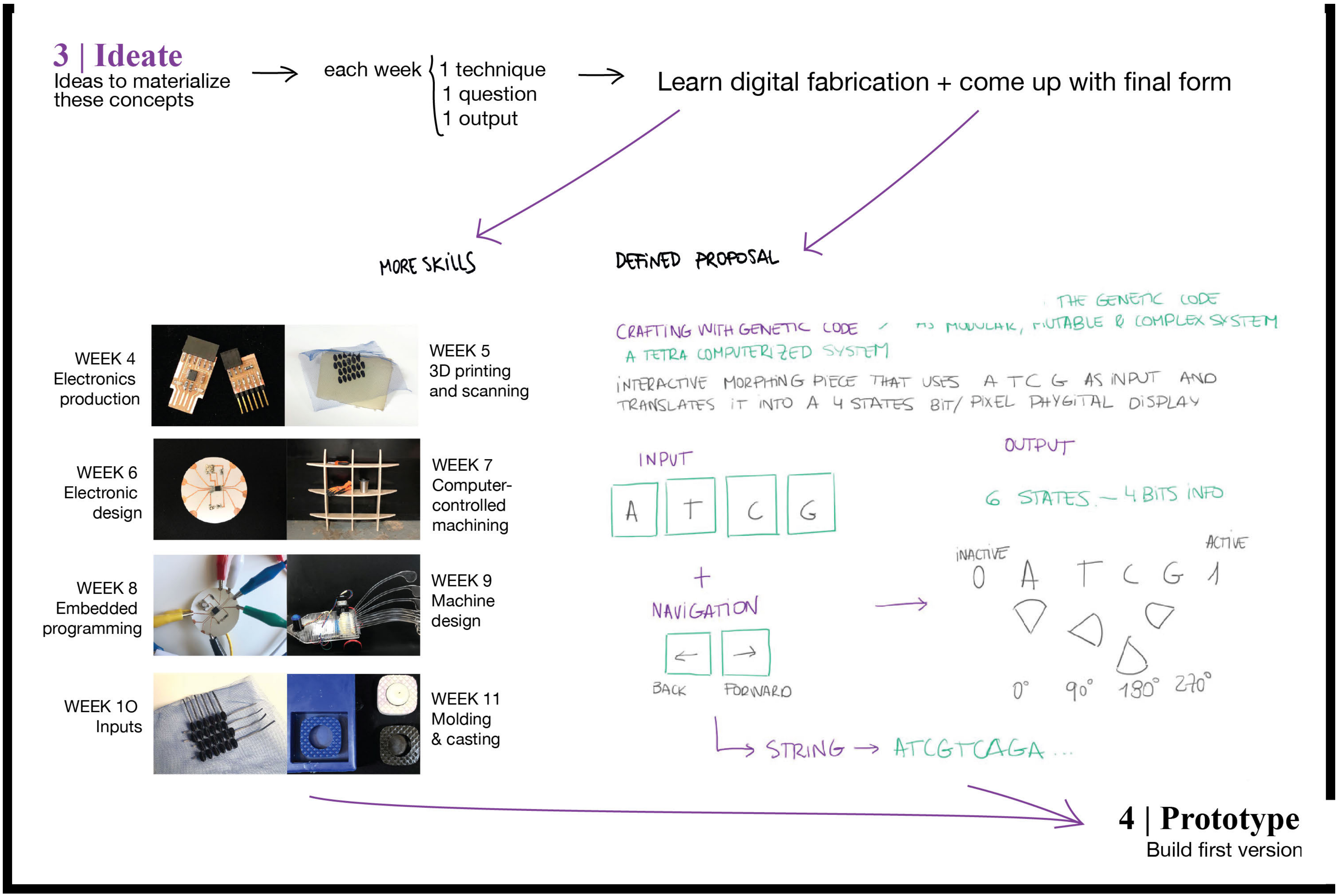


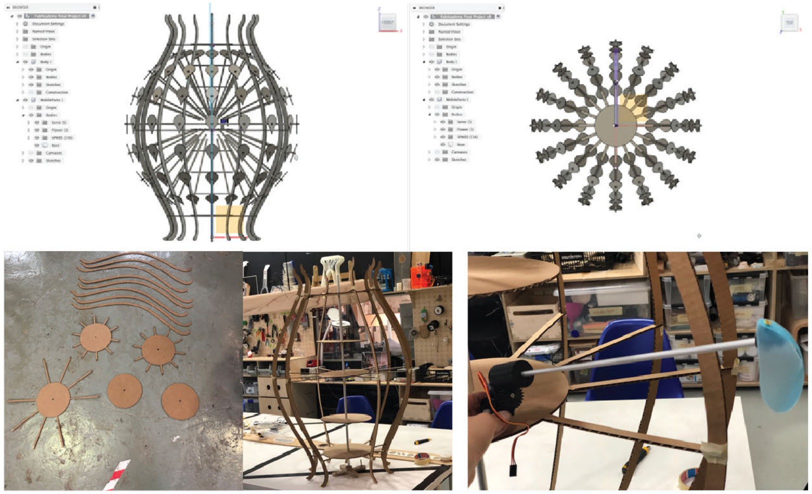
Figure 6 Ideate Phase Development Part 2 by the author.

4 | Prototype

Build first version → Weekly goals towards a final build → Build, test, iterate, build,... replicate

Week 11

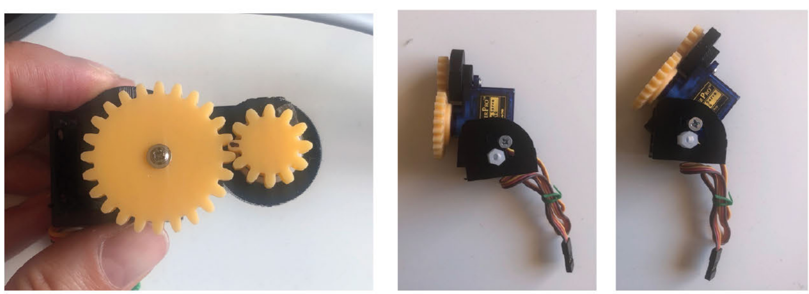
Can I use 3D modelling + laser cutting to build a solid, organic structure?



CAD ✅ LASER CUT ✅ STRUCTURE ⚠️ MATERIAL ❌ NODE ✅

Week 12 : outputs

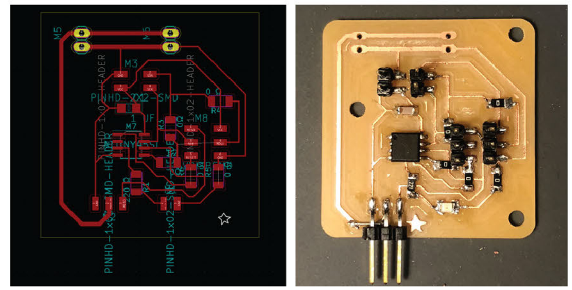
Can I create an output system able to show the A, G, T, and C states using 4 different angles?



CAD ✅ 3D PRINT ✅ FUNCTION ⚠️ MATERIAL ❌ NODE ✅

Week 13: networking

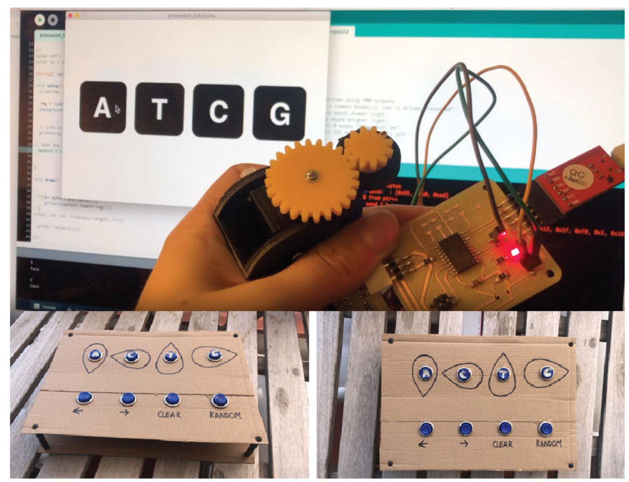
Could a networked system help me control my project's movable nodes?



KICAD ✅ MILLING ✅ I2C ⚠️ NETWORK ✅ POWER ❌

Week 14: Interface and application programming

Can I create an application controlled by a physical interface working like a keyboard + text processor?



CODE ✅ COMMUNICATION ✅ FORM ⚠️ MATERIAL ❌

Figure 7 Prototype phase development part 1 by the author.

Figure 8 Prototype phase development part 2 by the author.

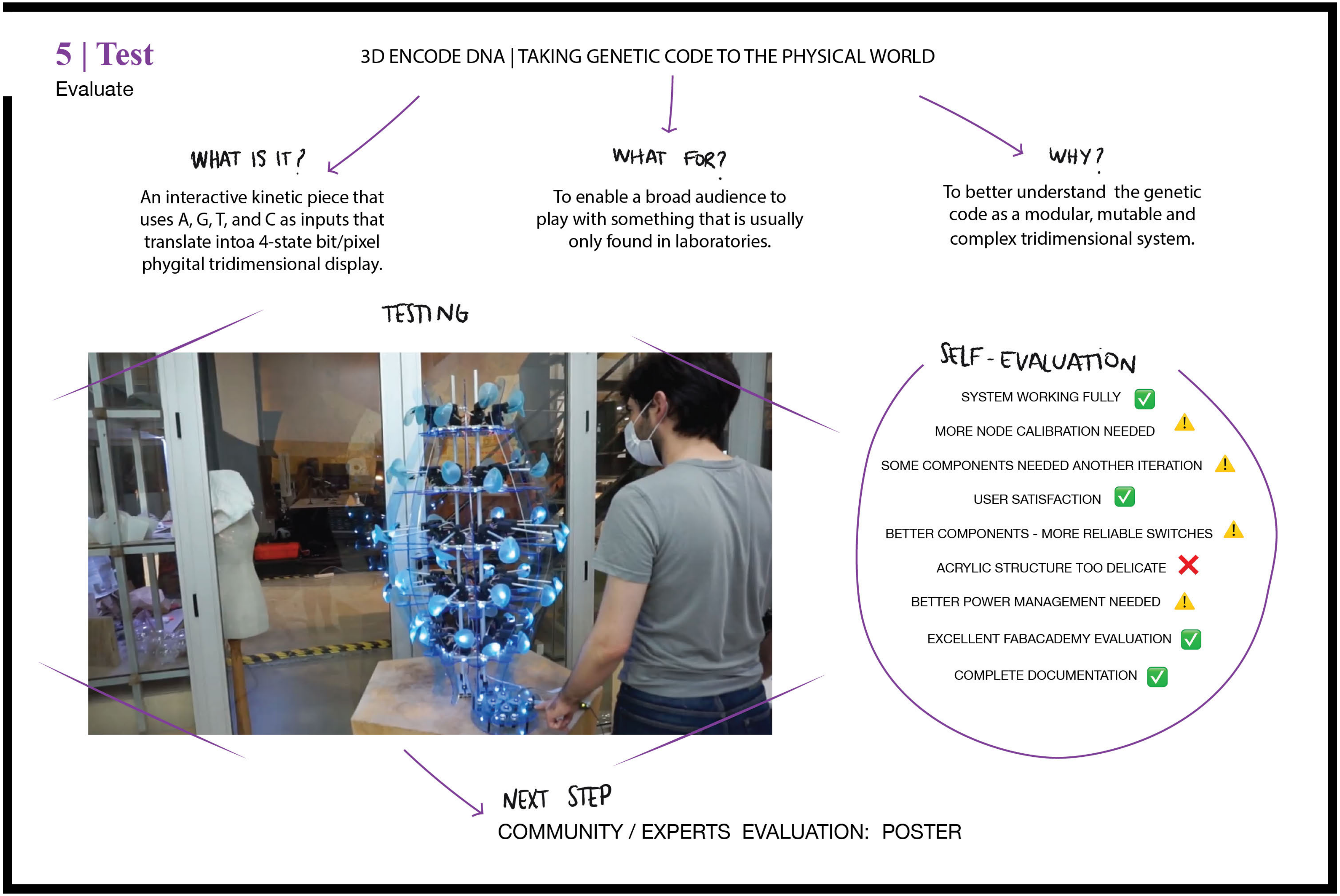


Figure 9 Test phase development by the author.

Figure 10 FabAcademy Final Presentation panel by the author.

Conclusion

What makes this prototype an object that democratizes scientific knowledge through the empowerment with digital fabrication? By definition, all Fab Academy final projects must be available online, including step-by-step instructions, blueprints, and construction files (3D printing, laser cutting, etc.) to be consulted and reproduced (link including author's Fabacademy folder). Is there any caveats? If one is not part of the Fabacademy community, regardless of how international and widespread the Fab Foundation is, the project might not reach its intended audience. So, for someone to find this information, it must be shared in broader communities. That is why I decided to visit different kinds of communities to get feedback and offer the process as a tool that anyone can build in a FabLab with a reasonable budget. To share the project in a synthesized and visual manner, I revisited the poster that I had to deliver with my Fab Academy assignment so I could focus more on the use, goals, and interactions rather than just the construction.

Additionally, it went for internal ChromDesign discussions to continue evaluating the prototype. After many fruitful conversations, some improvements were suggested. The most relevant were adding actual genomic data, allowing more complex interactions, having different modes, enhancing visualization, and giving more context for non-expert audiences. For this experiment, presenting the prototype to the ChromDesign community was critical as their validation was relevant to ensure scientific rigor and contextual fit. The prototype was then given to different communities for feedback through different scientific posters: Design Research Society Conference, Vizbi (Visualizing biological data conference), and Biosummit.

To sum up all the interactions and answer the initial questions: Can digital fabrication support creating interactive experiences to bring science closer to society? The answer is yes. Thanks to the broad exposure of the prototype, there was a clear outcome, a route on how to iterate on the same project, and an acceptance of the development proposal of interactive prototypes through the digital fabrication framework provided by the Fab Academy. Even so, how can we use an existing digital fabrication framework for prototype development? The presented development structure can work outside of the Fab Academy program, as the only requirement is having access to the tools you'd find in a Fablab because all the resources and lectures are available for free online (https://vimeo.com/academany) in addition to the project's step-by-step instructions.

Last but not least, the potential relies on future developments using DIY Interactive Popular Science for other contexts beyond the scope of this sole kinetic piece that will require revisiting before being put out in public again. Without a doubt, a more refined and sturdy version can be built in the future.

Acknowledgments

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Carla Molins-Pitarch, Ph.D., MFA, is an experience designer, creative technologist, and researcher working at the intersection of design, technology, and science to bring a tangible instance to complex concepts at the Image Processing and Multimedia Technology Center, Universitat Politècnica de Catalunya-Barcelona (DiCode: digital culture and creative technologies research group). Former Marie Curie fellow researcher at ELISAVA Barcelona School of Design & Engineering (ChromDesign project); doctoral researcher (GRECC & OCC) in science communication at Pompeu Fabra University (Spain); La Caixa Fellow, Design & Technology MFA '19 Parsons, The New School (NY, USA). Her practice has been centered on visualizing scientific concepts through haptic and interactive experiences, creating immersive experiences, including kinetic-robotic objects that materialize abstract concepts such as dark matter and genomes to provide learning and discovery. Her work and research have been presented and exhibited since 2013 in Spain, Finland, Switzerland, the USA, Belgium, Germany, France, Malta, and Austria.

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