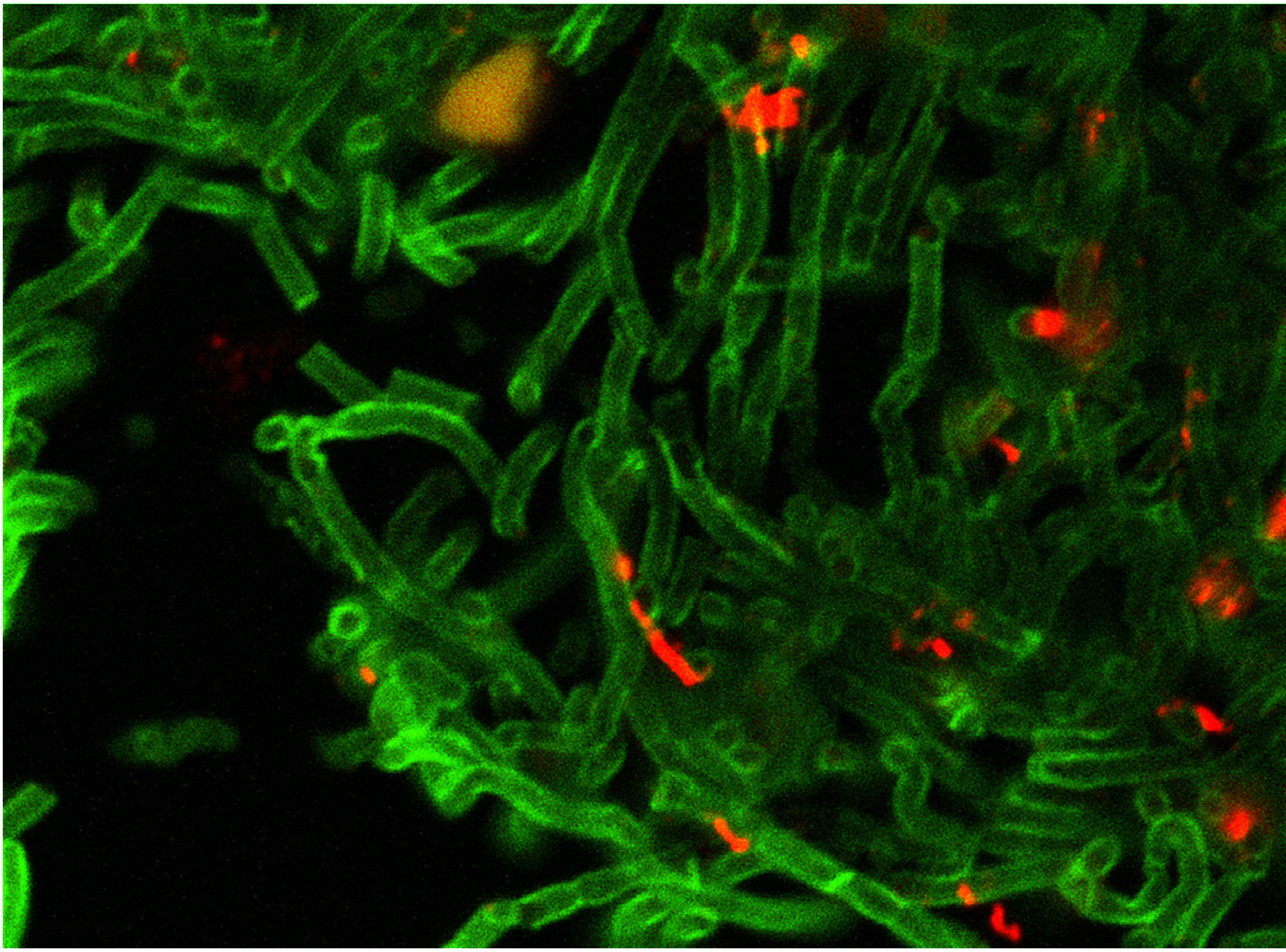
University of Applied Sciences and Arts of Southern Switzerland
Master of Advanced Studies in Interaction Design

SUPSI

DiPLab

An Interactive Multimodal Experience to involve Young People in learning about Antimicrobial Resistance



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Confocal micrographic image of Bacillus anthracis bacteria, revealing green-colored bacterial cell walls, and red-colored endospores. Image provided by CDC/ Dr. Sherif Zaki; Dr. Kathi Tatti; Elizabeth White. *Public Health Image Library from the Centers for Disease Control and Prevention (CDC)*

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1.1 Research Topic
1.1.1 Topic Introduction

Science is one of the most important fields in our world. Especially in recent years when dealing with human-related issues. Innovations in this area help improve the quality of our lives, our planet, and our flora and fauna.

Microbiology is one of the main areas of interest in studying the microorganisms that have been with us since the beginning. Raising awareness about these issues is critical to recognizing potential problems and keeping us safe and healthy. Moreover, most of the resources are hard to read and understand, so for children and teenagers is difficult to tackle this subject and for parents and teachers is even worse to explain this world. The main problem is therefore the accessibility of information and misleading data that can lead to the opposite result.

Attracting countless members of research teams that require little or no funding can spur innovation and uncover new opportunities. Engaging the public in activities related to a particular topic will help many real-life scientists collect data faster and find new opportunities in less time.

> ”For instance, citizen-science projects in astronomy might simply involve going out at night to observe stars—an activity that does not require sophisticated equipment or a specialised environment”
>
> (Garbarino, Mason 2016)

As suggested by Jeanne Garbarino and Christopher Mason, citizen science is used in accessible fields of study. For instance, the engagement of a citizen in the astronomic domain can be easily done by watching stars. Moreover, this experience can be done using no tools or simple ones and wherever. Nowadays, thanks to the advancement of technology are easier to tackle even more difficult-to-understand projects, like microbiology (Garbarino, Mason 2016).

By using the Citizen Science approach to support public engagement in scientific research, we can raise awareness of the field and make science accessible to all. This method should be used by scientists who are careful to give people clear instructions, prompt their attention, follow directions, and see helpful troubleshooting guidelines.

Note that all scientific research results are published in the form of static text and images in scientific papers and editorial articles. Additionally, the language used is highly specialised and difficult to read, and access to these sources is usually costly. Consequently, the non-scientific public accepts science journalism way of expression. Since this kind of communication is the handiest supply on hand to the citizen, and their goal is to hook human beings to examine greater their articles, this may be misleading (Sievert, Patel 2018).

> ”There is a growing narrative to engage the public with science in novel ways and to reach new audiences. To achieve these aims in informal STEM (Science, Technology, Engineering and Maths)

learning is challenging, and despite attempts organisers frequently report seeing a lack in audience diversity and repetitive clientele."

(Duckett et al. 2021)

Several projects are looking to bring STEM activities into non-technical settings, such as museum events. Public participation in activities is very helpful in increasing knowledge of science-related topics. Thanks to this kind of activity we can manage citizen science without recurring reading scientific papers that are difficult to understand.

1.1.2 Microbiology focus

Focusing on microbiology, the literature is even more complex and incomprehensible to those who wish to obtain the information themselves. As Paola Scavone suggested in their article, new communication methods should be sought to engage the public on this issue (Scavone et al. 2019).

> "We need to put microbiology onto our society's agenda, which is certainly a challenging task. It is necessary to debunk certain preconceptions about microorganism and to stress their importance in our lives and in every ecosystem. To contribute to the microbiology literacy of our society we need to explore every available resource in order to communicate the discipline in a clear and appealing way."
>
> (Scavone et al. 2019)

Hands-on STEM activities could be used to address the knowledge about this particular topic, generating more awareness and helping scientific research with little or no funding.

This thesis project would focus specifically on a particular area of microbiology, antimicrobial resistance (AMR).

As the World Health Organization notes on its website, AMR comes when bacteria, viruses, fungi, and parasites change over time and become unresponsive to drugs. Infections become more difficult to treat, and even easily cured illnesses can be fatal (World Health Organization 2021). The proliferation of superbugs that are no longer treatable by common antimicrobials such as antibiotics, is alarming. Developing new antibiotics is difficult, and in 2019, out of the 32 antibiotics established by WHO, only six were classified as revolutionary.

> "The main drivers of antimicrobial resistance include the misuse and overuse of antimicrobials; lack of access to clean water, sanitation and hygiene (WASH) for both humans and animals; poor infection and disease prevention and control in health-care facilities and farms; poor access to quality, affordable medicines, vaccines and diagnostics; lack of awareness and knowledge; and lack of enforcement of legislation."
>
> (World Health Organization 2021)

For example, the percentage of ciprofloxacin resistance increased from 8.4% to 92.9% as reported by GLASS (Global Antimicrobial Resistance and Use Surveillance System). This particular drug is used to treat urinary tract infections, a common condition, especially among women. This trend can be dramatic, as antibiotics are also used to prevent infections after surgeries such as caesarean sections, chemotherapy, and other medical procedures.

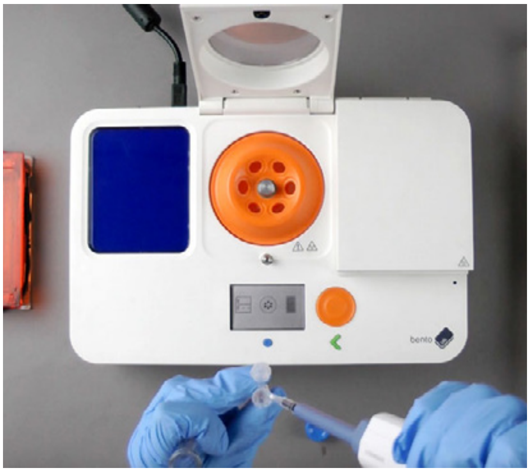

Fig 1: BentoLab is helpful to test your DNA including functions found in huge laboratories.

Fig. 2: Post/Biotics Solo Kit™ a citizen science project that helps to discover new antibiotics.

Since people don't change their mindset about antibiotic use, discovering more innovative drugs may not work (World Health Organization 2020).

> "AMR is a complex problem that requires a united multisectoral approach. The One Health approach brings together multiple sectors and stakeholders engaged in human, terrestrial and aquatic animal and plant health, food and feed production and the environment to communicate and work together in the design and implementation of programmes, policies, legislation and research to attain better public health outcomes."
>
> (World Health Organization 2021)

The research on this argument is increased over the past 20 years, as suggested in the article written by Luz C. F. et al., in 2018 there was an increase of 450% in comparison to 1999. To better understand the importance of this topic for medical researchers, the overall increase of PubMed publications from 2004 to 2013 is 48.9%; at the same time the AMR articles expanded by 129%, more than doubled (Luz et al. 2022).

1.1.3 State of the arts

The actual state of the arts reveals multiple projects that focus on citizen involvement in science topics, especially in the domain of DNA testing. These products work as portable labs [Fig. 1] where non-scientists can test themselves by collecting information using the provided kit and then sending the results to the researchers that can develop then a complete view of the family history and at the same time use the provided data to enhance the development of research. Moreover, there are other examples of scientific activities that are addressed in a different way having then a similar result. Specifically, there are experiences where a citizen can act as a "little researcher" and discover more about the area of interest; like POST/BIOTICS [Fig. 2] a platform that enables the public to discover more about antibiotics and their development by collecting samples of terrain and then analyzing it using the provided kit (Vidhi Mehta 2016). Another example of an activity done to disseminate science information is to design laboratories with the public to introduce easy-to-learn principles of science. The Science Festival in Genoa is a case of a simple approach to different science fields, suitable for different ages starting from kindergarten kids to university students (Associazione Festival della Scienza n.d.). Most events have a hands-on laboratory [Fig. 3] with a visible final result that represents a particular domain of the subject, delivered by a professional team.

There are other methods used to engage people on this topic, some researchers spread their knowledge by creating videos

Fig 3: Hands-on scientific activity during the "Festival della Scienza" in Genoa (2019).

on YouTube, like Zach Murphy as Ninja Nerd [Fig. 4] on the platform, focusing each time on different topics and thanks to the community aspect of the service citizen can easily ask further information to the creator or share their personal experience (Zach Murphy n.d.). Others from the Massachusetts Institute of Technology created a way to create music beats out of bacteria collected by people; thanks to a swab you can collect a sample of selected parts of your body (e.g. nose, belly button, etc.) and then streaked onto the biota-record [Fig. 5], a personalised petri dish that has the same shape as a vinyl disk, and then capture images of it. After processing the images, thanks to an algorithm the Biota Beats team can create hip-hop beats and create a song (David Sun Kong et al. 2017).

All these different activities, in another way, are helpful for a citizen to discover more about the domain of microbiology without having to read scientific papers or inform using possible misleading sources.

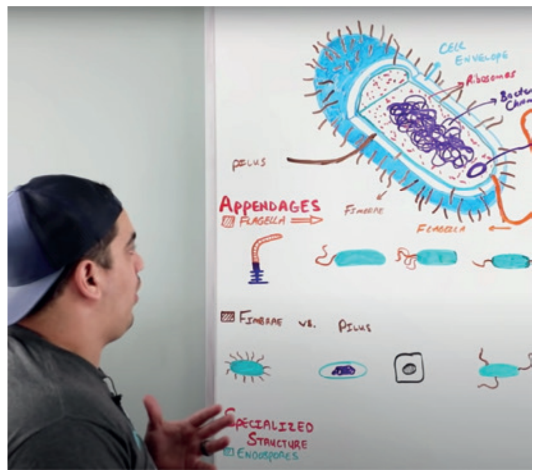

Fig 4: Zach Murphy (Ninja Nerd) on YouTube explains how a Bacteria works.

Fig 5: Biota Beats system was created by David Sun Kong a researcher in the Media Lab at MIT.

1.2 Research Question and Hypothesis

Thanks to the definition of the research topic, it is now possible to outline the main research question.

How might we disseminate complex scientific information to high school students?

Having the primary interrogation, we can shape more in-depth questions.

How might we engage high school students on microbiology science topics through meaningful and engaging digital and multimodal experiences?

How might we communicate interactively science specifically AMR and antibiotics?

A hypothesis is to include an interactive and intelligent component, providing a physical experience that is helpful to build awareness on the issue and acquire experience on a subject that demands a high level of expertise.

Because of the hands-on approach, using a tangible interactive product allows citizens to directly experience the subject. This type of exercise, in which the audience can see the final outcome of their contribution, is beneficial for learning while doing and so making people conscious of the explained issue.

As previously said, complicated science is difficult to transmit by graphics and words alone. Reading a scientific article is difficult due to the pricing and technical terminology. Lastly, science journalism, as an alternative, can be deceptive.

1.3 Research Aim

The investigation will focus on several topics of educational science. Specifically, citizen science and the approach to a complex and delicate topic such as AMR and antibiotic usage.

Because the experience needed to spread scientific concepts, it also focused a portion of the research at determining how we could treat a complicated issue effectively in order to gather as many data as feasible. Interviewing professionals active in the educational sector of science can be useful; the information required is about simplifying a difficult-to-understand issue without compromising crucial aspects in order to offer correct information. It will be intriguing to see how this is addressed by participating in various hands-on laboratories and understanding the benefits and drawbacks of this type of activity. At the same time, knowing how to promote awareness without frightening the public with an alarmist argument as antimicrobial resistance is beneficial.

Another key aspect of the research is the investigation of solutions that are safe to share with the public, which will be uncovered through interviews and concept development with microbiological specialists. This component might be quite crucial in determining how this experience should operate; it is critical to build a safe setting in which to conduct experiments without causing potential threats to the public.

Another significant aspect of the research will be the usage of a tactile interface to better convey the needed information. The primary focus will be on generic research into how we might help citizens' scientific learning through the use of relevant and engaging digital and multimodal experiences that people can directly experience. Then, to better comprehend new approaches and possibilities, it might be highly valuable to examine the technology used in similar items.

While using digital products, it is also essential to analyze the potential connections between all of the technology items that are now in use. It is possible to increase the power of a single digital product by connecting different devices.

All of this information should be sufficient to better comprehend the area of interest and create a solution that answers the previously provided research questions.

1.4 Research Outcome

The desired output will be an interactive solution that may aid in the understanding of complicated subjects such as microbiology and provide answers to research questions. The emphasis will not be on creating a totally digital product. Although the usage of a tangible product can include a digital component, it also allows the user to interact with the environment and/or control outputs in addition to physical feedback. It is now feasible to collaborate with people utilising the learn-by-doing approach, in which the public must play the primary role. Experiencing a topic as a protagonist intensifies the experience and aids comprehension.

> "Hands-on activities bring life back into learning. It gets students up and moving. It gets their blood pumping and their mind revved up. It forces them to listen to instructions so they understand the next step to take or how to overcome a challenge."
>
> (Arnholz 2019)

Microcontrollers may combine millions of different sensors, allowing for more customisation of the end product through connections with other devices. The created experience must be clever in order to produce an entirely new science activity. Furthermore, as originally stated, the final output should interest the audience in elusive themes such as microbiology and AMR. As a result, a physical interface will be simple to use and quick to master. The goal is not to instruct the general audience on how to use the product, but to establish support for learning something new about a hard issue. Another critical problem is promoting awareness without frightening the audience. Microcontrollers may combine millions of different sensors, allowing for more customisation of the end product through connections with other devices.

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The research procedure allows the outcomes to be characterised more clearly in light of the aforementioned principles. It is planned to provide a unique physical interface to educate the general population and enhance understanding of microbiology, with an emphasis on antibiotic resistance.

2. Analysis of the State-of-the-Art

Desktop Research Integration

2.0 Introduction

The investigation of the current state of the art explores three distinct groups of artefacts. In particular, educational tangible kits will be examined, where all products or activities to explore science-related or non-scientific topics with the help of a physical kit; secondly, a hands-on approach will be considered thanks to laboratories where participants can directly experiment with the topic; and finally, the researcher's sharing through digital experiences and the community aspect will be investigated.

2.1 Tangible education kit

As previously anticipated, we examine the learning process using tangible devices. Some examples are directly tied to science-related issues, such as microbiology, while others are intriguing ways of physical instruction with a broader goal.

POST/BIOTICS

Through the Post/Biotics tools, anybody may become an antibiotic researcher. It's a portable scientific lab that anybody may use to test new compounds in their surroundings for antibacterial qualities. Many Post/Biotic toolkit users' databases are returned to a scientific database and checked by microbiologists and scientists working on new antibiotic research.

An incubation zone, 5 incubation test plates, a sample collection tray, sample bags, buffer solution, isopropyl alcohol, non-pathogenic E.Coli cultures, bio-waste disposal bags, and safety gloves are included in the product. [Fig. 6]

An Android phone is linked to the physical device to collect data from consumers and share it with scientists who can see the results on the backend. Inside the toolkit's box, is it possible to find different accessories that support the experience like a mortar and pestle, agar solid media plates, nitrile protective gloves, syringes, buffer solution, microcentrifuge tubes for samples, Escherichia Coli bacteria, antibacterial control, and an inoculating tube.

The most intriguing aspect of this physical experience is the opportunity for everyone to participate in the creation of new antibiotics in daily settings such as green spaces. Another interesting aspect of the project is the creation of a scientific international library based on citizen research conducted using basic tools and backed by a multimodal product that acts as a support during the experience.

Bento Lab

Thanks to Bento Lab is it possible to have a mini DNA testing environment similar to huge laboratories that allows anyone to take a biological sample, extract its DNA, and do a rudimentary genetic study. The product may be used as a portable laboratory or as a learning tool for doing some simple experiments like DNA extraction from saliva.

Fig. 6: Post/Biotics Solo Kit™ a citizen science project that helps to discover new antibiotics.

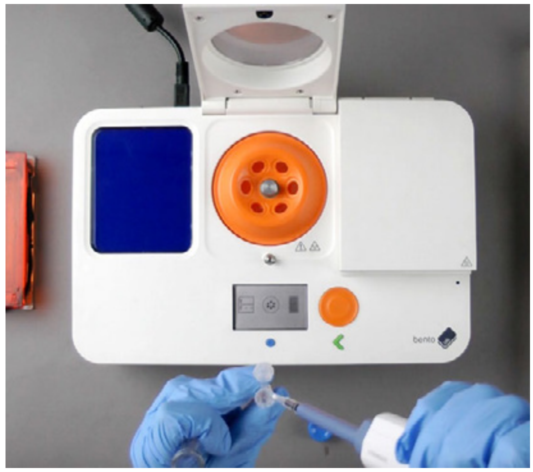


Fig 7: BentoLab is helpful to test your DNA including functions found in huge laboratories.

The product is composed of a PCR thermocycler, centrifuge, gel electrophoresis, transilluminator and a screen to interact with the lab. [Fig. 7]

Unitec Institute of Technology lecturer Stephane Boyer utilises Bento Lab to teach Molecular Biology to students interested in biodiversity. He also provides one- or two-day outreach programmes for schoolchildren and the general public. Stephane's study focuses on species identification and biodiversity assessment. He frequently goes to remote locations to obtain DNA samples, and he may use Bento Lab to ensure that the samples are of high quality before returning them to the lab. (Bento Bioworks 2022)

> "Bento Lab allows me to give each student real hands-on experience in molecular analysis. I want to put a Bento Lab in the hands of every one of my students."
> Stephane Boyer
> (Bento Bioworks, 2022)

The interesting part of this project is the use of a professional tool even to conduct educational activities with students. The product is then used by researchers to develop their activities around the world and at the same time to spread knowledge on a scientific topic in any kind of environment without recurring to a testing laboratory.

miniPCR

The miniPCR is a portable Polymerase Chain Reaction machine that thanks to the interconnection with computers, tablets and even smartphones can perform molecular photocopying to amplify DNA in order to study it in detail.

Thanks to the portability of the object, is it possible to use it as a researcher's machine everywhere, from forests to school classes and even in space (in fact, was used on the International Space Station).

The product has 8 [Fig. 8] or 16 slots to accommodate PCR tubes to prepare them to be analysed later. The software is capable of doing a wide variety of thermal programs, including polymerase chain reactions, heat blocks and temperature ramps.

The company also created the Learning Labs™ to explore innovative approaches to key subjects while pushing students of all levels. The target here is young students from middle school to college that during school time will explore topics that need a PCR machine to experiment.

Fig 8: The miniPCR mini8 thermac cycler, also used in the space aboard the ISS.

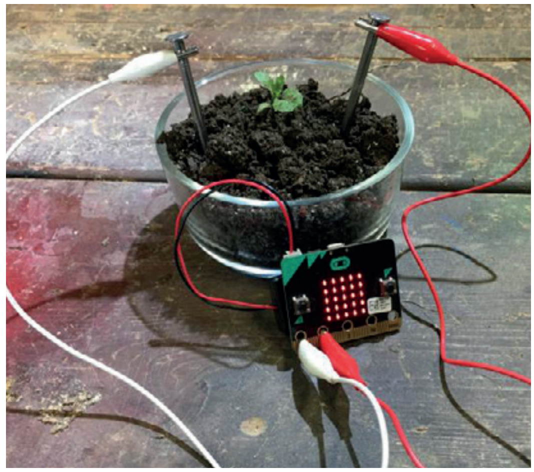


Fig 9: A biology project that can be done with Micro:bit - track the soil moisture of your plant..

> "The kit is incredibly well organized and truly self-contained; we had everything we needed to do an actual molecular biology experiment; The students said it was their favourite activity of the year."
> Debbie Granger
> Durham Public Schools Biology Teacher
> (Amplyus, 2022)

> "Getting hands-on and experimenting with the micro:bit is critical to helping children better understand important technologies early in their development."
> Gareth Stockdale
> CEO Micro:bit Educational Foundation
> (micro:bit, 2022)

Micro:bit

The BBC micro:bit is a credit card-sized microcontroller that is ideal for teaching children and newbies how to code due to its simple interface. This allowed them to turn their concepts into interactive projects, games, or robots.

The board has two programmable buttons, 25 individually programmable LEDs, a microphone, a speaker, a touch-sensitive logo, and an accelerometer. On the bottom, 3 independent Analog/Digital I/O connections, a 3.3V and a ground port, all compatible with banana plugs or crocodile clips, may be connected. [Fig. 9]

The ability to programme the microcontroller allows for the creation of a wide range of projects. Indeed, on the micro:bit website, you may discover various activities to help you learn how to use the board and gain a better understanding of the world of physical computing.

The software has an intriguing feature in that it allows anyone with no prior experience in the subject to construct an interactive project. Furthermore, the user may observe the outcome of the initial action immediately through the output, such as the LEDs or the speaker, without the need for additional parts or equipment; all that is required is a computer and the board.

My First Biolab

My First Biolab (MFB) is a laboratory in a box designed by Milab for hands-on experiments in the field of microbiology, to experiment with live microorganisms at schools.

The product [Fig. 10] is composed of a transparent box where all the electronics are stored, in particular, is it possible to see three main components: a heat transfer plate that is useful to heat the cultivation area with the microorganism inside, a magnetic peristaltic pump that permits to the liquid to circulate and help the growth of bacteria, and a spectral sensor to collect

Fig 10: My First Biolab, visualize and grow bacteria inside a box.

Fig. 11: The robotic arm of the project OpenLH.

data about the spreading of microorganisms.

The bag is made of two sheets of Polyacrylamide-Polyethylene (PAPE) welted together using a laser-cutting machine and is magnetically linked to the main box. This technology makes it completely safe to experiment with live microbes without the risk of spreading infections. Indeed, the use of a laser cutter allows for the creation of particular liquid channels to increase circulation and chambers to keep the bacterial liquid until the user interacts with it and mixes it with the media.

The user interacts with the system using an application, which allows the user to start all of the components, track the progress of the experiment, and view the data generated from the sensor.

The approach of generating a sterile environment in which to operate without the risk of spreading microorganisms is the most intriguing aspect of this device. The approach employed to make the bag and the couplings with the box are intriguing; the product assisted in the invention of a novel form of data collection using a modular system. Furthermore, the laboratory was built to be utilised in high school, and because there are harmful compounds within, rules must be followed, specifically the Biosafety Level 1 requirements (BSL1).

2.1.6 OpenLH

The OpenLH is an open liquid-handling system designed for safe, flexible, and accurate microbiological experiments. The system is built on a robotic arm, precisely the uArm Swift Pro, which allows the user to operate without touching the components directly. The robotic arm [Fig. 11], bespoke 3D printed parts, a customised pipette, and a block-based programming interface compose the product. It is feasible to utilise several materials to generate different experiments thanks to the system. The research shows that OpenLH is valuable for the Human-Computer Interaction community since it uses live microbiology in unconventional sectors, such as using E. coli for visual experiments on petri plates.

The team produced two distinct results; the technology developed was utilised to assess its feasibility in non-scientific experiments: visual design and beer brewing.

The first employs graphics made with layer-based software; each layer has a colour representing a microorganism. Following the export of each layer, the pictures are converted from Bitmap to Bioprint. This is accomplished using software developed by the researchers that converts a picture to X, and Y coordinates reads the dimension of each pixel and converts it into microliters to inject into the petri dish. The team was able to construct an agar plate that is disclosed after 12-24 hours, which is necessary for bacteria to proliferate.

The second experiment focuses on beer production and the amount of yeast in the beverage. It is feasible to do a serial dilution using the system to calculate the number of microorganisms in the original solution. As long as the amount of yeast used remains consistent, the brewer can determine the extraction time and amount of yeast solution to utilise.

The system is intriguing since it employs microbiological laboratory techniques to produce studies that are unrelated to the scientific world. Another essential element is that owing to the robotic arm, the system can be used without directly contacting the petri dish with bacteria inside, and it is safe to view a result even without touching anything within the product.

2.2 Hands-on laboratories

As mentioned in the thesis project description, one of the finest ways to learn something about science is through hands-on experience. Indeed, this strategy is the underlying idea of several experiences aimed at disseminating scientific topics to individuals, particularly young learners.

Simply Science

Simply Science is a foundation that aims to encourage young people's interest in technical and scientific matters. The project's purpose is to prepare students for a possible future profession in this environment. Furthermore, it creates a link between schools and businesses through partnerships with science industries, which includes 250 Swiss organizations working in the pharmaceutical, chemical, and life science sectors.

The emphasis is on the website, where the organisation offers science news and a variety of activities that may be done at home or school. The initiatives are organised into three categories: children, adolescents, and teachers. The first two are intended for home experiments that may be carried out with simply the guidance of an adult, particularly for children. The instruc-

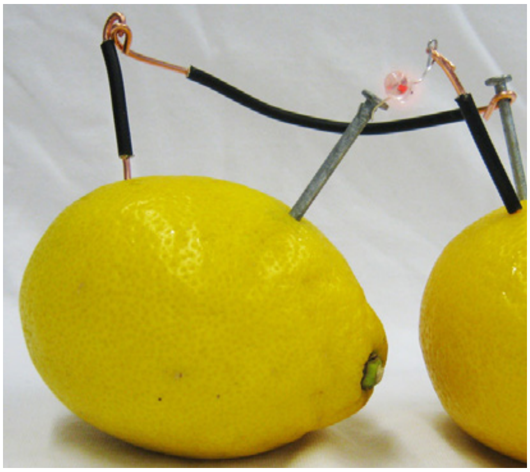


Fig 12: Lemons to create a battery othat can be found on the Simply Science website.

Fig 13: Hands-on scientific activity during the "Festival della Scienza" in Genoa (2019).

tor category is more concerned with the resources needed to teach a topic.

The analysis considers initiatives for teenagers, as this is the intended audience for the thesis project. To better comprehend how an experiment is described, we will focus on one specific example: producing electricity with two lemons [Fig. 12].

The page explains what materials are required for the experiment and where to get them if necessary. Following that, it is written step-by-step instructions on how to perform the exercise. Furthermore, scrolling down the page reveals a helpful guide for locating the project's frequent issues. The science that remains in the backdrop of the experiment and the history behind it is written as the final section of the page.

Because of the specific target chosen for the trials and to find how a science-related experience is built for them, this project is beneficial for investigation. What is possible to notice is that the experience comes before the scientific facts; so, the young user should be interested in the argument following the conclusion of the experiment.

Festival della Scienza

The Genoa Science Festival is a major event for scientific dissemination in Italy and Europe. Is intended to cover a week's worth of science-related discussions, experiments, and experiences. All meetings are planned by scientists, researchers, scientific organisations, or institutions. Except for the first and last days, when it is possible to participate in more than 90 activities, there are more than 100 events every day. Out of 100 meetings in one day, there are more than 60 laboratories where citizens, mostly young pupils, may explore science. The studies range from medication formulation to coding without a computer and have no recurring theme. Each event aims to achieve a certain goal, increasing or decreasing the complexity of the material delivered.

In general, all of the activities [Fig. 13] make use of a real laboratory or a transportable one. Some events, such as coding without a computer, may be accomplished using simply scraps of paper or wood. The purpose of each experiment is to undertake a hands-on exercise that allows each person to test themselves and experience something new. This strategy, as previously said, increases students' attention and the learning component.

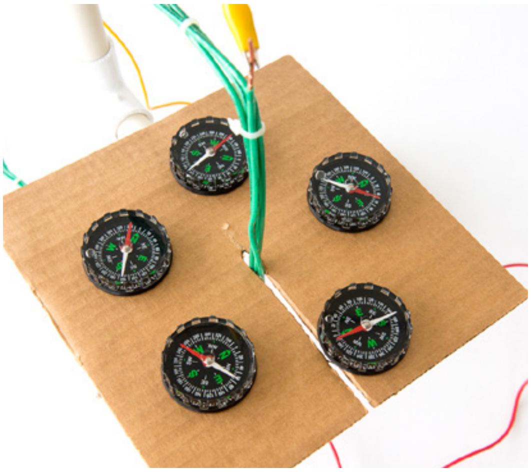


Fig 14: A snack for high school students, the circle of magnetism from Science Snack.

What is intriguing is the method of including a large number of young people in a science-related event. A qualitative study would be important to better understand how this is accomplished and how scientists or researchers communicate with students.

Exploratorium “Science Snack”

The Exploratorium, a public laboratory located in San Francisco, California, allows visitors to view the world through the lenses of science, art, and perception.

The nonprofit organization has a wide range of resources, including science exhibitions and art galleries; the research will be centred on “Science Snack.” This project is a collection of experiments for teachers that have been tried out by educators and can be carried out at school or home by parents without the use of sophisticated equipment.

The homepage of the snacks can be accessed to view some highlighted projects and the opportunity to select from experiments broken down by subjects, family-friendly activities, experiences that are integrated with videos, and a special category called “bocadillos cientificos” where all Spanish-language projects are gathered.

The experiments are divided into grades as well, making it possible to select an experiment while taking into account the young learner’s aptitude and potential for project-based learning. To better understand the division by grades, it is necessary to keep in mind that school grades in the United States are completely different; in fact, the target high school chosen for the project is the equivalent of grades 9 through 12.

It was decided to choose a project that is intended for the target, the circle of magnetism [Fig. 14], to better understand how experiments are described. The page begins with a brief project description, followed by a list of materials needed to complete the experiment, and then lists the project’s steps in order of completion. Additionally, some pertinent details can be useful when experimenting, followed by the theoretical information related to the project.

The experiment’s page’s division, which is very similar to Simply Science in that the experience comes after the theory related, is what makes the “science snacks” interesting for the aim of the project.

Fig 15: Biota Beats system was created by David Sun Kong a researcher in the Media Lab at MIT.

Fig. 16: La Fisica Che Ci Piace - Vincenzo Schettini on his videos' cover..

2.3 Digital experiences

The last category includes all initiatives that rely on digital output, including music production and videos posted to TikTok or YouTube. These projects are intriguing because of the unique dissemination strategy used due to the diverse target audience.

Biota Beats

The Biota Beats is a project created by the MIT media lab to spread knowledge about microbiological concepts, specifically how we co-exist with bacteria and the growth process. The project's goal is to produce music using bacteria gathered from people around the world.

The project [Page 15] is broken down into four main phases: gathering, growing, processing the data, and creating beats.

The team prepares some petri dishes where bacteria will be stored and allowed to grow as the first step in gathering data from citizens. After that, they must give each person a swab and show them where to rub the stick to collect bacteria from the public. Due to the bacteria gathered, all of the petri dishes have been relocated to a secure location where they can allow bacteria to grow in 24-48 hours. Additionally, the team can scan all of the cultivated bacteria's plates after one or two days and categorize them based on where the swab was applied: the mouth, feet, genitalia, belly button, and armpit.

An algorithm can produce a musical beat that will be played back to the participant after all the bacteria have been divided and the biota record, a customized petri dish with the shape of a vinyl disc, has been created. The algorithm used to convert the sounds produced by bacteria takes into account the section's density, diameter, radial distance, and angle from the dish's centre.

The experiment was made on a large scale to disseminate microbiological knowledge, such as how bacteria grow, the various types of bacteria inside our bodies, and the fact that we spend our entire lives surrounded by bacteria that are safe for us, which makes this project interesting. However, given that the experiment could last up to three days, it is challenging to comprehend how a large number of people can be amused throughout the entire duration of the investigation.

LaFisicaCheCiPiace

Vincenzo Schettini [Fig. 16], a content creator better known on TikTok as LaFisicaCheCiPiace, posts brief videos about science, from physics to mathematics. Young people can respond to some quizzes in the form of written comments or a "duet" in between the science videos.

In the last year, the professor starts teaching at the school as an external educator.

Here is a breakdown of the video on the physics of a pizza so you can see how the lesson is structured. To explain how the theme was handled in the video, Vincenzo begins by demonstrating a real pizza in a pizzeria. It's important to note that TikTok is only a few seconds long. What is the best mixture for a pizza? is the key query. The video continues with the professor hanging a small whiteboard on which the Roman and Neapolitan mixtures are drawn, with arrows representing heat to show the differences between them. The primary heating formula is below, where the thickness of the substance—in this case, pizza—is highlighted. Vincenzo goes on to say that Roman's pizza is the best in terms of physics because the thickness is uniform and the heat is distributed across the surface more effectively.

This kind of video, as it is possible to see when Vincenzo goes to school, is very appreciated by young people because thanks to the length and the real examples they can see how things work and why science impact our life. At the same time, the information shared is more likely learned by students because they can connect a real fact to something they need to study, and since TikTok is not required by schools if they watch LaFisicaCheCiPiace is because they want to.

2.4 Insights

Is it possible to discern from the current state of the arts that all projects relating to science or those with the goal of disseminating scientific information use the same methodology, an observable or palpable example that illustrates the theoretical topic that remains at the core of the experience. To keep the environment safe for those taking part in the activity, strict guidelines must be followed by all projects involving real bacteria. Government regulations determine the rules, so it depends on the location of the activity. Additionally, projects that simulate a laboratory attempt to take a particular task completed in a tank in a laboratory and concentrate it in a product; this is done to reduce the complexity of a particular tool used in a real lab and to keep the cost as low as possible.

Projects that want to share scientific information that is not necessary for the activity share the theoretical portion after the practical activity. This can be used to support the scientific idea of visualizing the outcome and comparing it to the example done before.

Another crucial point is that, when addressing high school students, the time required to conduct an experiment or share a video must be minimal to effectively convey an activity based on scientific data. During the qualitative interviews with them, this can be a crucial point to comprehend more thoroughly. If the project must be completed in a school, it is essential to keep in mind that many lack a dedicated or general laboratory to conduct specific experiments. This is another critical point for this particular target.

Qualitative interviews with high school students and science educators will be conducted to better understand how to communicate scientific information.

3. User Research and Concept Design

Qualitative research and ideation

3.1 User research

As anticipated before, qualitative research using one-on-one interviews with high school students and educators who work in the scientific sector was conducted following the state of the arts.

In particular, it was possible to interview Maria and Alberto, two students from different high schools in Italy (names made up to protect their anonymity). Maria [Fig. 17], who is 17 years old and studies lanuages, dislikes most scientific subjects and is concerned with getting the best grades in each subject on her exams. Alberto [Fig. 18], who is 14 years old and studies applied science, enjoys learning about science-related topics and, whenever possible, attends science festivals and workshops to learn more about it.

It was also possible to interview four educators with various backgrounds from Italy and Switzerland. Aldo Winkler [Fig. 21] is the Laboratory Head at the National Institute of Geophysics and Volcanology in Rome. He is also very interested in education and speaks about air pollution and magnetic solutions to the issue at the Science Festival of Genoa. Chiara Segré [Fig. 20] is employed by the Umberto Veronesi Foundation in Milan as a Scientific Supervisor. She focuses primarily on science communication for the foundation and works as a freelance author and educator for the Science Festival of Genoa. Cristina Corti teaches microbiology at various high schools and universities in addition to working at the SUPSI Microbiology Laboratory in Mendrisio. With a background in social policies, Mattia Cavin [Fig. 19] works as an extracurricular educator for a group that works with high school students while also attending the SUPSI Master of Interaction Design in Mendrisio.

Attempts were also made to reach science educators working in the digital world, such as content creators on YouTube or Tiktok, but it was impossible to arrange an interview.

3.1.1 High School Students

It was possible to learn a lot about how high school students approach scientific topics and generally how they approach the study of a new argument from their interviews.

The interview began with a task intended to help participants better understand their knowledge of antibiotics and antimicrobial resistance to gauge their level of familiarity with the topic.

The first realization is that, as was predicted, neither of the two interviewees had any knowledge of the topic; Alberto, in particular, had a lot of inaccurate information.

> "The antibiotic cures the disease, goes to find the source of the disease and eradicates it, goes to get the viruses and kills them."
>
> Alberto, 14 years old

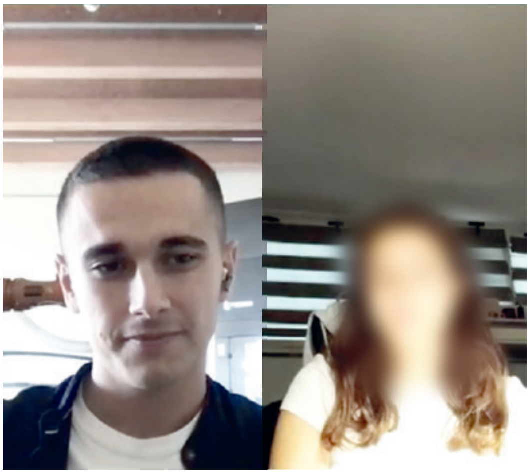


Fig 17: Interview with Maria.

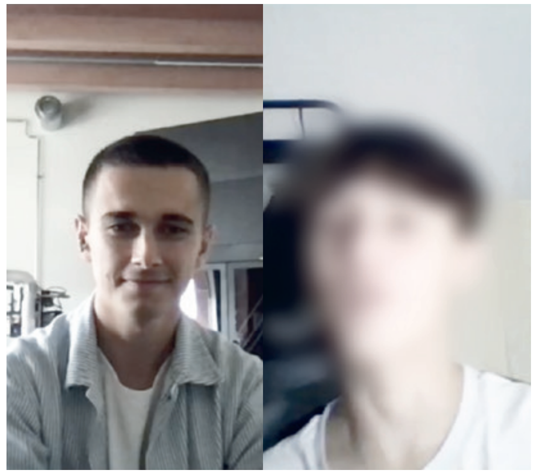


Fig 18: Interview with Alberto.

The interviews continued with more specific questions about their experiences with school lessons after the introduction game, which served as an effective icebreaker. In this case, the outcome was that theoretical subjects, when they are explained in a book or with a typical frontal lesson, are challenging to follow and the information delivered is difficult to remember.

A manual activity raises attention to a high level and is simpler to follow and understand while doing only a book-based lesson keeps the attention span very low. Even for scientific journalism, which Alberto read when he was younger, the realization is that the only interesting parts were brief texts and real-world experiments. Then, concentrating on practical exercises, Maria provided a wonderful example. She does check videos on TikTok when she needs to review a subject for a test, and she finds the ones that present information through a real-world experiment to be the most interesting. She acknowledges that she understands science-related topics more effectively after visualizing the theory through practical activities, even though she hasn't touched it directly. Alberto also brought up a crucial point regarding practical laboratories. He stated that while it is preferable for him to experience something firsthand rather than read about it in a book or listen to a typical lesson in class, the laboratory activity requires more time to complete.

Finally, when discussing their expectations for an activity that needed to address the problem of antimicrobial resistance, they shared that they thought it could be fun to interact with other students and use their own devices. Another crucial point was that they understood that while they have a very short attention span and cannot follow a theoretical lesson for a very long time, by doing something concrete they could focus for a longer period.

3.1.2 Scientific educators

Many different perspectives on how to communicate scientific information to high school students have been offered by educators.

The purpose of the interview was to learn more about their approach and practical knowledge.

The first realization is that there are differences between high school teachers and extracurricular educators. The first one is responsible for quickly disseminating scientific knowledge, whereas the second one must instruct students on a variety of arguments in greater depth while taking into

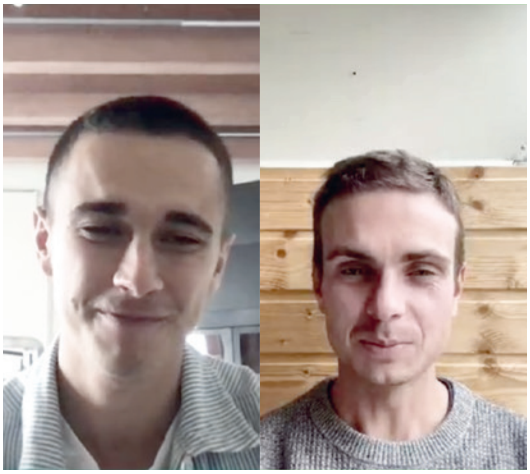


Fig 19: Interview with Mattia.

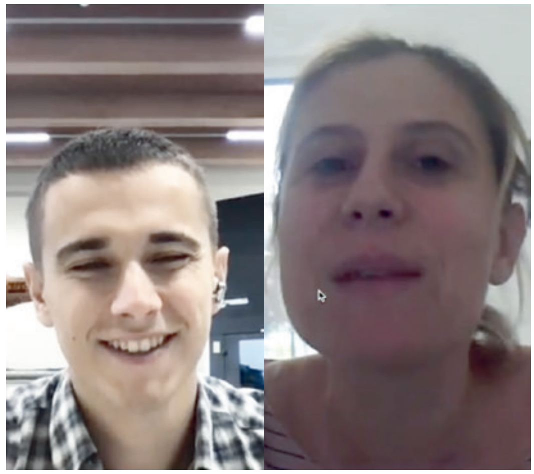


Fig 20: Interview with Chiara.

account individual circumstances and experiences. Another crucial point was how students today approach new subjects. Although they acknowledged that attention span issues are widespread, high school students can now jump from one argument to the next quickly and make connections between them. The third realization had to do with feelings. Particularly when discussing scientific subjects, some people (like Maria) are uninterested and require encouragement to pay attention to the lecture. Some educators try to engage students' attention by using emotional examples that are based on real-world situations that they may already be familiar with.

Additionally, educators brought up the fact that for students to fully grasp a subject, they need to touch it with their hands.

> "A certain degree of manual dexterity always helps. [...] Materiality is part of our nature and our species."
> Chiara Segré, Scientific Supervisor at the Umberto Veronesi Foundation in Milan

When a student she had in high school returned to see her in college, according to Cristina Corti, they were ready for the same argument because the topic had been covered in a practical activity involving plasticine, which helped the student remember it. Aldo Winkler provided important feedback on this subject, stating that, in his opinion, only the first 10 people in his vicinity can follow a scientific experiment and understand the information related to science.

The simplification of scientific topics is an additional crucial consideration when discussing complex subjects like antimicrobial resistance. Here, it's crucial to keep in mind that it's practically impossible to cover all the information about a topic in a lesson or experience; instead, it's best to cover the fundamentals and give students the tools they need to dig deeper later. Last but not least, they discussed a variety of techniques they employed to communicate scientific information to students; I've listed the most intriguing ones below.

> "Understanding the difference between an electromagnetic wave and a mechanical wave is a very complex concept. Taking the example of the radio instead, this becomes simpler."
> Aldo Winkler, Laboratory Head at the INGV in Rome.

> "Biology can also be about images, so when I explain a concept I use images, even for complex topics such as hygienic regulation."
> Cristina Corti, Laboratory Head at the SUPSI Microbiology Laboratory in Mendrisio.

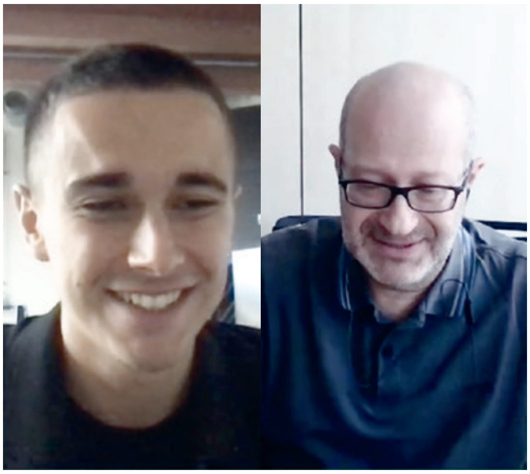


Fig 21: Interview with Aldo.

3.2 Opportunity area

The user journey, which is shared later, will also make it possible to see that there is a significant opportunity area in high school students' education.

In particular, the project's goal is to educate high school students about the use of antibiotics and antimicrobial resistance, as stated in the thesis introduction. As a result, the opportunity area identified as a result of user research and user journey design is the involvement of high school students in Antimicrobial Resistance (AMR) using manual activities and a brief theoretical explanation carried out through an extracurricular experience.

3.3 Personas and User journey

Following the findings of the qualitative research, it was critical to consider the user who would be performing the experience and create two user personas, one for the youngest student and another for a more experienced user. The two personas and the user journey map are presented below.

The phoney wise student

"I know what are antibiotics, they are powerful! They go directly into the nerves and destroy the disease!"

Reto thinks he knows what antibiotics are and answers the question very convincingly and confidently. Actually, that is not the correct answer; if it were explained to him that what he said is not correct, he would change his mind. He is very interested in science and likes to experiment with his hands.

Behaviours

- If I don't know something I search directly on the Internet
- I follow science laboratories but I hate theoretical lesson
- I prefer to search online instead asking to someone
- I love when I can interact with an activity with my hands
- I trust a lot my family, if I need some important info I ask them
- My attention span is very low

Attitudes

- I trust my educator in general
- I feel annoied after a lot of time spend on theoretical lesson
- I go to science festival if it possible
- I put more effort on scientifical subject

Motivations

- I trust an experiment if I can see the result
- I trust educators since they are there after a long study
- I would like to use more my smartphone during a lesson

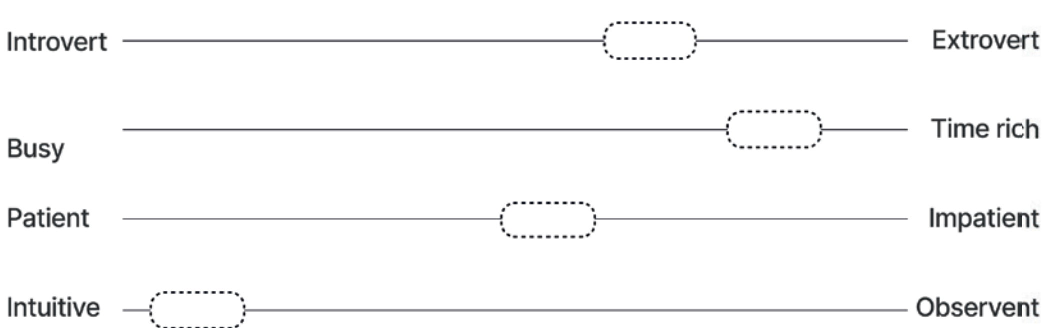
Pain points

- After a long time seeing only someone that talks I loose my attention
- I hate to study everything, I don't need that!
- I wish I could experiment more
- I no longer want to study in a book just for the test

Needs / Goals

- More intereaction with others during a lesson
- Theoretical information in a short time, like a pill
- Discover new things experiencing them
- More usage of technology, I hate books
- Even if a lab takes more time, I prefer it instead of a frontal lesson

Personality



The empowering student

"Even if I don't like the lecture I take a lot of notes, otherwise I miss the test."

Chiara is a student nearing the end of her high school studies. She is not very interested in science subjects but knows that she has to study them anyway. She does not understand much of what is explained, but she studies a lot and manages to learn the concepts even with a lot of effort.

Behaviours

- I take a lot of notes during school
- I always study for a test a lot, even if I don't like it
- I always follow lesson otherwise I miss the test
- I double check every information with my family
- If I miss something I ask to somebody, I share a lot of information with my friends

Attitudes

- I trust educators
- I love when it comes the time to see something instead of studying
- I don't like a lot science festival
- I love to study languages
- To revise a topic before a test I use a lot TikTok because of short videos

Needs / Goals

- I need to experience something to better understand
- I like to share information with my friends

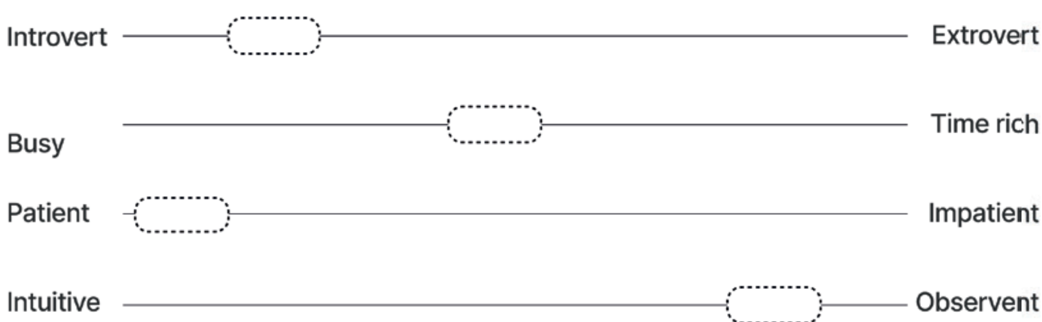
Motivations

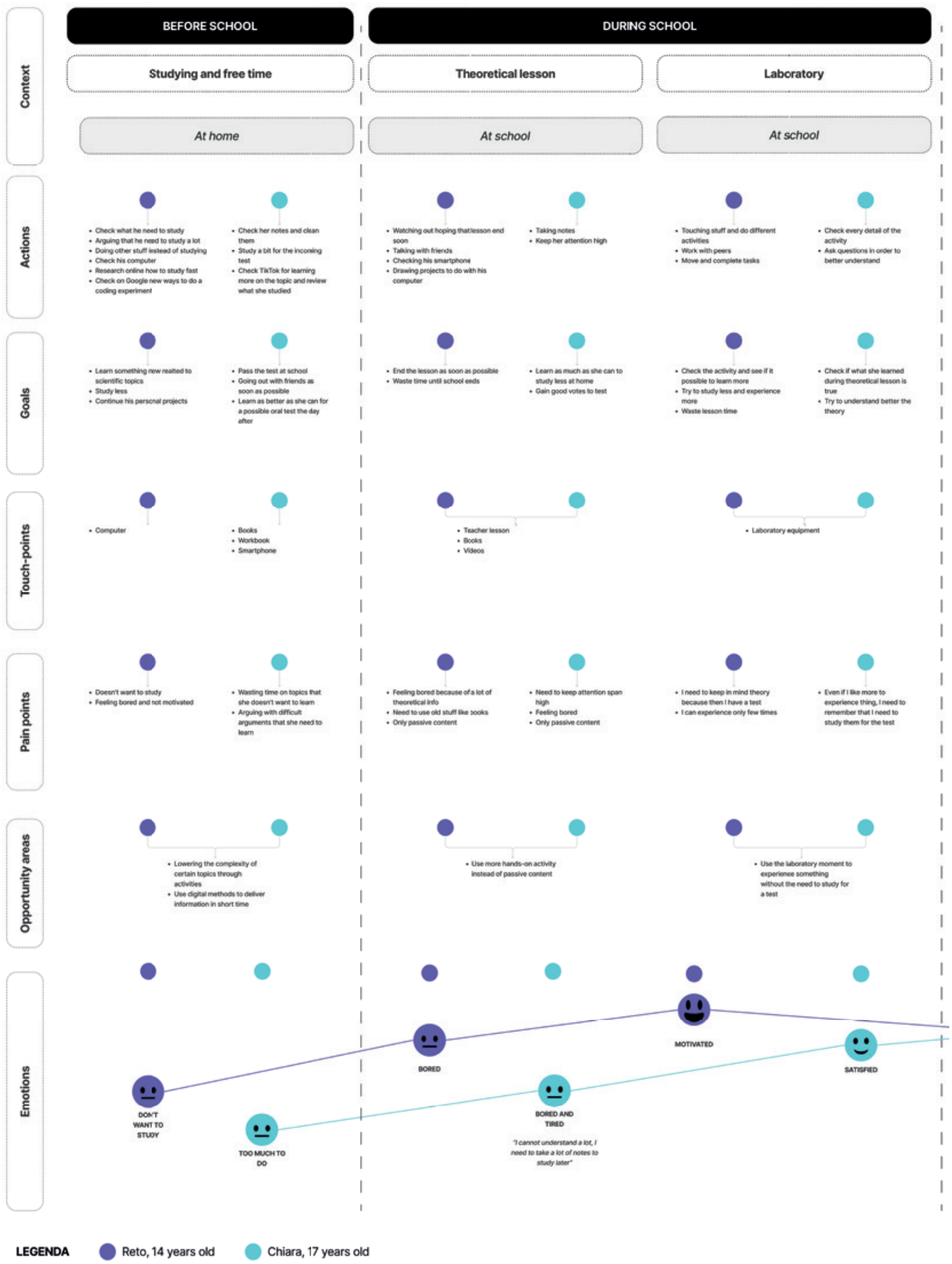
- I think that is good to know a lot of stuff
- I'm more motivated if I can touch things instead of visualizing them

Pain points

- I can't memorize a lot of theoretical information
- I hate studying scientific topics
- I hope I study more what I really like
- I hate to study on books topics that I don't like

- DI love to see a result after an activity, something that I can remember easily




Context
Actions
Goals
Touch-points
Pain points
Opportunity areas
Emotions
BEFORE SCHOOL
DURING SCHOOL
Studying and free time
Theoretical lesson
Laboratory
At home
At school
At school
• Check what he need to study • Arguing that he need to study a lot • Doing other stuff instead of studying • Check his computer • Research online how to study fast • Check on Google new ways to do a coding experiment
• Check her notes and clean them • Study a bit for the incoming test • Check TikTok for learning more on the topic and review what she studied
• Watching out hoping thatlesson end soon • Talking with friends • Checking his smartphone • Drawing projects to do with his computer
• Taking notes • Keep her attention high
• Touching stuff and do different activities • Work with peers • Move and complete tasks
• Check every detail of the activity • Ask questions in order to better understand
• Learn something new realted to scientific topics • Study less • Continue his personal projects
• Pass the test at school • Going out with friends as soon as possible • Learn as better as she can for a possible oral test the day after
• End the lesson as soon as possible • Waste time until school eeds
• Learn as much as she can to study less at home • Gain good votes to test
• Check the activity and see if it possible to learn more • Try to study less and experience more • Waste lesson time
• Check if what she learned during theoretical lesson is true • Try to understand better the theory
• Computer
• Books • Workbook • Smartphone
• Teacher lesson • Books • Videos
• Laboratory equipment
• Doesn't want to study • Feeling bored and not motivated
• Wasting time on topics that she doesn't want to learn • Arguing with difficult arguments that she need to learn
• Feeling bored because of a lot of theoretical info • Need to use old stuff like books • Only passive content
• Need to keep attention span high • Feeling bored • Only passive content
• I need to keep in mind theory because then I have a test • I can experience only few times
• Even if I like more to experience thing, I need to remember that I need to study them for the test
• Lowering the complexity of certain topics through activities • Use digital methods to deliver information in short time
• Use more hands-on activity instead of passive content
• Use the laboratory moment to experiene something without the need to study for a test
DON'T WANT TO STUDY
TOO MUCH TO DO
BORED
BORED AND TIRED
"I cannot understand a lot, I need to take a lot of notes to study later"
MOTIVATED
SATISFIED
LEGENDA
Reto, 14 years old
Chiara, 17 years old


AFTER SCHOOL
DURING AN AFTER-SCHOOL EXPERIENCE
AFTER THE EXPERIENCE
Learning som ething new
First Approach
Hands-on activity
Studyng and free time
At home
In a University class
In a University class
At home
• Search on Google what I can learn
• Talk with my parents and see that there's a science laboratory
• Check TikTok for educational video
• Talk with friends
• Keeping attention level high
• Ear how I can do the experience after
• Check correlation with school
• Learn how to do the activity
• Put his hands on the activity
• Share knowledge with peers
• Use theory to do the activity
• Put hands-on
• Learn something while doing
• Continue doing what he likes
• Study
• Continue studying
• Go out with friends
• Having fun
• Learn more
• Do the activity as best as I can
• See if it is possible to learn something new for general knowledge
• Experience a lot
• Have fun with the activity
• Do something new that can be interesting for my future
• Continue learning
• Have fun
• Pass tests
• Keep in touch with friends
• Computer
• Smartphone
• Educator
• Activity
• Computer
• Books
• Workbook
• Smartphone
• Learning something from unknown source
• No involvement of technology
• Too much time to acquire basic knowledge to start the experience
• Too similarities with a school lesson
• Distance from my interests
• No tangible result
• No use of technology
• No use of personal device
• Too technical experience
• Use of difficult to understand instruments
• Forgive the experience done
• Does not have anything left from the activity
• Shape a learning experience to involve high school students on new topics
• Design a short and interactive activity to better understand a topic
• Move tc arguments that are not shared in schools
• Design an experience that can continue afterwith personal device
• Use of an interactive hands-on activity
• Use of similarities to explain something difficult
• Design a tool that can be easy to use for a high school student
• Let the experience continue even after
HAPPY
HAPPY
NORMAL
NORMAL
HAPPY
HAPPY
HAPPY
HAPPY

3.4 Onliness Statement and Concept Overview

A conceptual overview and an onliness statement can be reached as a result of the research and insights that were developed in the previous chapter. With the help of these details, the project can now take shape and be visualized.

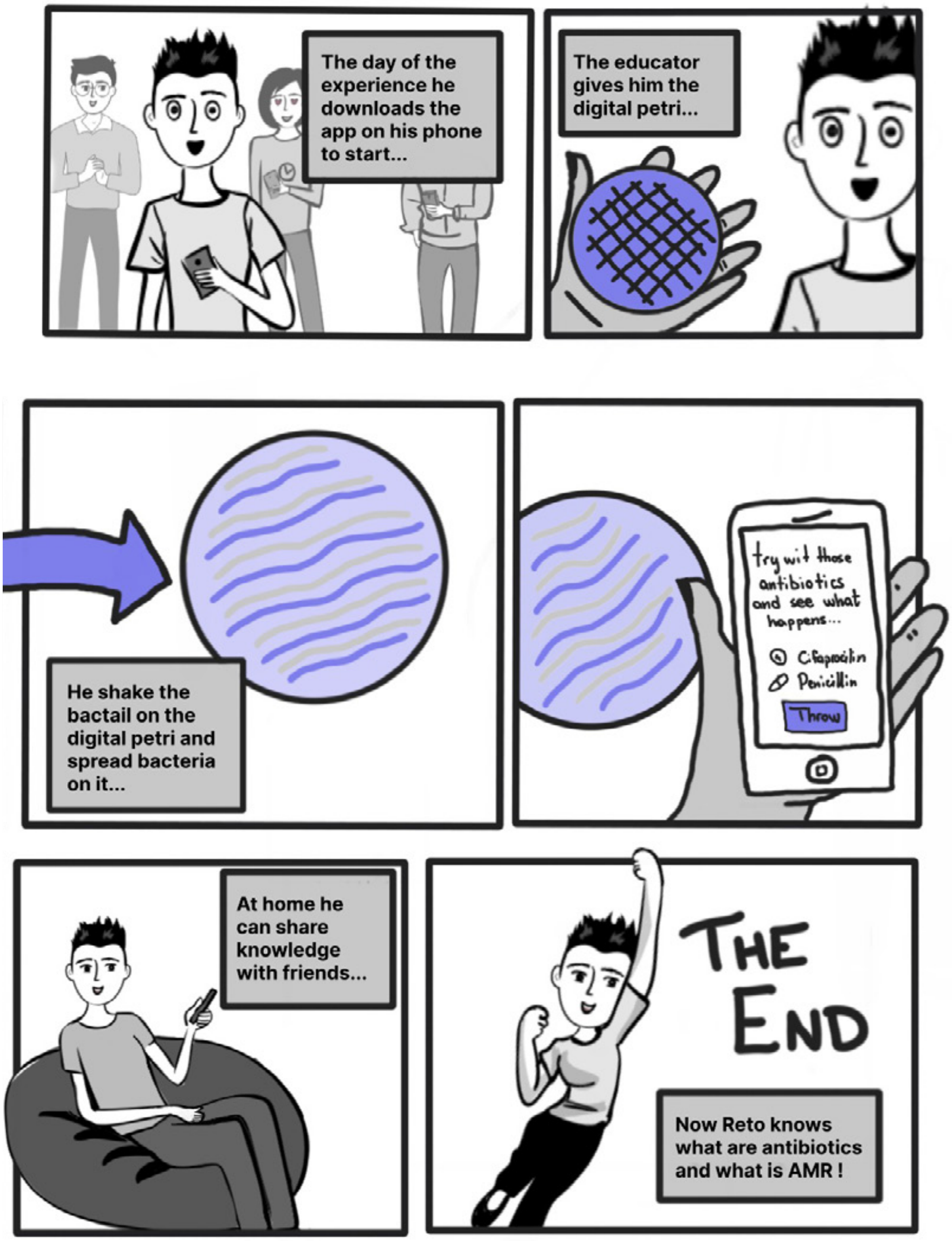
This is the only digital laboratory experience that disseminates the issue of Antimicrobial Resistance for high school students in Switzerland who want to experience scientific topics using an interactive tool.

The idea is to give high school students a multimodal digital tool that simulates a Petri dish so they can experience using antibiotics against bacteria firsthand and see what antimicrobial resistance looks like. The student's smartphone and a tangible object called the digital petri to serve as the activity's two main touchpoints. The smartphone is used as an interface to design the petri dish and learn more about bacteria and antibiotics, while the custom device aims to visualize the creation and, thanks to the custom features, can be used to see the experiment's progression in a matter of minutes rather than hours or days. These two devices function as digital twins. The purpose of the main activity is to create a digitalized petri dish where it is possible to see how bacteria and antibiotics interact, and the experience wants to educate students about this interaction. The experience then continues with a customized playful experience that enables the students to have fun and divert from the scientific subject having at the same time the possibility to see what they have done before; since the two activities were connected, this can be helpful to maintain a high attention span and increase the effort that each student can put into the prior scientific activity. The experience will be designed to be done in a dedicated context such as informal learning spaces like fablabs, science festivals and science initiatives.

3.5 Storyboard

It was created a storyboard to show the most important points of interaction during the experience in order to better visualise the concept.


Reto doesn't know what an antibiotic is and how it works...
He search on the internet... and he found a workshop on that!
connect the digital petri with the code:
Petri code:
123
He connect the petri to his phone...
Bactail
He save the experiment on his phone...



Character illustrations made with Comicgen by Gramener

3.6 Detailed Concept for Prototyping and Features

The detailed concept and the functionalities that must be incorporated into the project will be described here to give readers a better understanding of how the experience will operate.

As expected, the activity will take place in a designated space that only needs tables and chairs for participants; no other equipment is needed. The educator supplies the kit with several digital petri, which kicks off the activity and introduces the theme and the experience for the next few hours. Following this, we'll begin the brief opening lecture, which will introduce the theme of antimicrobial resistance. The distribution of the digital petri will come next, followed by help downloading the application (if it hasn't already been installed) and connecting to the device. The journey detailed in the storyboard will then begin. The digital petri and the smartphone, which were both previously introduced devices, were both presents here.

It will be crucial from the standpoint of smartphones to develop a specialized application that enables us to take advantage of the BlueTooth module to connect the phone to the device, the gyroscope to enable the interaction of putting bacteria and antibiotics inside the digital petri dish, and of course the touchscreen to interact with the system and move around in the application.

The device will simultaneously be built to accommodate a microprocessor (such as an Arduino Board, Raspberry Pi, or ESP32) that will serve as a hub for connecting all the various components, a circular screen that will serve as the top of the digital petri dish, a dial to specifically control the timeline of bacterial growth, some buttons to interact with the device, and a Bluetooth module to enable communication with a smartphone.

The main features of the project are:

- Inoculate bacteria with the movement of the smartphone on the top part of the digital Petri;
- Put the antibiotics inside the petri by moving the smartphone to the device;
- Move the gear inside the custom-made Petri dish to see the timeline of the bacteria interacting with antibiotics;
- Save the experience on your smartphone and continue the experience later at home.

4.0 Project Development

DiPLab is the **only** digital laboratory **experience** that **disseminates** the issue of **Antimicrobial Resistance** for high school students in Switzerland who want to experience scientific topics **using an interactive tool**.

4. Project Development
Design and prototype

4.1 Initial Design and Prototype

After developing the overall concept, it is possible to begin iterating on the prototype and initial design.

Right after concept ideation, the first cardboard prototype was created to begin an investigation of the device's interactions and multimodality with the phone. This prototype was primarily a round product in the shape of a Petri dish, with a screen and a single point of interaction a ring all around the circle. The interaction with the product in this first prototype is limited to a two-way movement, back or forward; this allows the user to zoom in or out without issue while also switching to the second mode of interaction to see changes in the Petri history.

The cardboard prototype allowed to understand some issues with interaction and technology integration. Indeed, most of the screens available for prototyping are not circular, and incorporating a ring directly behind a screen appears to be difficult due to spacing and mechanics.

As a result, in order to diverge on the possible interactions, it is necessary to continue iterating on the concept and find other alternatives while also taking into account the technology available.

Fig 26: First cardboard prototype

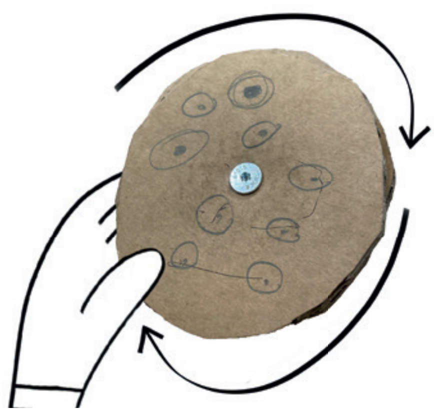


Fig 27: Main interaction

Fig 28: One of the groups during the ideation phase.

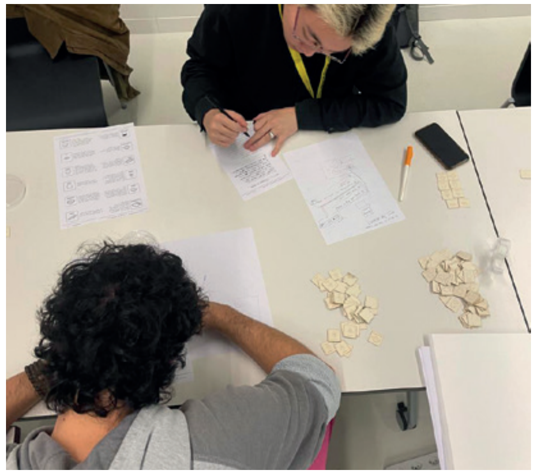


Fig 29: The documenting phase of two ideas.

4.1.1 Junior Design Research Conference Workshop

Because of the opportunity to present the thesis project at the Junior Design Research Conference in Basel, a workshop on low-fidelity prototyping focused on tangible products was also held.

The experience was divided into two parts: the first, in which the thesis topic and the concept of rapid prototyping with paper were introduced, and the second, in which participants directly experienced it with their hands.

The workshop began with an introduction to prototyping and the differences between low-fidelity prototyping and high-fidelity ones. Since the goal was to diverge and create as many ideas as possible and the timeframe was less than an hour, the theoretical part focused more on low-fidelity prototyping. The advantages of this type of prototype are that it does not require a lot of resources to be done; it can also be done using a piece of paper and a pen; it is not time-consuming and thus can be done in a short period of time without requiring the use of complicated machines; it is easy to change during the process and participants feel less wedded to it. At the same time, there are some drawbacks, such as the fact that the interaction is essentially non-existent and requires humans to fake it; it may be unclear to test participants what is supposed to work and what isn't, because a low-fidelity prototype requires a lot of imagination from the user, limiting the outcome of user testing. Despite its limitations, low-fidelity prototyping is a quick and easy approach to transforming a design concept into a somewhat more physical depiction of a product.

Because the students had less than an hour to brainstorm and prototype their ideas, three unique challenges were assigned to them in order to enhance the ideation process. The initial issue was to create the phone connection, therefore the questions were: how do you pour germs into the digital Petri dish? How can I link the two devices? The second problem was to create an interaction with the Petri: how could I zoom in on the Petri? How can I visualise the evolution of bacteria? How do I get about inside the Petri dish? Can I communicate with the bacteria? The third task was to create an interaction between Petri dishes: is it feasible to establish an interaction between Petri dishes? How will they get along? Why should they interact? Finally, it was given the opportunity to create something unique with no constraints.

Fig 30: One of the groups starting exploring cardboard prototyping.

Fig 31: Explaining what a Petri dish is.

Following the introduction, the students were separated into two-person groups. Each group received two Petri dishes, several electronic components, a template to capture their ideas, and various prototyping tools and materials such as cardboard, scissors, and glue. To finish the task, the sole criterion was to come up with a minimum of two ideas per group, or one well-defined concept. Following the brainstorming and prototype phases, each group was given two minutes to showcase their ideas and explain the process.

The experience allowed to examine how this type of activity may help individuals comprehend a topic better and how different types of designers approach the same issue. There were some unexpected discoveries, such as the student's desire to have the challenges always visible during group work in order to have boundaries where they can stay. There was also a lot of interest in the Petri dish, and many students asked me to describe the actual process of pouring bacteria inside it and specifically how antibiotics react. Because of this level of participation, I was also able to go one step further and show them some of the studies that I'm currently following, such as MAKEAWARE! and the Spearhead project. All of the ideas generated were documented and exhibited here, along with some photographs taken during the workshop. Finally, it was very interesting the different approaches of the different groups:

- someone hand-sketched the idea and create a sort of storyboard to show the concept, others created a 3D prototype using a lot of different electronic components;
- some others generated a hand-sketched physical prototype and used the component only as a reference drawing them back in the prototype.

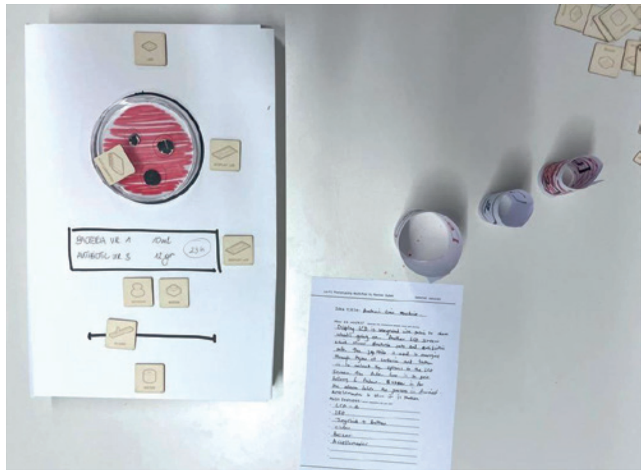


Fig 32: "Bacteria time machine" concept #1.

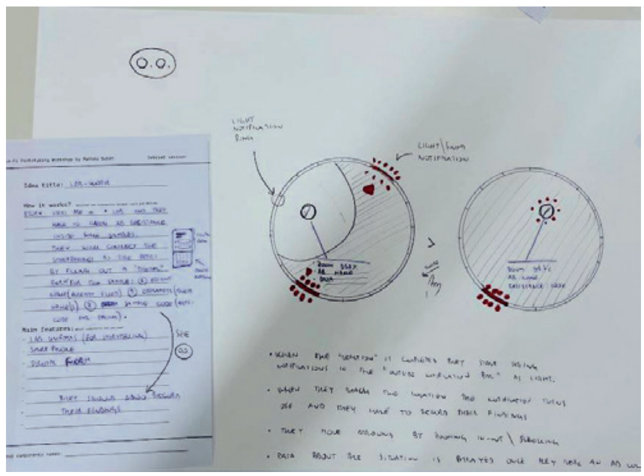


Fig 33: "Lab-Work" concept #2.

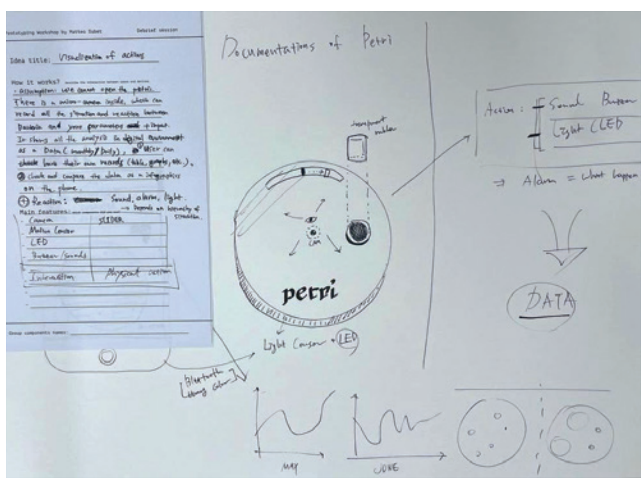


Fig 34: "Visualization of actions" concept #3.

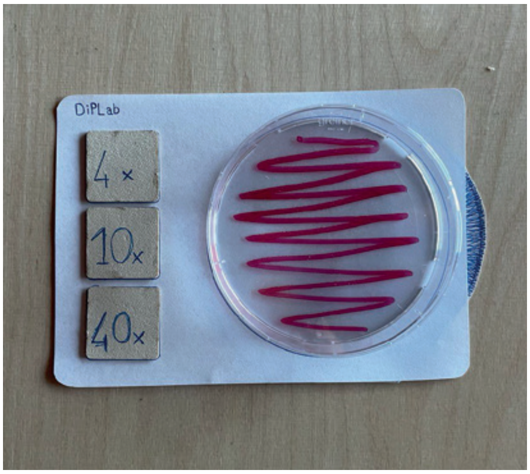


Fig 35: First product concept..

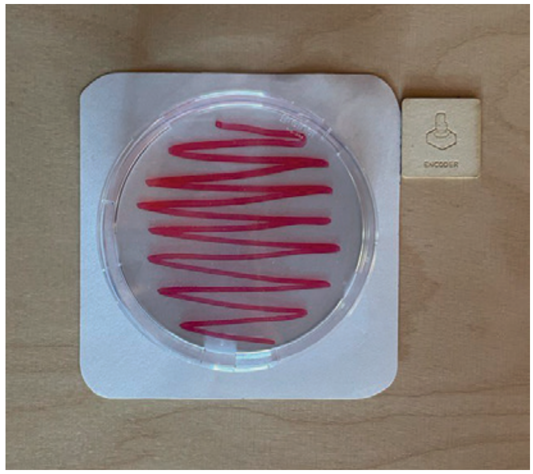


Fig 36: Second iteration.

4.1.2 Iterations

Because of the prototypes created during the workshop, it was possible to begin sketching out some solutions for the product and the interactions required to deliver the activity. The core of this section is the method of interaction with the product and the potential points of interaction. The product moved from a round shape into a box where it is possible to work in a different way with the technologies that are currently available, and from the idea of a display-only Petri dish to a digital laboratory where other components such as the mobile phone can be added. This concept allowed us to sketch the first product concept which included:

- a physical interface with three buttons;
- a round display;
- a rotary encoder.

With a second iteration, the three buttons were removed and replaced with an interaction with the rotary encoder, which became useful for zooming in and out and moving through the Petri dish history. With this knowledge, the next step is to scientifically validate the product.

Cristina Corti, head at the SUPSI Microbiology Laboratory in Mendrisio, assisted in validating the two features: visualization of Petri dish history and microscope that is specifically shown in the following chapter.

4.2 Detailed Design

Because of the previous research, having an initial design, and iterations of the prototype, it is possible to move into a detailed concept touching all the steps of the experience and creating a base layer from which the entire experience can be built.

It is possible to test the overall experience and see if it works using the information architecture and wireframes.

4.2.1 Information Architecture

The developed information architecture is divided into two parts: one for the application [Fig. 37] and one for the product [Fig. 38].

Starting with the application, it is clear that it is divided into two sections: “DiPLab Library” and “New DiPLab experience.”.

Considering the library, the information delivered to users is based on previous experiences. Initially, an image of the experiment is displayed, which is generated automatically when it is saved; additionally, the bacteria used to conduct the journey, a reference of the experience such as the date when it was completed, the average resistance inside the Petri dish, and the username of the person who did it are displayed. Inside the single page of each experience, there is a specific description of the bacteria that can be found inside the digital Petri; all the antibiotics used with a specific description of each of them, where they are placed inside the Petri, and the specific resistance versus the bacteria used; and finally, the option to share the page of the experiment and/or the image generated with friends.

In terms of the experience, it begins with the DiPLab product being connected to the user’s smartphone, where information is now shared between the smartphone and the product. To complete the first step of creating a new digital Petri dish, select a single bacteria to use as a base for antibiotics and then spread it inside the DiPLab; here, the user requires the name of the antibiotic, as well as a related image to better identify it, the media or base layer required to grow the bacteria, and the average resistance of this bacteria to the antibiotics available. Furthermore, the user is asked to choose antibiotics, which are represented by an illustration of the tablet used in the experiment, the name of the antibiotic, the scientific abbreviation, the year it was released to the market, and the average resistance with the selected bacteria. Throughout the experience, the application delivers the information required to complete the experience and does not leave any pieces behind. The journey concludes with a recap of the experiment and a preview of the page generated directly from the application.

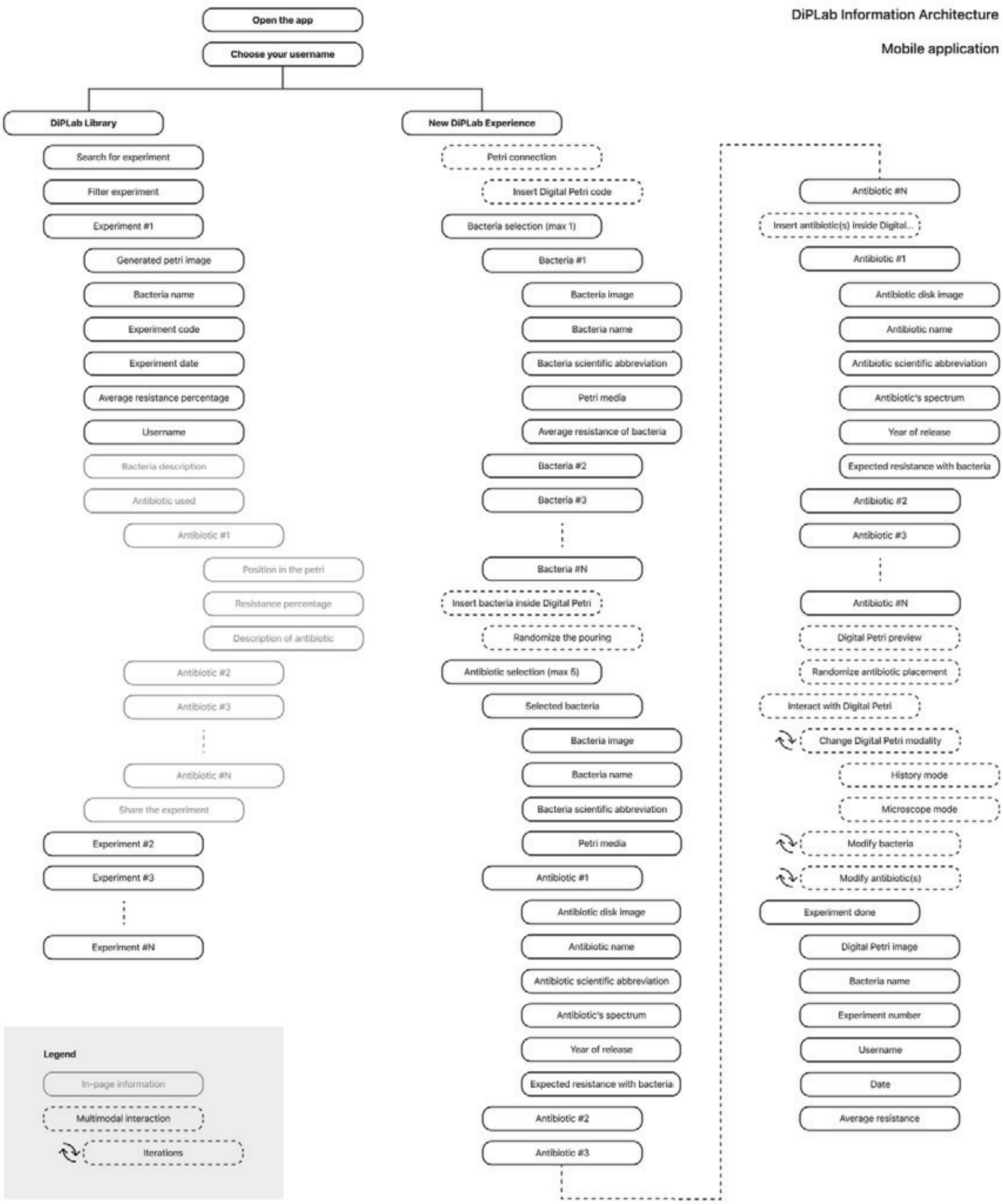


Fig 37: Mobile application Information Architecture.

Moving on to the product itself, the first piece of information provided is the product code required to connect the two devices. Following that, all of the information delivered is visually based; the bacteria with the media or terrain, and the antibiotic tablets with their associated resistance. The interaction with the product via the rotary encoder and the smartphone that acts as a control panel for the DiPLab allows for the visualization of what is the resistance and how bacteria grow.

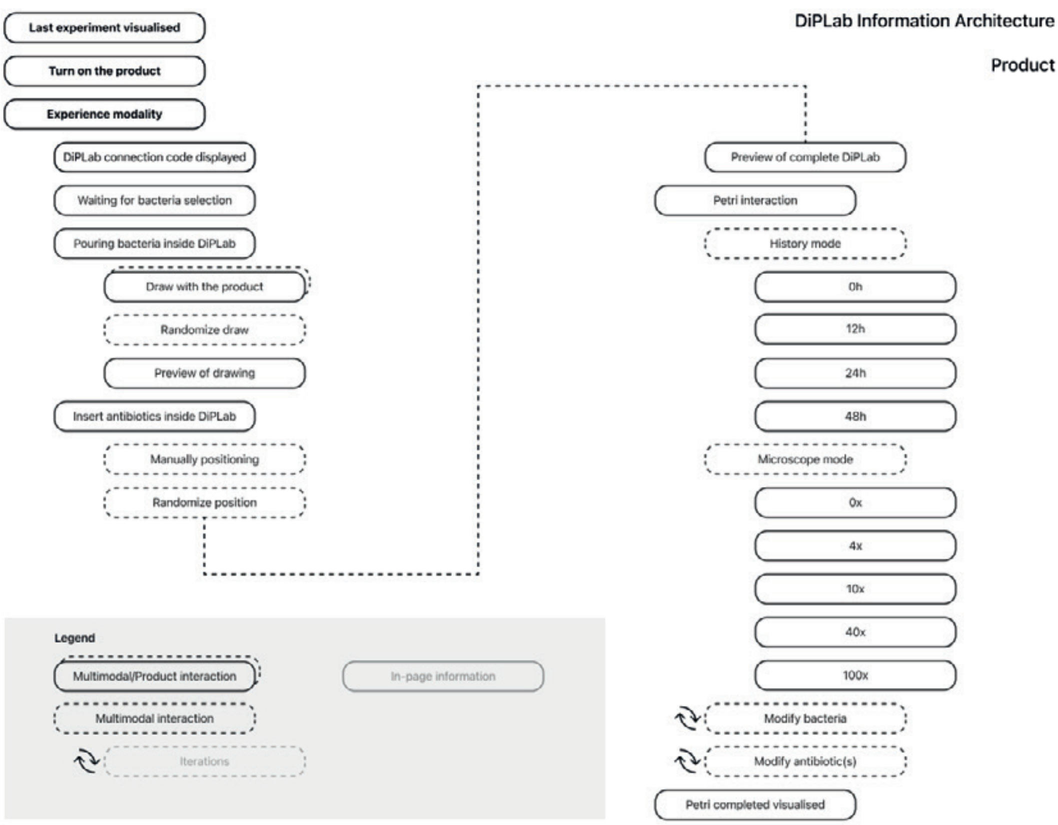


Fig 38: Product Information Architecture.

4.2.2 Wireframing and Interaction Modalities

To begin the experience, enter an email address into the application and enter the school and classroom code to retrieve all of the experiments completed by the user's colleagues. [Fig. 40]

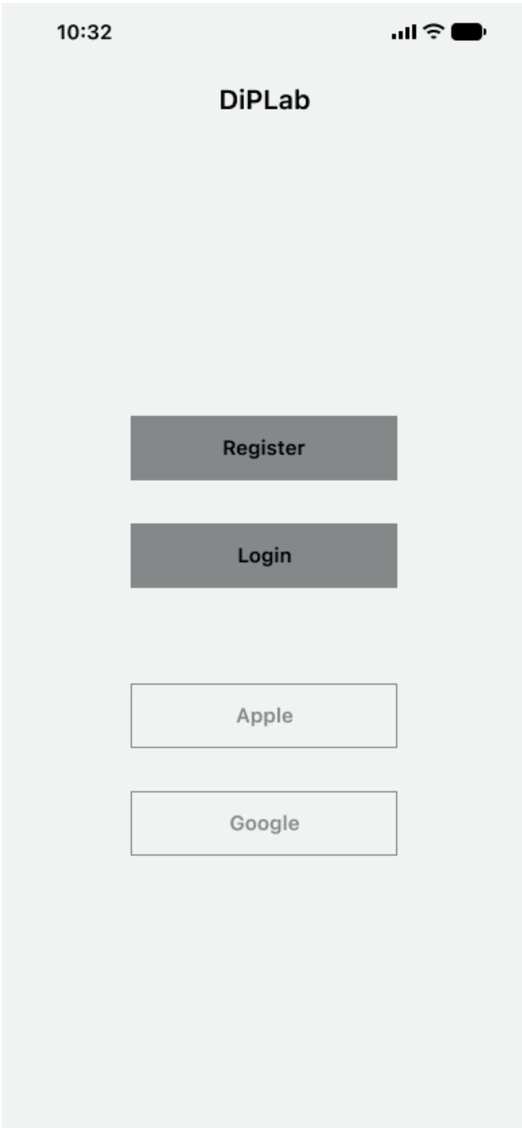


Fig 39: Fist screen of the applicaiton.

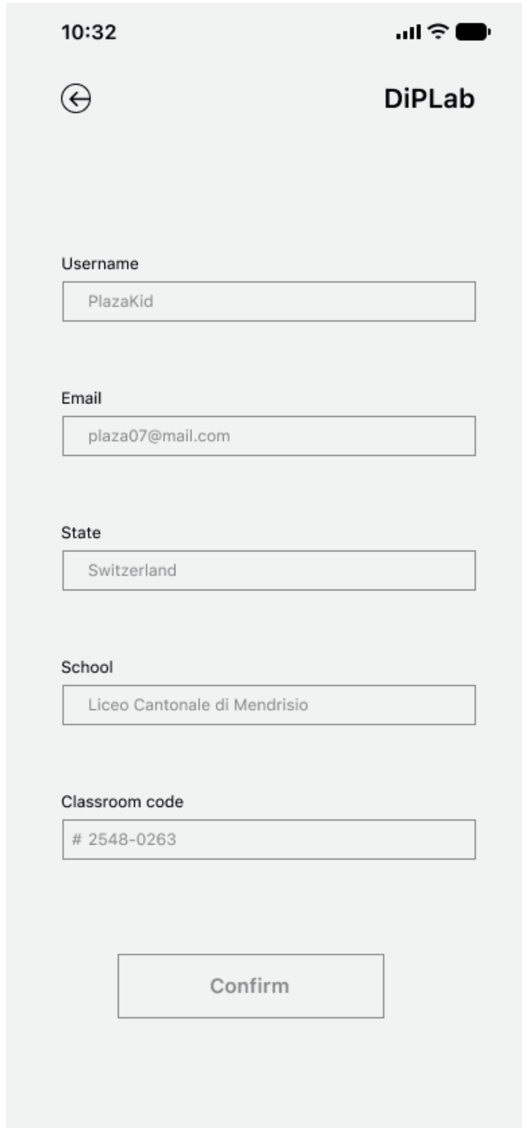


Fig 40: Registration form.

After entering all of the information into the registration form, the application suggests a brief overview of the product and experience. The DiPLab product, which will be used to conduct the experiment later, is shown for the first time here.

Fig 41: Onboarding #1.

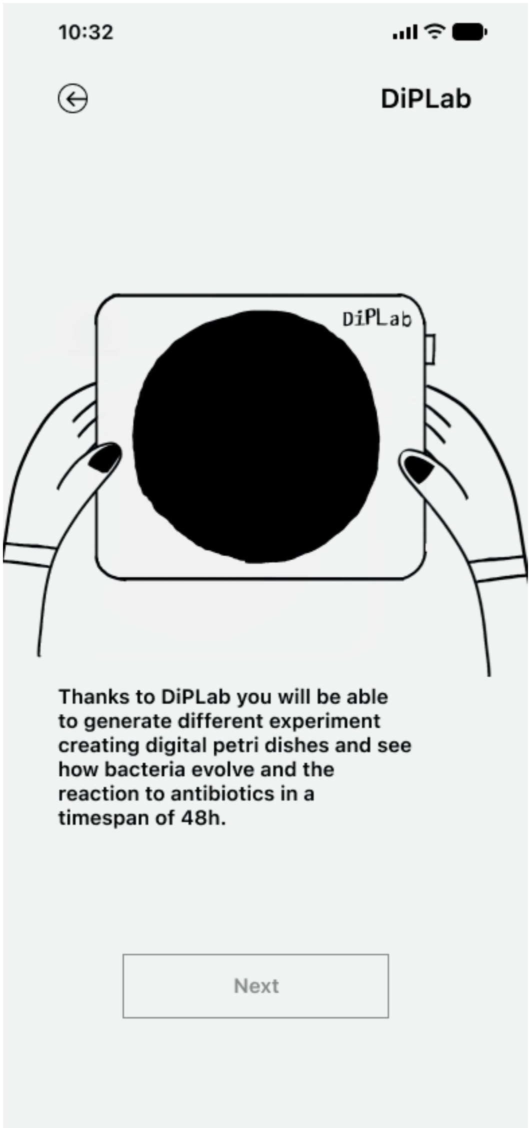


Fig 42: Onboarding #2.

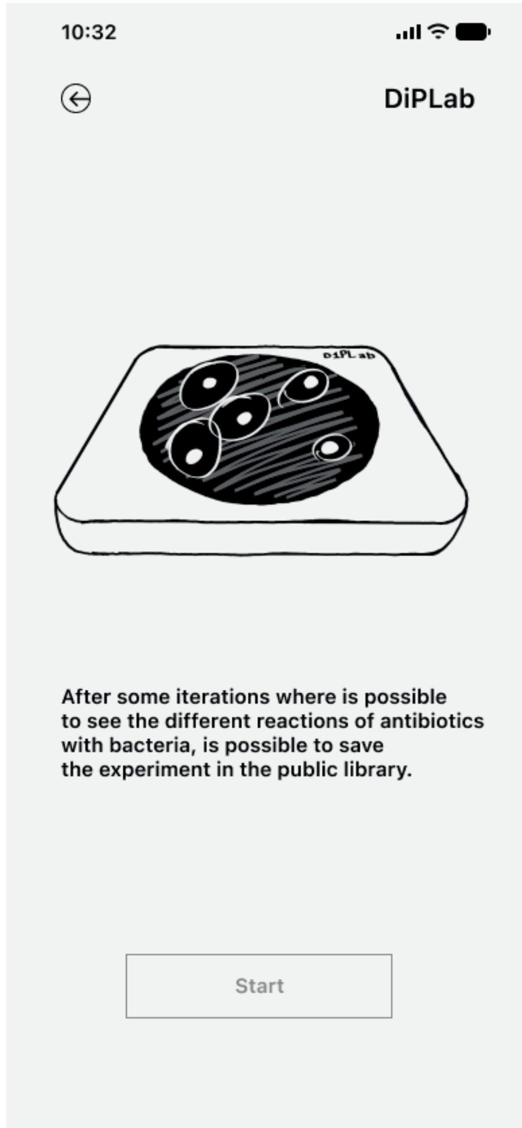


Fig 43: Onboarding #3

To introduce the user to the experience, upon entering the application, a library containing all previous projects completed by all participants will be displayed. The search bar can be used to narrow down the results by searching for a specific bacteria, antibiotic, username, or classroom code. [Fig. 44]

Fig 44: Library.

Each experiment has its own page with detailed information; from here, the user can share a specific experiment with their friends by sharing a link or saving the image generated after the experience. [Fig. 45]

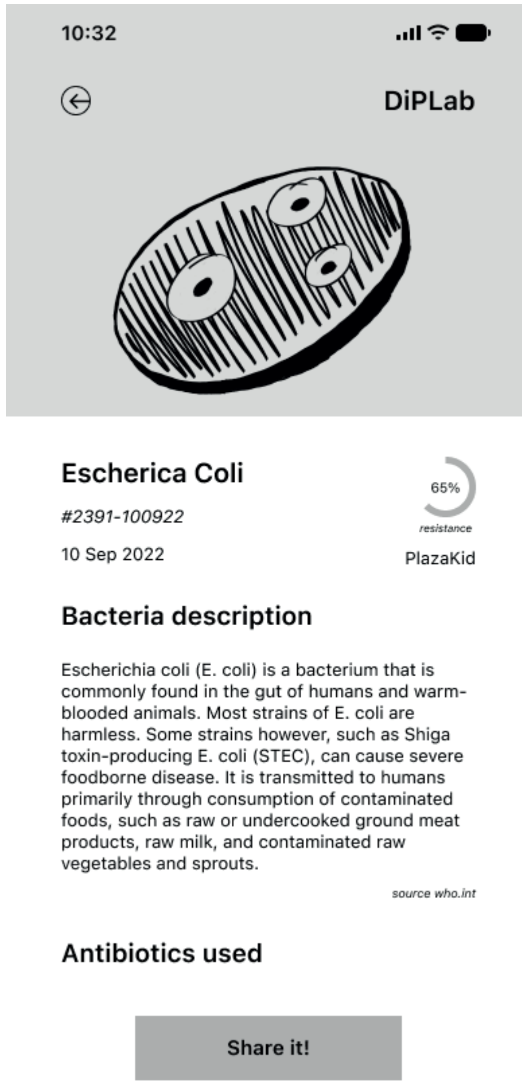


Fig 45: Experiment page.

The user enters the flow of a new experiment after clicking the “Join the experience” button. The first step is to connect their phone to the DiPLab product, which is accomplished through a Bluetooth connection and a DiPLab-specific code. [Fig. 46]

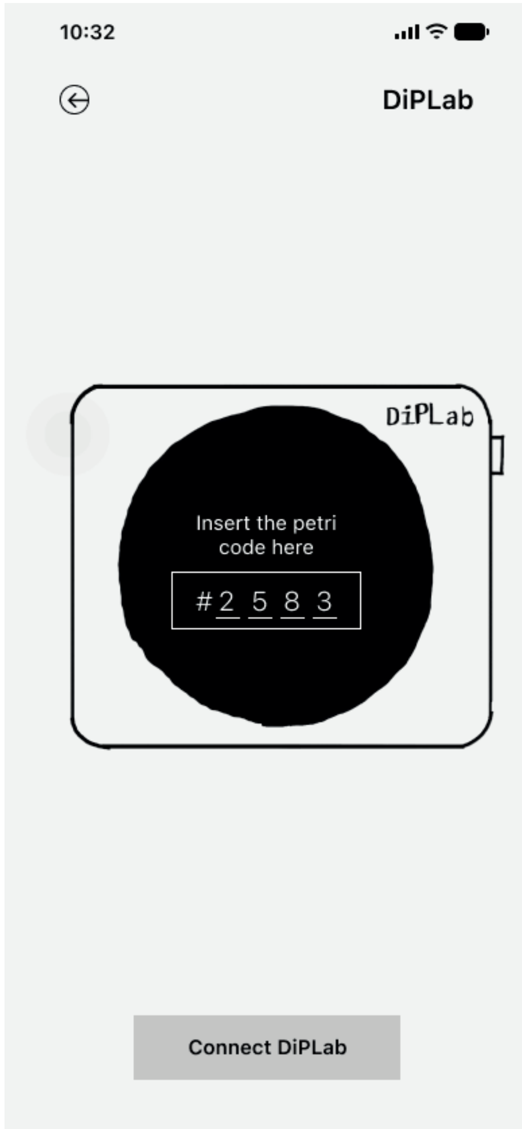


Fig 46: Connection w/ DiPLab.

Following the setup of the two touchpoints, it is now necessary to choose a specific bacteria to spread into the DiPLab. Because of the information provided, the user can select a bacteria to investigate further and see how it interacts with antibiotics. To limit the visualization of antibiotics reaction, the maximum number of bacteria that can be chosen is one. [Fig. 47]

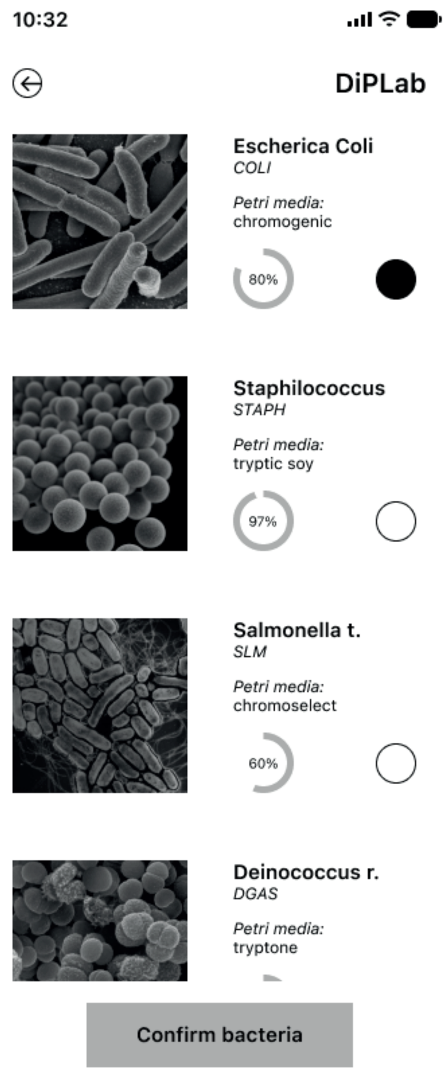


Fig 47: Bacteria selection.

Following the selection of the bacteria to be spread, the system recommends that the user use the DiPLab product to spread the bacteria inside the digital Petri dish. It's helpful to be able to see how each antibiotic reacts. Instead of using the product to spread the bacteria, it is also possible to randomize the spreading by simply clicking a button on the smartphone application's digital interface. [Fig. 48]

Furthermore, after selecting the bacteria to complete the DiPLab and the Petri dish, the antibiotics to use inside must be chosen. The page always displays the bacteria chosen before beginning to connect the elements. Because the visualization can be more clean and specific for those antibiotics, the maximum number of antibiotics that can be selected here is three [Fig. 49]. The interaction to put antibiotics inside will follow the same logic as the bacteria spreading, so the user takes the DiPLab and spreads it using the product; otherwise, a button on the smartphone screen can be used to randomize the position of the antibiotics. [Fig. 50]

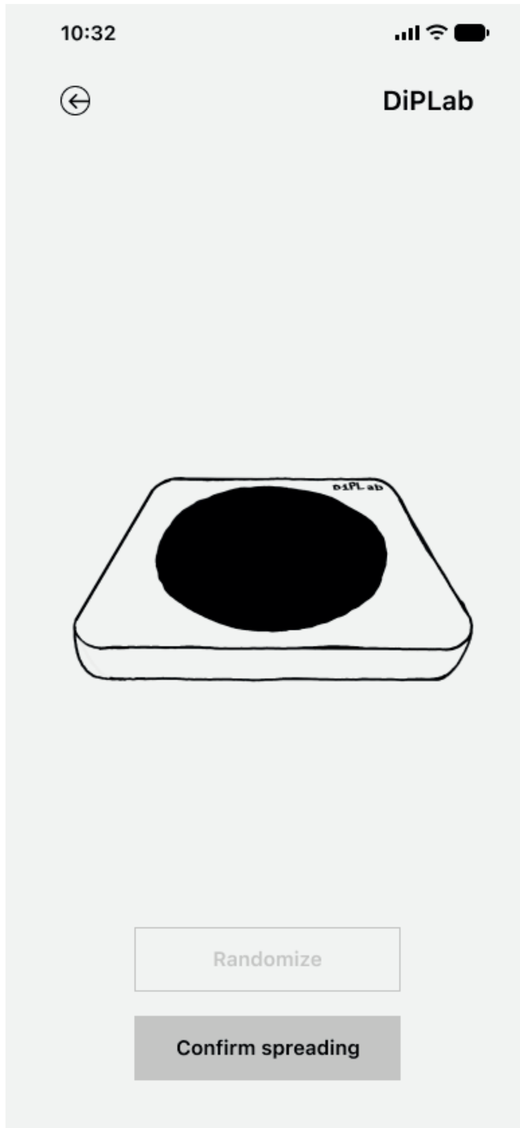


Fig 48: Spreading bacteria.

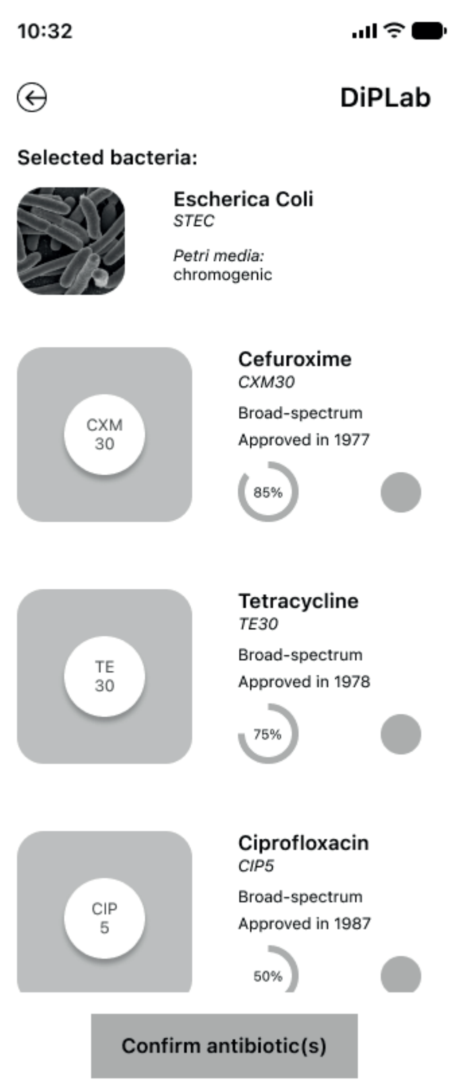


Fig 49: Antibiotics selection.

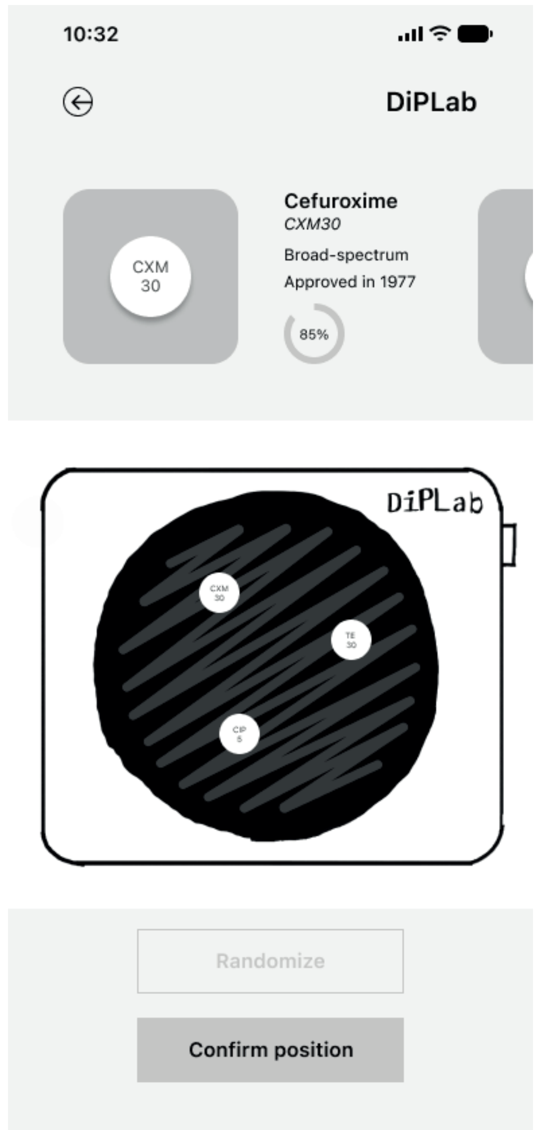
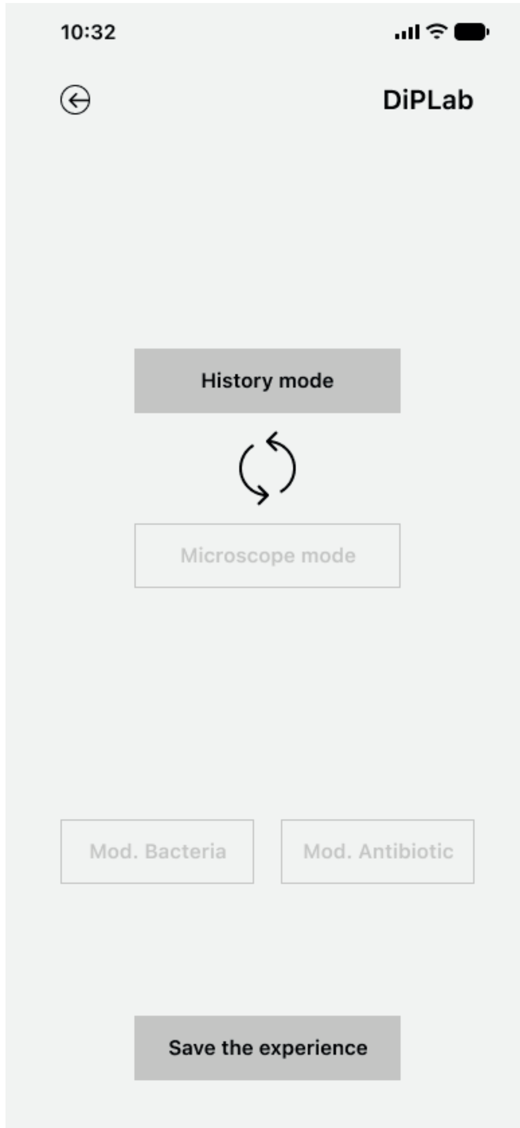


Fig 50: Inserting antibiotics.



It is possible to begin interacting with the digital Petri dish after it has been set up. As a result, the user can now access the history mode, which displays the evolution of the digital Petri dish. The rotary encoder allows the participant to move forward or back in time and see differences from 0h to 48h. It's crucial to visualize the following main points: 0h, where the Petri dish has just been completed and no reactions can be seen, 12h where the bacteria is growing and something can be seen in the base layer, 24h where the bacteria have finished growing and antibiotics have already done or are starting to do a reaction (this step is also scientifically identified as the first antibiogram test), 48h where the correct effect of antibiotics can be seen in the DiPLab (this step scientifically identified as the second antibiogram test). [Fig. 51]

Fig 51: DiPLab's control panel.

By pressing a button on the application the user enters into the microscope mode to zoom in with some specific visualizations, 0x where is visible the overall dish; 4x where is possible to see a single antibiotic and the possible inhibition zone (the zone where the antibiotic works), 10x where is possible to see more specifically the antibiotic specifically where the inhibition zone is null or very small, 40x where is possible to visualize the bacteria as little points and start defining the bacteria type (gram-positive or gram-negative) thanks to the colour, and finally 100x where the bacteria are bigger and is possible to see also their movement and a general shape (coccus, bacillus, spiral, coccusbacillus, vibrio). On the same screen is possible to iterate into the experience by changing the base layer of bacteria and or the antibiotics inside and see the differences between the reactions.

After the participant's desired number of iterations with the product, the experience and final result are saved to the library, and the user can view a summary of their experiment. [Fig. 52]

Fig 52: Recap of the experience.

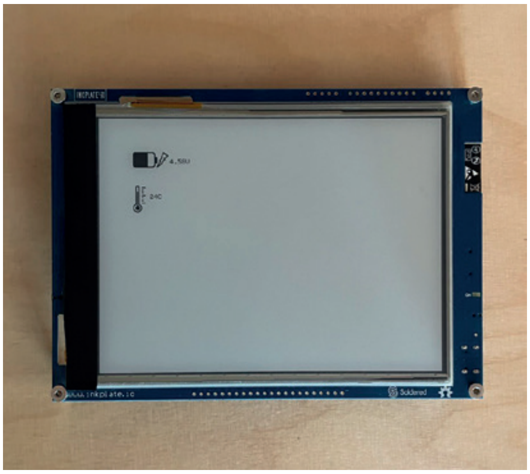


Fig 53: Front view of ESP32 with an E Ink display.

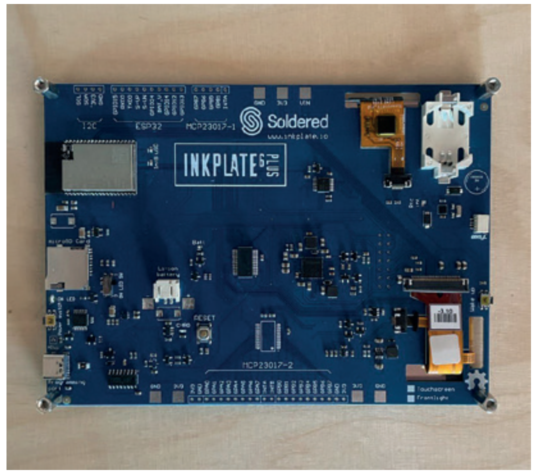


Fig 54: Back view of ESP32 with an E Ink display.

4.3 Detailed System Specifications

Starting with the DiPLab product, the system is built around a microcontroller that can connect to a display. This can be accomplished by using a microprocessor with enough RAM to store data for each pixel on the screen; the development board chosen is thus linked to the density of pixels in the display chosen. Another essential feature is the availability of a Bluetooth module and a Wi-Fi module to allow connection with the smartphone and generation of the digital Petri dish visualization. Furthermore, the ability to connect external sensors, such as a rotary encoder, is required to control the physical interface. To better understand the potential solutions, the first iteration is testing an ESP32 processor with an E Ink display [Fig. 53]; this type of solution already has all of the connectors for the display to the microprocessor and has Bluetooth and Wi-Fi components installed. The board's pinout also allows for the connection of external components such as a rotary encoder [Fig. 54]. The refresh rate of the E Ink display is a limitation of this solution, which will be tested in the next phase.

It is critical to consider the smartphone application when developing a solution that can easily interact with the microprocessor and supports Bluetooth connectivity. The first iteration involves testing a web-based solution built with javascript, HTML, and CSS. This enables the development of a single solution that can be used with any device without the need to install any applications on the participant's Furthermore, both devices can be connected using this solution. This is also a piece that will need to be tested during the next project phase.

5. Project Final Phase
Prototyping and Refinements

5.1 Introduction

The research conducted up to this point is essential for a deeper understanding of the project and for determining the best method for putting the experience into practice. Due to the prior thought, it is now possible to begin creating the first prototype and conduct user testing. Since the design process necessitates constant revisions, some aspects of the project have been slightly improved since Project Development.

In particular, the app has been made simpler so that it is only focused on the Petri experience; even though it will be visible in the following information architecture, the app now begins by connecting to the Petri dish via WiFi and ends with the experience saved. All of the projects completed during the workshops are now displayed on a website that works also as a repository for the project. The information architecture and then the visuals are specifically discussed in the following chapter.

The first prototype made was also put through user testing; in fact, two different tests with two different boys—one 14 years old and the other 16 years old—could be conducted. This identified a few issues with the flow, especially in the application section, where the descriptive part was insufficient to fully comprehend what the user should need to do.

Contrarily, the microscope and history mode were completely understood by them without any explanation, and following the experience, their interest in antibiotics and antimicrobial resistance was extremely high.

5.2 Detailed Design

The project is focused in two main parts, the visual aspect where the application, product display and branding is detailed and the technology part where is analyzed the technical part done to realize the working prototype.

5.2.1 Visual Design

In order to develop the branding for the project, it is essential to focus on specific keywords that accurately represent the product's identity. In this case, the four keywords chosen for analysis are teen, science, low-fi, and educational.
Teen represents the target audience of the brand. This keyword helps to ensure that the visual appeal and messaging of the brand will resonate with the target demographic. Science indicates that the brand is focused on science-related content, while low-fi represents a more clean and easy user interface. Educational highlights the importance of providing educational content to the target audience.
By focusing on these four keywords, the brand will be able to create a consistent and cohesive image that accurately represents its identity.

Typography

Two different fonts have been selected for the typography, one for the brand identity and the other for the application and product display texts.

The first one was chosen using the open source font Oxygen Mono by Vernon Adams from the Google Fonts Library (Google, 2023).

Aa

Oxygen Mono

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0

H1 - Heading	Regular - 34pt
H2 - Heading	Regular - 32pt
Captions	Regular - 10pt

Ratumquat alit pratiaerios aturiberitae parum, omnis excest quisinv elition perovid exeriatias eaqui rerum quodi bea apienihitio endigent maiossu ntibus in conseque est, non nissedi onectiis quunt.

Inis et inulpa voluptatur apicab ipsani ratinventin pore intestrum nectus mil mo blam quundae vendici menitaquatur maiorpo riorerum eveliquibus eum acero molendit aut de prem explabo. Occus venti cusam laccupt atectur, soluptatus

The Poppins font from Indian Type Foundry and Jonny Pinhorn font from the Google Fonts Library were selected for the second one (Google, 2023).

Aa

Poppins

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0

H1 - Heading	Regular - 28pt
H2 - Heading	Medium - 24pt
Captions	Medium - 14pt

Ratumquat alit pratiaerios aturiberitae parum, omnis excest quisinv elition perovid exeriatias eaqui rerum quodi bea apienihitio endigent maiossu ntibus in conseque est, non nissedi onectiis quunt.

Inis et inulpa voluptatur apicab ipsani ratinventin pore intestrum nectus mil mo blam quundae vendici menitaquatur maiorpo riorerum eveliquibus eum acero molendit aut de prem explabo. Occus venti cusam laccupt atectur, soluptatus

Colour Palette

The display of the product served as the starting point for the color scheme because E-Ink technology only allows for two colors: black and white. Neon green, which is prevalent in the products that the target users use today, was chosen as a secondary color to support the research and move it closer to the world of high school students.

#131313

#f1f1f1

#adff00

High Fidelity Visuals

It is possible to create the high fidelity visuals in accordance with the wireframes that were previously shared, the information architecture, and the research that was done to define colors and typography.

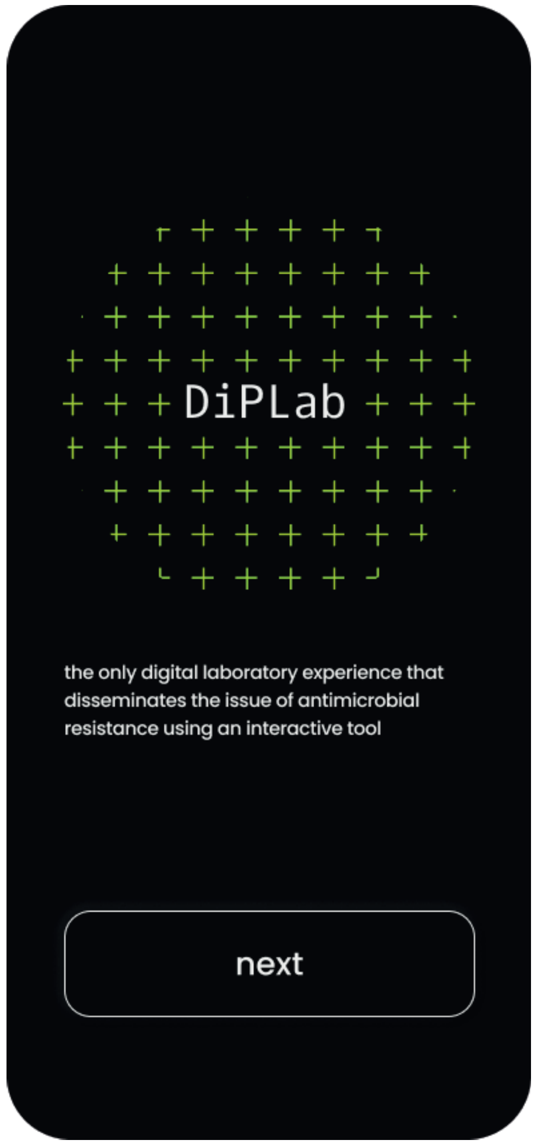


Fig 55: Introduction page.

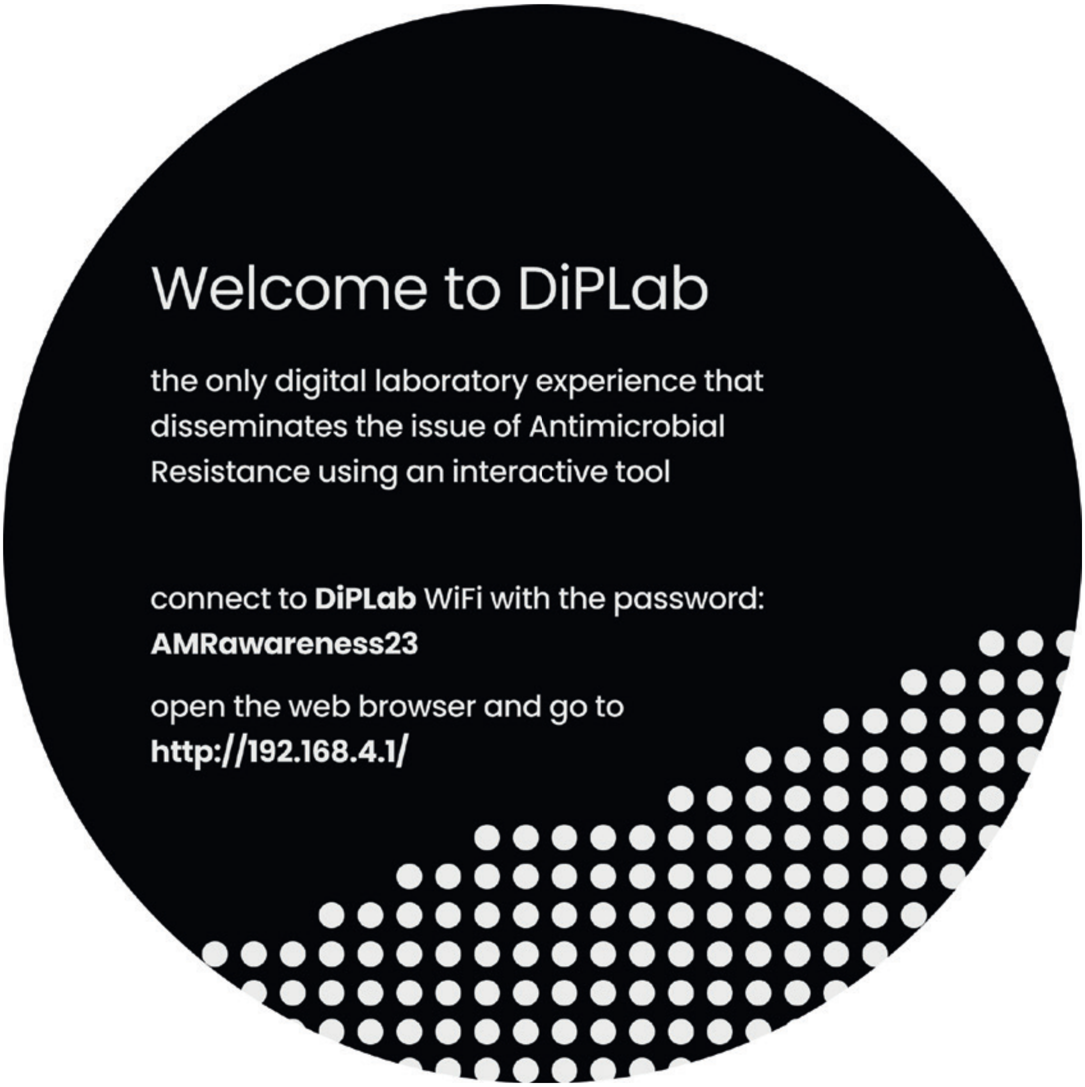


Fig 56: Device's introduction screen.

Fig 57: Participant's informations.

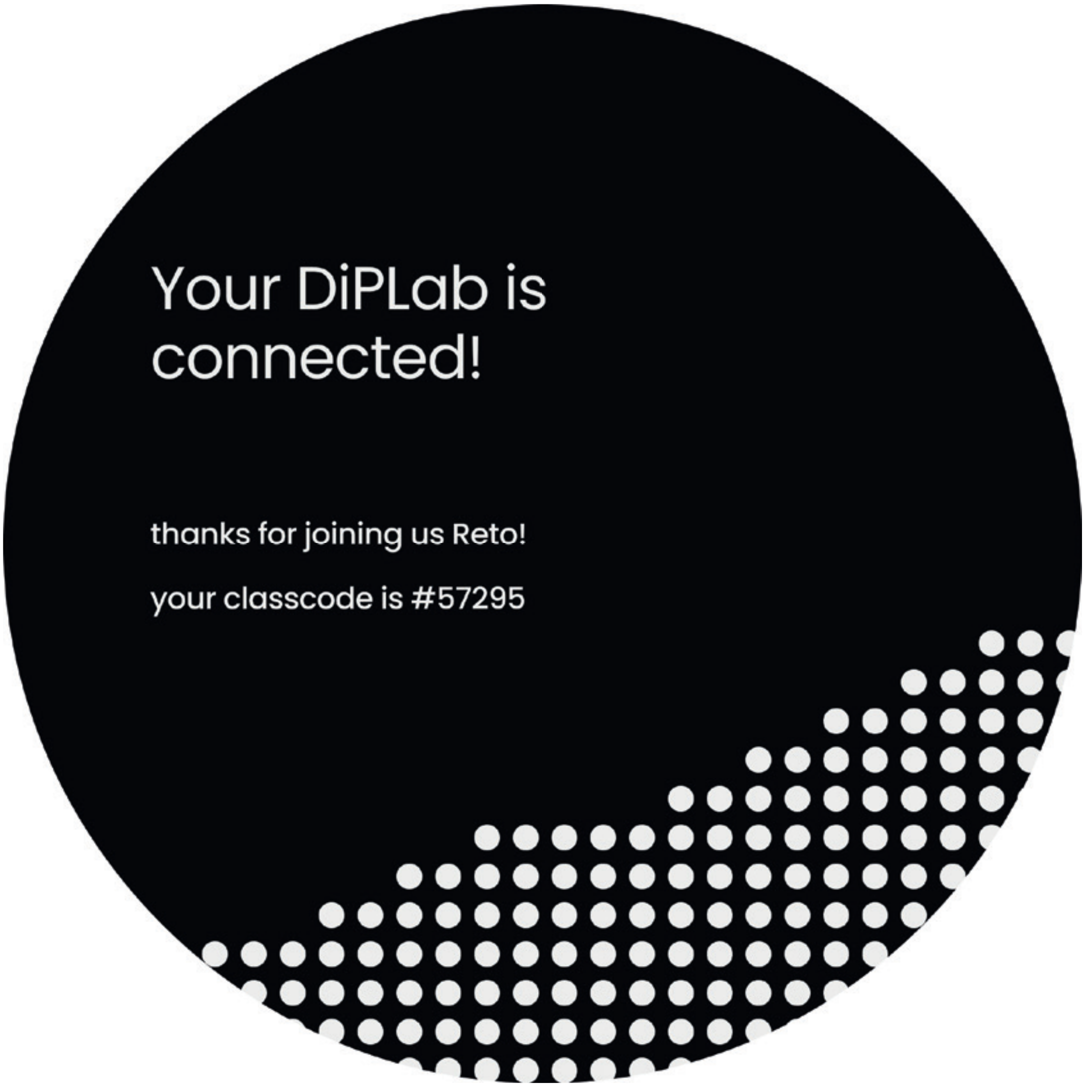


Fig 57: Device's participant feedback.

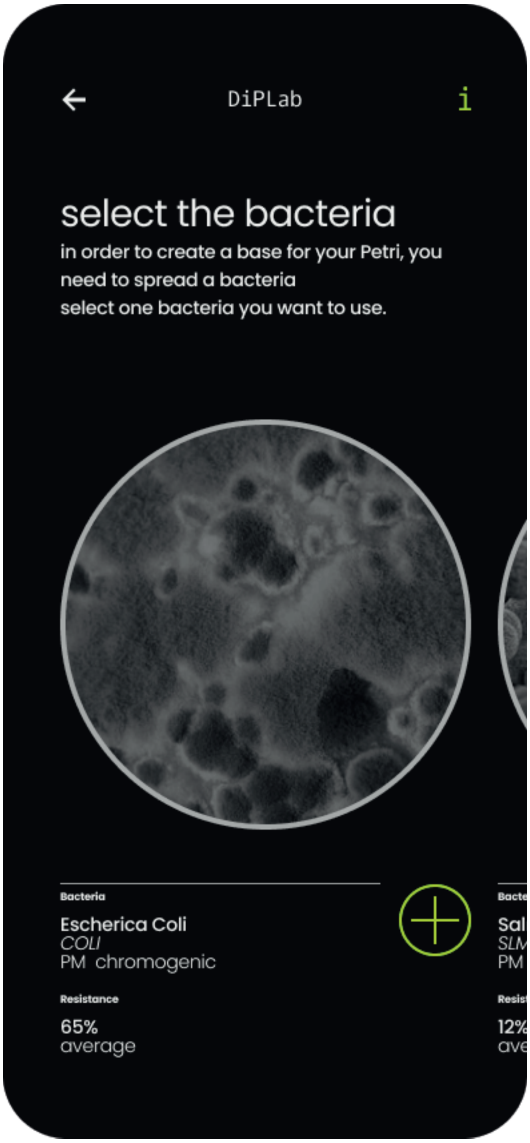


Fig 58: Bacteria selection page.

Fig 59: Device waiting for bacteria.

Fig 60: Bacteria spreading page.

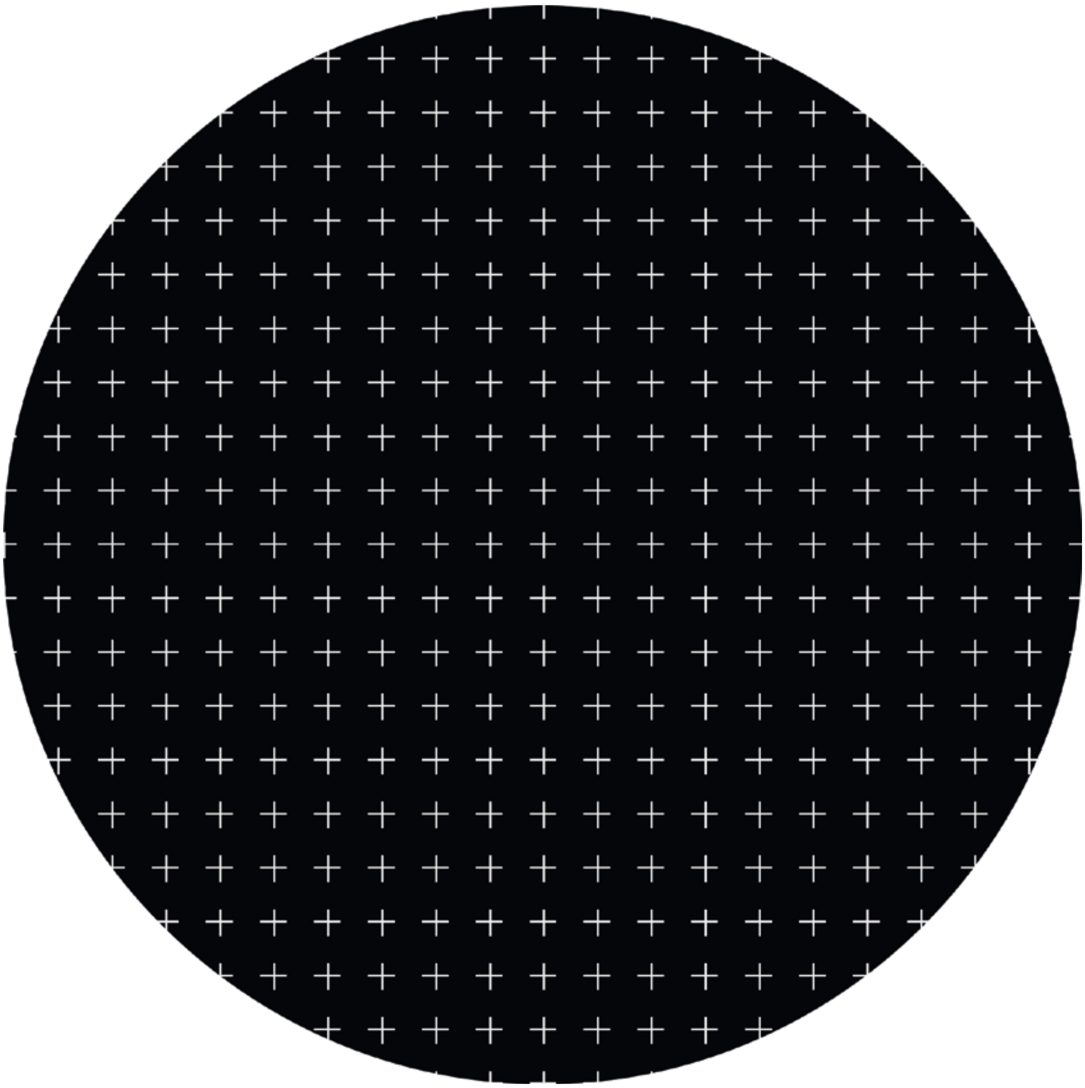


Fig 61: Device showing bacteria's pattern.

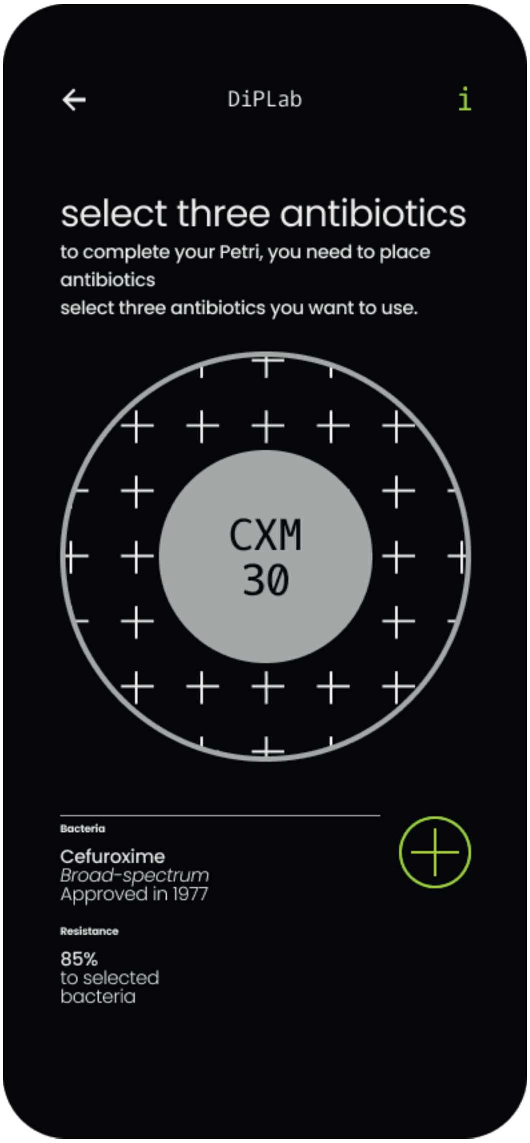


Fig 62: Antibiotics selection page.

Fig 63: Antibiotic waiting for selection.

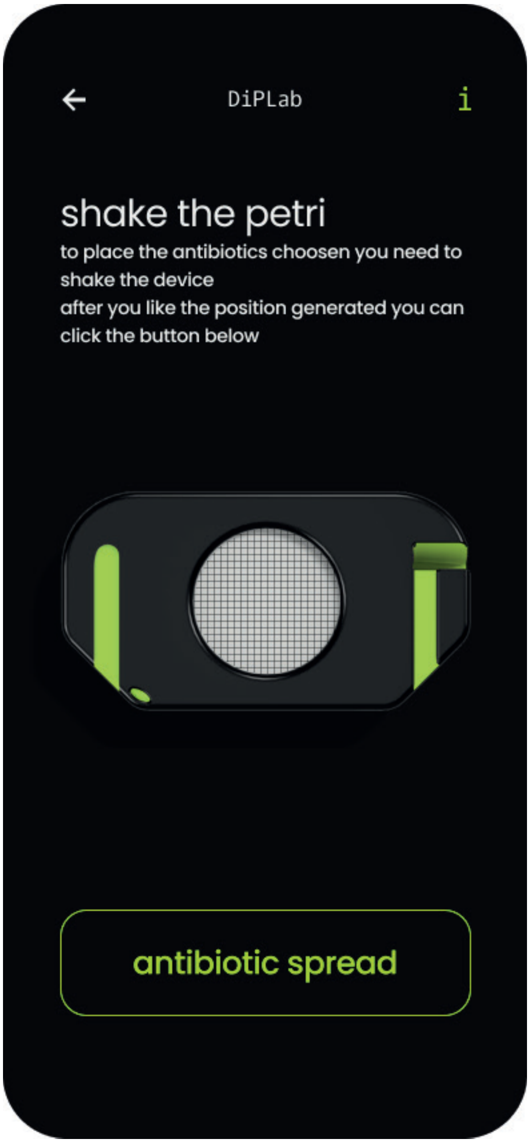


Fig 64: Antibiotics placing page.

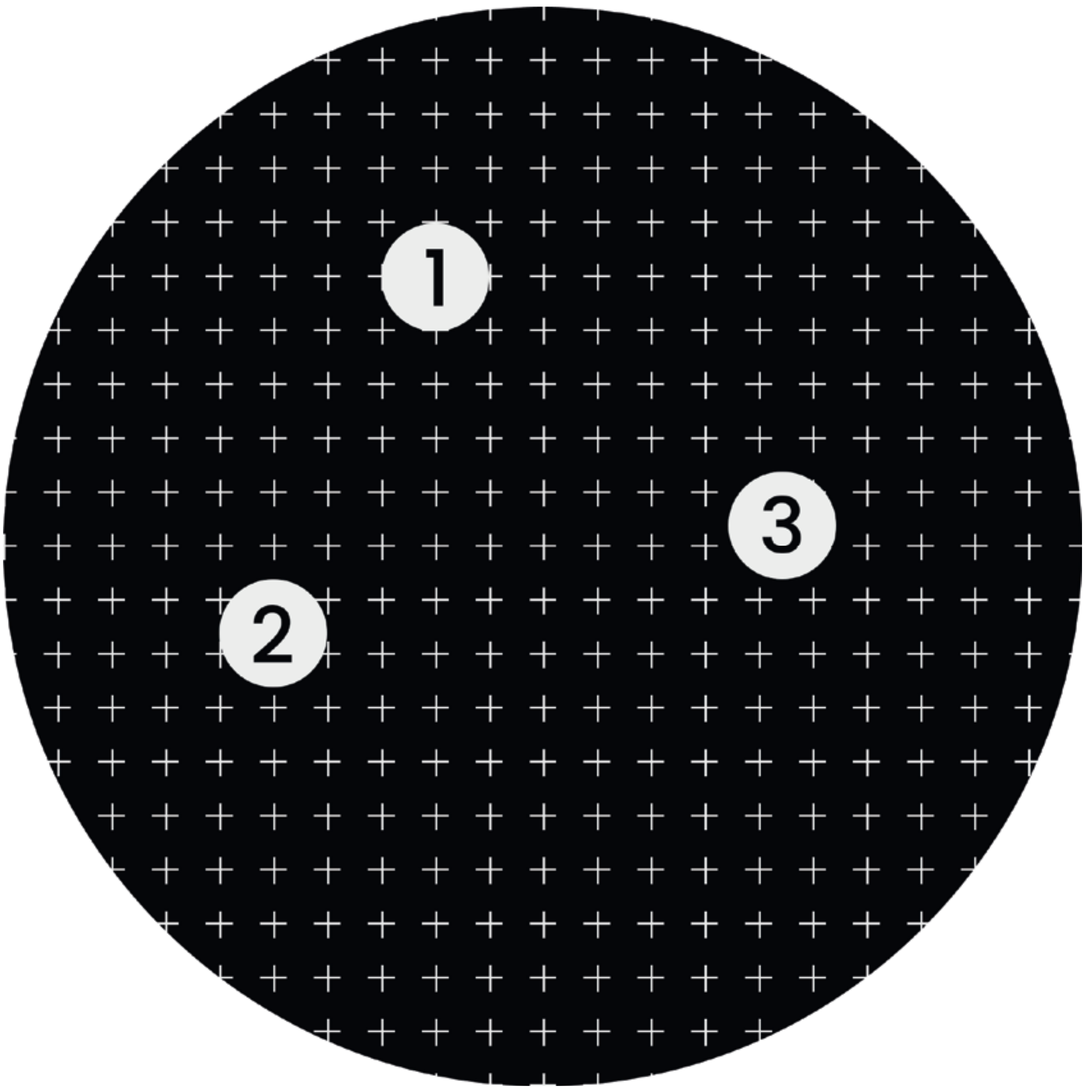


Fig 65: Device showing antibiotic position.

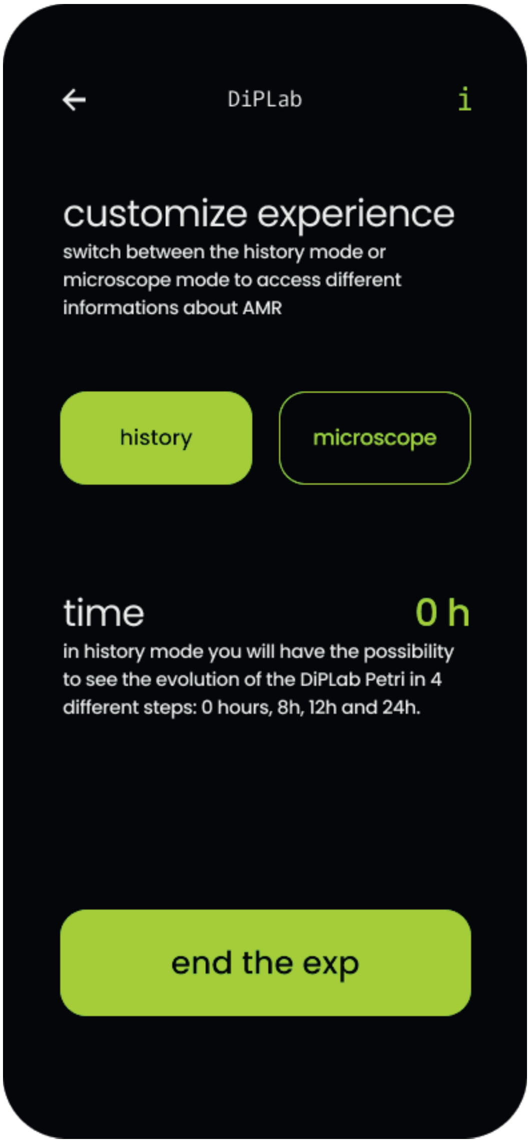


Fig 66: History mode page.

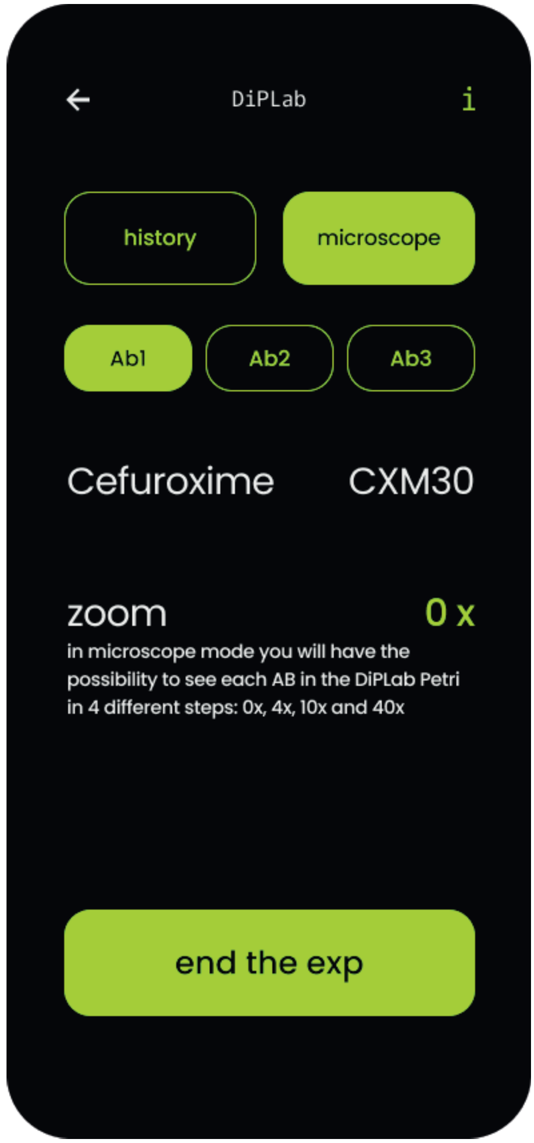


Fig 67: Microscope mode page.

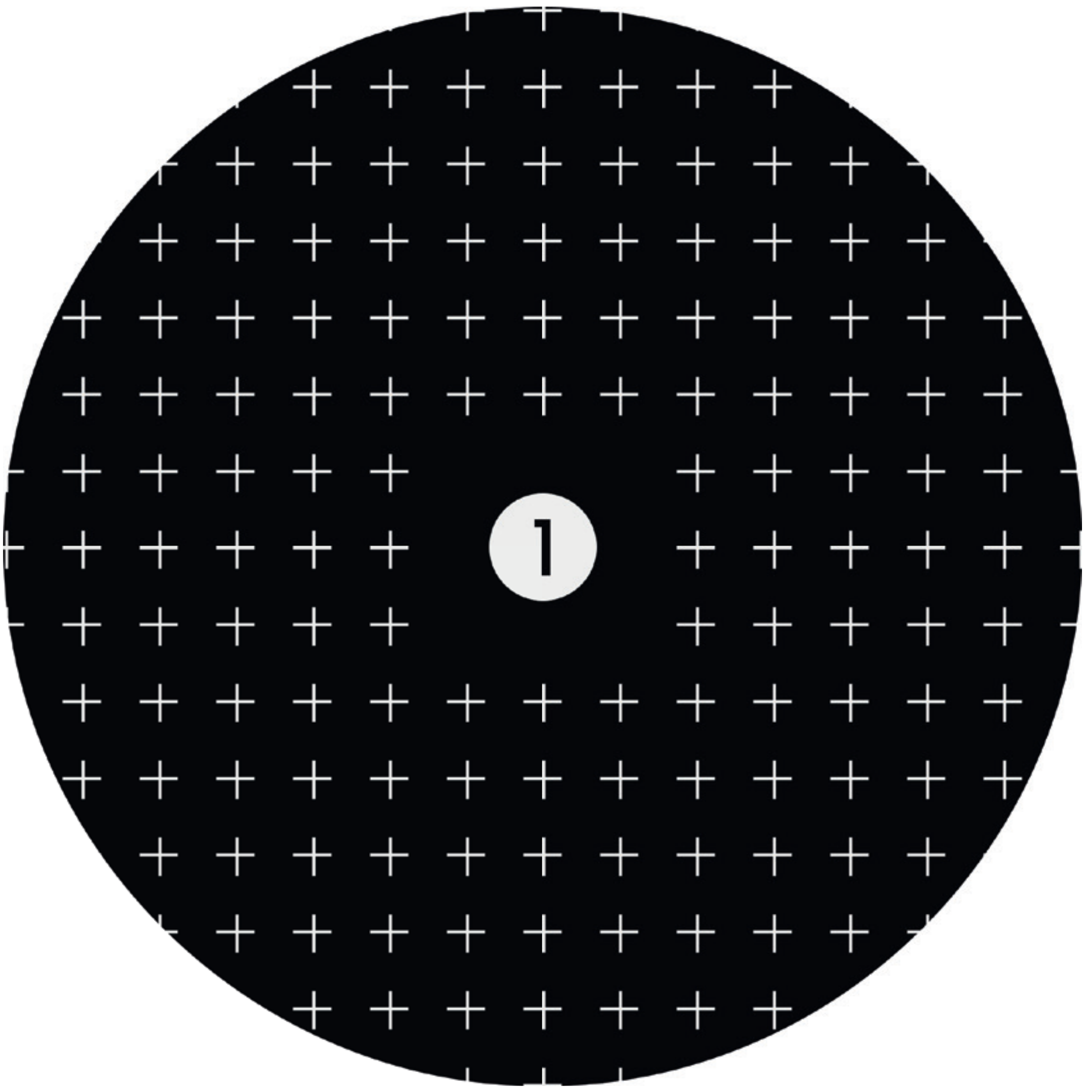


Fig 68: Device showing antibiotic number 1 zommed-in at 4x.

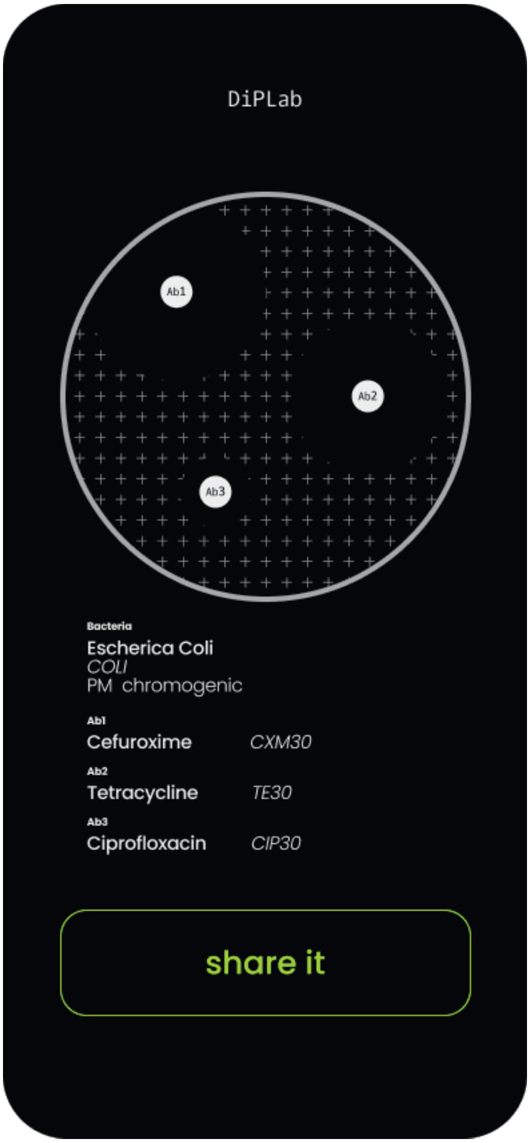


Fig 69: Recap experiment page.

5.2.2 Technology

The Inkplate 6 Plus from Soldered Electronics is the technology being used for the project. The technology for the project is Inkplate 6 Plus from Soldered Electronics. Since the libraries and their schematics are completely open source, it is possible to use this board for any purpose, which is great for maintaining an open license for this thesis project.

The ESP32-WROVER microprocessor, on which the board is based, has already built in an antenna to enable WiFi or Bluetooth connections with other gadgets. The processor has an additional 8MB SPI Pseudo Static RAM and an external 4MB SPI flash.
The ability to read files from an SD Card, which is actually used as a test system for the storage of webpages, is another significant feature of the Inkplate board.

It was necessary to use a Grove sensor known as the 3-Axis Digital Accelerometer because the system lacks an integrated accelerometer.

The first prototype created was based on a collection of websites with buttons or calls to action that launch URL queries, such as /string?bacteria="coli." .Therefore, it is possible to transfer data from the smartphone to the device using this system. This system uploads each page from a SdCard through the pre-mounted SdReader, this had some complications in terms of speed and the connection of the reader was unstable since the SPI method of connection is used also for other tasks on the board.

This system allowed for much faster communication, which increased the speed at which each webpage could be uploaded to a smartphone. The second prototype was created using the ESP32's internal memory to address these issues. However, there is still a communication problem between the device and the smartphone with this system. The communication system based on URL queries is actually only effective in one direction, specifically from the webpage, or the smartphone, to the device. Additionally, each webpage is uploaded using this system following a device trigger, making a clear delay between each page.

The third prototype was subsequently created, with a completely different communication system to address the earlier problems. Actually, in this case, communication takes place via a JSON file that updates a particular element with a particspecificular value. This list makes it possible to instantly communicate from a device to a smartphone and vice versa. With this system, it is also possible to switch pages without having to request that the previous page be uploaded from the device. As a result, the webpage uploads much more quickly.

5.3 Information architecture

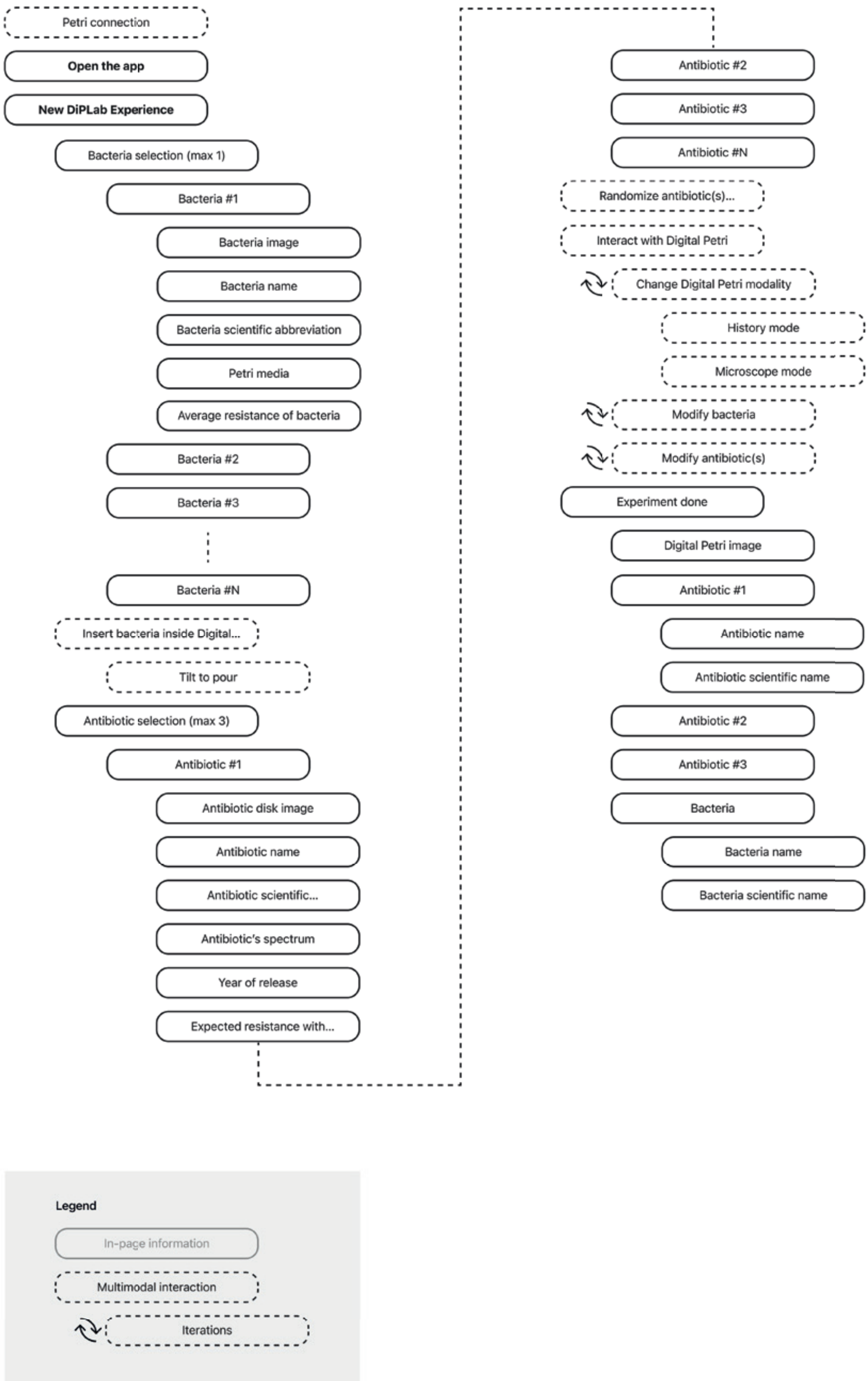
Application, device, and website are the three main components of the architecture under reviThe website serves as a landing page for new users and/or a repository for the projects completed with the help of the system while the application and the device, as previously demonstrated, are both working simultaneously.

5.3.1 App

As a controller for the experience, the application is in operation. The phone must be connected to the device via WiFi in order to launch the experience and see the app.

Following that, a step is necessary to verify the connection between the two devices. The user is prompted to enter their name and the classcode that the tutor has provided as the first action in the experience. The user is required to spread the bacteria by tilting the device after selecting it as the base for the digital Petri dish. The experience can begin with this first interaction. The selection of antibiotics comes next. As with the previous phase, the participant must choose three different ABs, and the interaction is shaking the digital Petri dish to distribute them randomly.

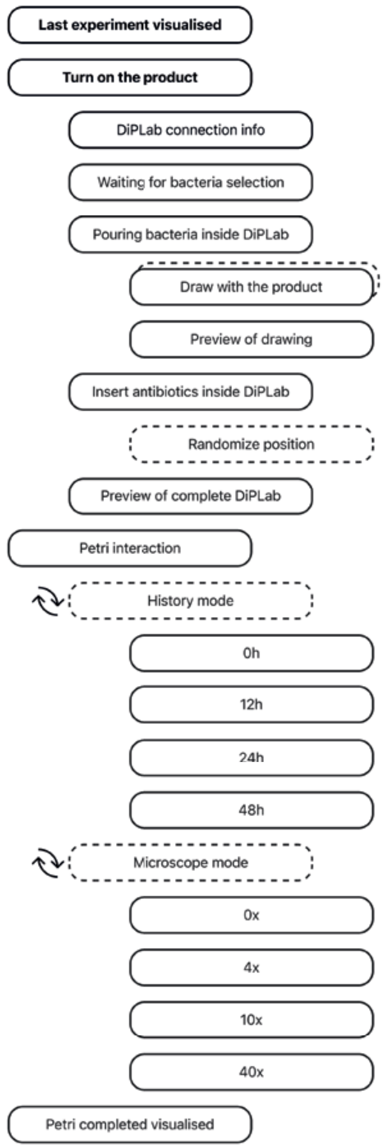
Now that the creation is being examined in the history mode or microscope mode, the user can learn more about their creation. The user has the option to stop the experience while saving the result or change the antibiotics or bacteria every time. The participant can save an image with a summary of their creation after the Petri has been saved in the library.



Petri connection
Open the app
New DiPLab Experience
Bacteria selection (max 1)
Bacteria #1
Bacteria image
Bacteria name
Bacteria scientific abbreviation
Petri media
Average resistance of bacteria
Bacteria #2
Bacteria #3
Bacteria #N
Insert bacteria inside Digital...
Tilt to pour
Antibiotic selection (max 3)
Antibiotic #1
Antibiotic disk image
Antibiotic name
Antibiotic scientific...
Antibiotic's spectrum
Year of release
Expected resistance with...
Antibiotic #2
Antibiotic #3
Antibiotic #N
Randomize antibiotic(s)...
Interact with Digital Petri
Change Digital Petri modality
History mode
Microscope mode
Modify bacteria
Modify antibiotic(s)
Experiment done
Digital Petri image
Antibiotic #1
Antibiotic name
Antibiotic scientific name
Antibiotic #2
Antibiotic #3
Bacteria
Bacteria name
Bacteria scientific name
Legend
In-page information
Multimodal interaction
Iterations

5.3.2 Product

From the perspective of the product, the architecture is very similar to that of the mobile. In fact, it happens after every smartphone interaction; after choosing the bacteria and antibiotics, tilting and shaking charge the bacteria and antibiotics in a digital petri dish, respectively. The information provided to the user on the device for the microscope and history mode is the evolution of bacteria that responds to antibiotics placed on top; this evolution is divided into four different stages and, as previously mentioned, follows the standard procedure of an antibAdditionally, when using the microscope mode, the user can enlarge each antibiotic by 4x, 10x, or 40x. x, 10x, 40x. As a final step, the experiment is visualised as a traditional Petri after 48h of incubation. The product can be turned off by the user, and thanks to the technology employed, the petri will continue to be visible until it is turned on again.



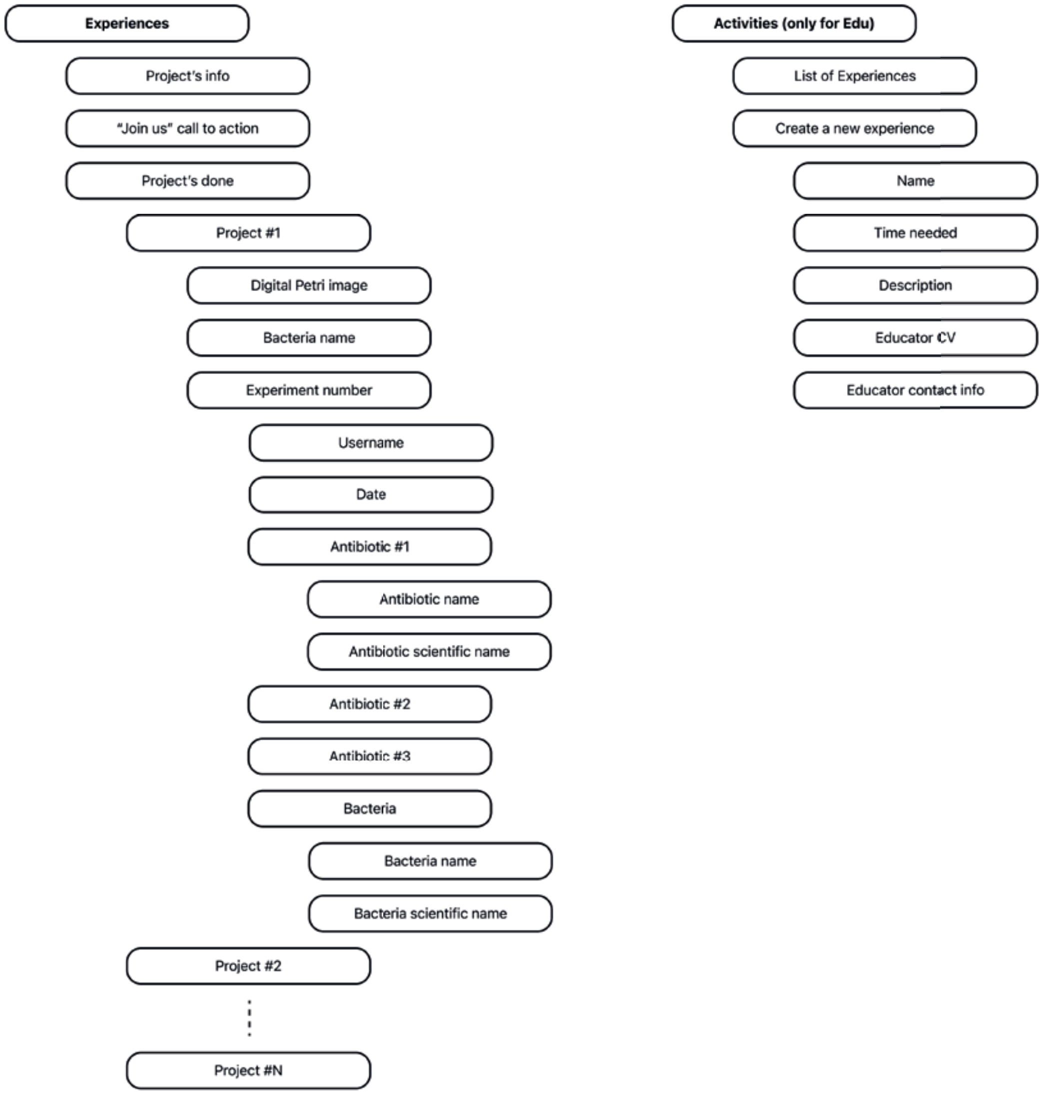
Last experiment visualised
Turn on the product
DiPLab connection info
Waiting for bacteria selection
Pouring bacteria inside DiPLab
Draw with the product
Preview of drawing
Insert antibiotics inside DiPLab
Randomize position
Preview of complete DiPLab
Petri interaction
History mode
0h
12h
24h
48h
Microscope mode
0x
4x
10x
40x
Petri completed visualised

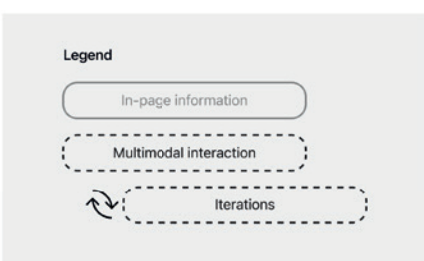
Legend
Multimodal/Product interaction
In-page information
Multimodal interaction
Iterations

5.3.3 Website

The user of the website can view a collection of all the previous student's projects organized by classcode, bacteria used, or antibiotics.

The website displays all DiPLab-related information, including the opportunity to attend workshops or learn more about AMR. Educators can use the service to design new learning experiences related to the topic.


Experiences
Project's info
"Join us" call to action
Project's done
Project #1
Digital Petri image
Bacteria name
Experiment number
Username
Date
Antibiotic #1
Antibiotic name
Antibiotic scientific name
Antibiotic #2
Antibiotic #3
Bacteria
Bacteria name
Bacteria scientific name
Project #2
Project #N
Activities (only for Edu)
List of Experiences
Create a new experience
Name
Time needed
Description
Educator CV
Educator contact info


Legend
In-page information
Multimodal interaction
Iterations

5.4 Prototype

The images shown below show the final physical prototype that was created for the intended user experience. Making this prototype was an essential step in making the product a reality.

The objective was to produce a physical representation of the product that could be tested and used for demonstrations in order to highlight its features and capabilities. The prototype-making process took countless hours of planning, testing, and research.

The finished product serves as a physical representation of the research conducted up to this point and is evidence of the effort and commitment put forth to develop a product that will satisfy the needs of the target.

Fig 70: The device with laboratory instruments.

Fig 71: Result of a experiment done with the device.

Fig 72: Proportion of the object with a hand.

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