Teaching informal repair knowledge and sustainable practices through interactive design

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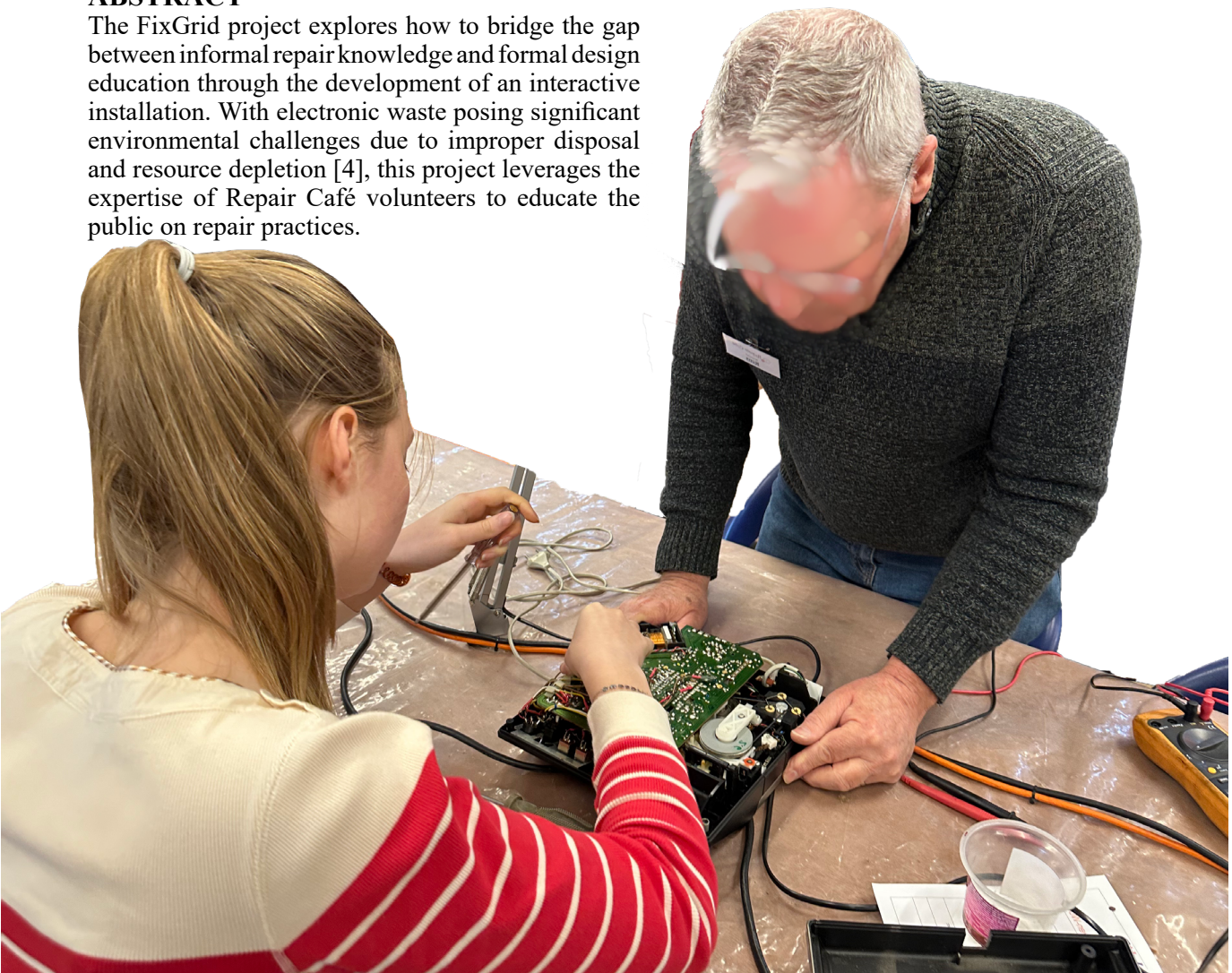
ABSTRACT
The FixGrid project explores how to bridge the gap between informal repair knowledge and formal design education through the development of an interactive installation. With electronic waste posing significant environmental challenges due to improper disposal and resource depletion [4], this project leverages the expertise of Repair Café volunteers to educate the public on repair practices.



on transferring the repair knowledge of Repair Café Our research focused on creating a demonstrator that combines a large-scale replica of a vacuum cleaner circuit board (PCB) with a custom-built multimeter. Participants learn to diagnose and repair faults, gaining practical experience in using a multimeter. The installation also visually represents the environmental impact of e-waste, highlighting the benefits of repairing over replacing electronic devices.

Methodologically, the project involved extensive literature research on e-waste and repair culture, ethnographic studies, interviews and observational research at Repair Cafés, and iterative design processes. These methods informed the design and refinement of our demonstrator, ensuring it is both educational and engaging. By integrating gamification elements, we aimed to enhance user engagement and learning outcomes.

KEYWORDS
Repair Café, multimeter, vacuum cleaner, e-waste, environmental impact

FixGrid

4988 words

INTRODUCTION

The environmental impact of electronic waste (e-waste) around the world is significant and multifaceted. E-waste is a growing waste stream, with an estimated 52 million metric tons generated worldwide in 2020, growing at a rate of 3% each year[4]. Despite the urgency to address this issue, a significant portion of e-waste is disposed of inappropriately, with only 20% adhering to standard recycling methods[4]. This inappropriate disposal of e-waste has several negative environmental consequences.

Firstly, e-waste contains a range of hazardous substances, including lead, mercury, cadmium, and brominated flame retardants, which can leach into the soil and water and pose a risk to human health and the environment[4]. Secondly, e-waste can contribute to climate change. The production of new devices costs a significant amount of energy and resources and the disposal can release greenhouse gases into the atmosphere [15]. Thirdly, it can have a negative impact on biodiversity because the extraction of raw materials can lead to habitat destruction and the displacement of wildlife [15].

Over the past decades, producers have reduced their production costs so purchasing new products is no longer exclusive to the affluent. However, cheap products make repairing less appealing, which leads to an increase in waste. Nowadays, repairing is often even more expensive than buying a new one. This leads to a decrease in repair services and thus repair knowledge. [10]

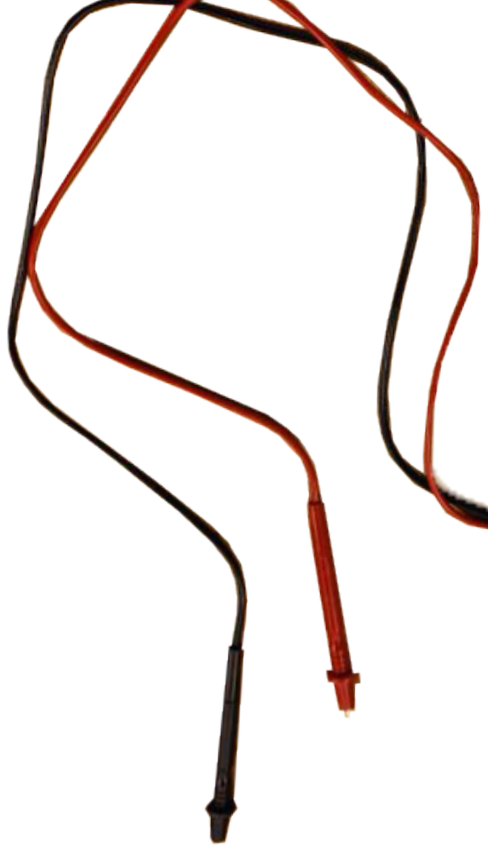
To address the decline in repair culture and increase in waste, Repair Cafés were founded. Repair Cafés, an initiative by Martine Postma, are community spaces where volunteers help people to repair broken products for free [10]. Repair cafés origin from the Netherlands in 2009 and were quickly spread worldwide [10]. This concept aims to reduce the amount of waste by convincing people to repair instead of buying new products after they break down [10]. The volunteer teaches the repair processes during the reparation so the visitors are more likely to do it themselves the next time. [10] In general, participating in a Repair Café is part of larger concerns regarding global environmental problems [10].

This research aims to blend the informal repair knowledge from Repair Café volunteers with design education. An exploratory demonstrator was created to share this knowledge to non-Repair Café volunteers in a tangible and experiential way. A specific focus was put on the multimeter, the hero of electrical repairs in Repair Cafés. Besides, the demonstrator zooms in on vacuum cleaners, one of the objects that is brought in most often to Repair Cafés [10](Appendix F). To encourage people to repair, attention was paid to the environmental impact by emphasizing its advantages.

This research aims to provide an answer to the following research question:

“How can we teach how to use a multimeter to show the environmental impact of repairing with the knowledge of Repair Café volunteers?”

This report describes the methods used in the research, the results and insights gained. Moreover, the final design of the demonstrator is explained. A discussion on the research is provided with recommendations for future work. Lastly, a conclusion is included.



RELATED WORK

In developing our demonstrator, we drew inspiration from various projects that successfully incorporated interactive and educational elements to engage users. This section details the key projects that influenced our design and how we integrated their successful aspects into our demonstrator.

Wij Doen Dingen

The portfolio of Wij Doen Dingen is filled with projects that use gamification in educational settings. Their projects often transform traditional learning environments by making them more interactive and enjoyable through games. Their project Waterhelden [28], which focuses on raising awareness about water conservation through interactive games, influenced our inclusion of environmental impact information in our design. We aimed to provide a structured and enjoyable learning experience that motivates users to take action while seeing the consequences, thus enhancing the educational aspect of our demonstrator. [29]

Kiss the Frog

Kiss the Frog's work at the Sheikh Abdullah Al Salem Cultural Centre offers a profound example of how interactive exhibits can be used for education and engagement. Their exhibit where visitors program a robot arm to perform tasks demonstrated how hands-on interaction can be an effective teaching tool. We adapted this concept to allow participants to use tools to diagnose and fix issues within electronic circuits, learning the steps and consequences of each repair choice. [8]

Katrien van Riet

As an alumna of Tu/e, Katrien has a great portfolio filled with aspiring projects. Her Final Master's Project, in particular, stands out to us, called Soft Circuits Toolkit [27]. Her research project aims to lower the entry barrier to the soft robotics field, and additionally teach electronics through the fluidics analogy. She does this by designing a toolkit for educational purposes to be used in schools. She represents different electrical components with simplified, abstract objects, which is very similar to what we are doing. It was inspiring to see how such a complex issue can be handled in a simple way, especially in a high-level project, like FMP.

METHODS

Literature research

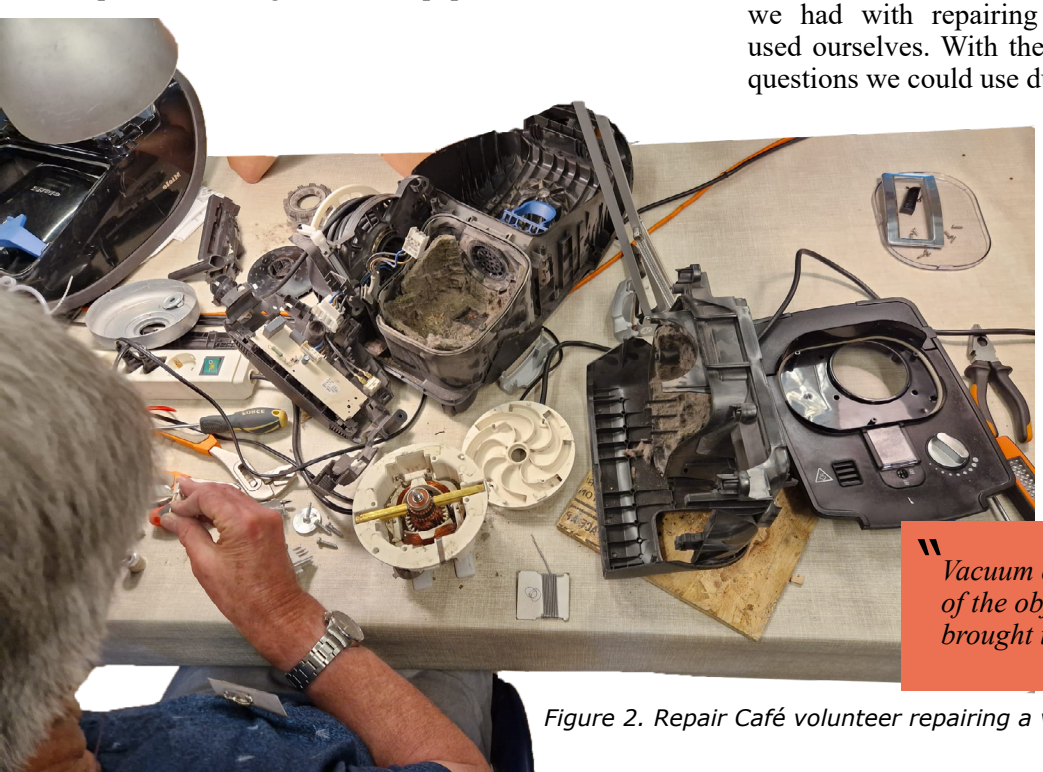
When starting this research project the most accessible way for us to collect information about Repair Cafés was to do literature research about it online. With this method we wanted to gain more general knowledge about the Repair Cafés and what their main incentives are. The client we were working with is Martine Postma who is the founder of the Repair Cafés in the Netherlands [11]. She wrote a book about the Repair Cafés with a lot of information about why there are Repair Cafés and what the value of them is [10].

Postma requested an environmental impact to be implemented in this research and therefore we also used literature research for this. We dove deep into the materials and processes needed to make certain products through academic papers.

Observational studies

The main research method used during this project was observational research, where Repair Cafés were visited and the practices observed. To know how Repair Cafés operate we visited these cafes multiple times, Repair Café Woensel was a reoccuring place to visit but we also visited the Repair Café in Acht once to see if they use the same practices and have the same atmosphere.

Repair Café visits:
Before visiting these Repair Cafés we tried repairing an object ourselves to see where our own struggles lie when it comes to reparation. We purchased multiple objects such as a citrus juicer or a printer to dismantle ourselves (Appendix D). By sitting down together and unscrewing all the parts and searching for faults we wanted to understand which problems we had with repairing and which practices we used ourselves. With these small tests we prepared questions we could use during one of our visits.



"Vacuum cleaners are one of the objects most often-brought to Repair Cafés."

Figure 2. Repair Café volunteer repairing a vacuum cleaner

Opening up a Braun Citromatic by ourselves

Figure 1. Opening up a citromatic

Our first visit was mainly focused on observing the general atmosphere within one of these Repair Cafés. The project was not mentioned during this first visit to ensure we got the full experience of how these cafés run. We wanted to learn how the volunteers work and what the practices were that they used. By bringing in our own broken objects we could observe these practices well.

Ethnography:
While observing the atmosphere during our first visit we found it useful to collect more detailed data on the practices and decided to create an ethnography on our next visit (Appendix E). We chose to do an ethnography since this is a great way to get qualitative data and is useful for drawing conclusions on how these Repair Cafés function [30]. The volunteers every actions were observed and written down. With this data we could proceed with our next step which was usability testing.

Carousel:
Activities provided by the squad gave the opportunity to do more observational studies. During the carousel users were given a citrus juicer and encouraged to open it (Appendix D). With this method we were able to conclude where problems lie when it comes to repair for students. With this data we could compare the practices used by volunteers and the practices used by people at the carousel.

Figure 3. A,B,C,D,E Carousel photos

User testing

The user testing method was mainly used to collect quantitive data about our iterations of the demonstrator and analyse the interactions of users with our artifacts. With this method we could learn more about how users knowledge about electronics and test how they tackle repair practices.

First iteration: Midterm Demo Day

Another activity provided by the TP squad was the mid-term DemoDay where different projects were presented and feedback was given. This demo was the first demonstrator from this project and an opportunity to do user testing. Users could not yet interact with it but were given a simplifier of how an electrical circuit works. The demonstrator was explained and people could give feedback on the usability and its effect on them.

Figure 4. Midterm Demo Day stand

Second iteration, Grid + metaphorical components
Our second iteration was a grid like board with electrical components but then made metaphorically. These metaphoric components where user tested to see if this would make the components easier to understand.

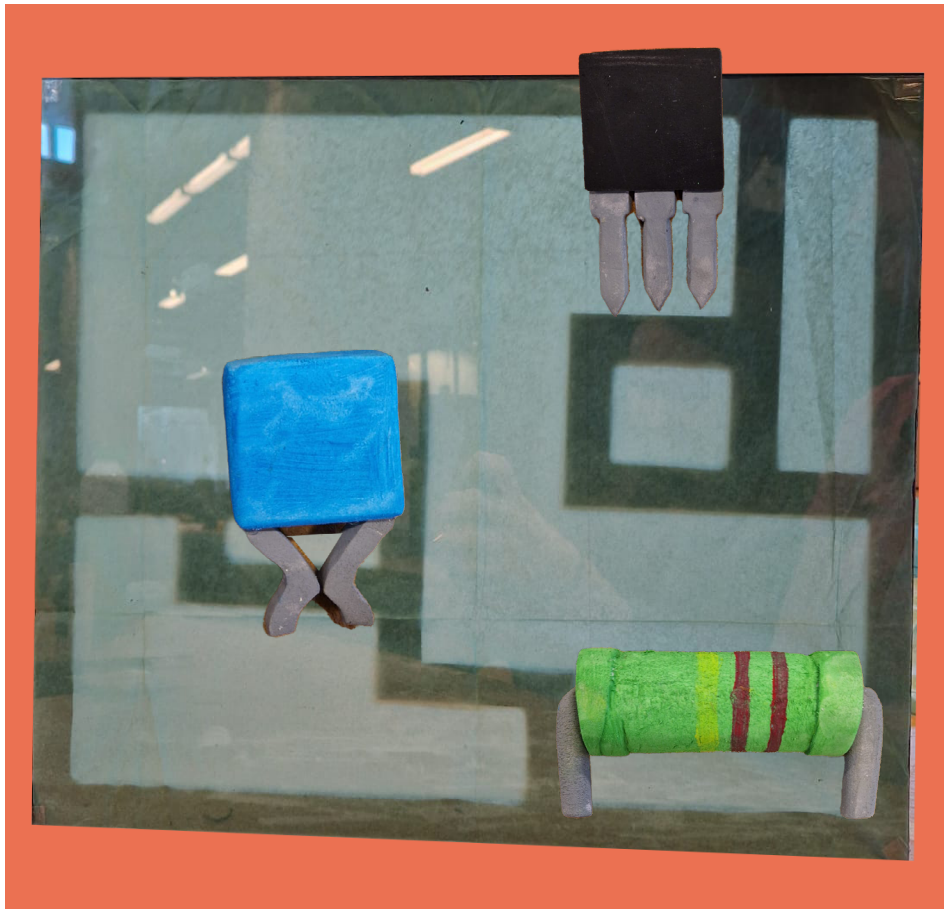


Figure 5A. Iteration board

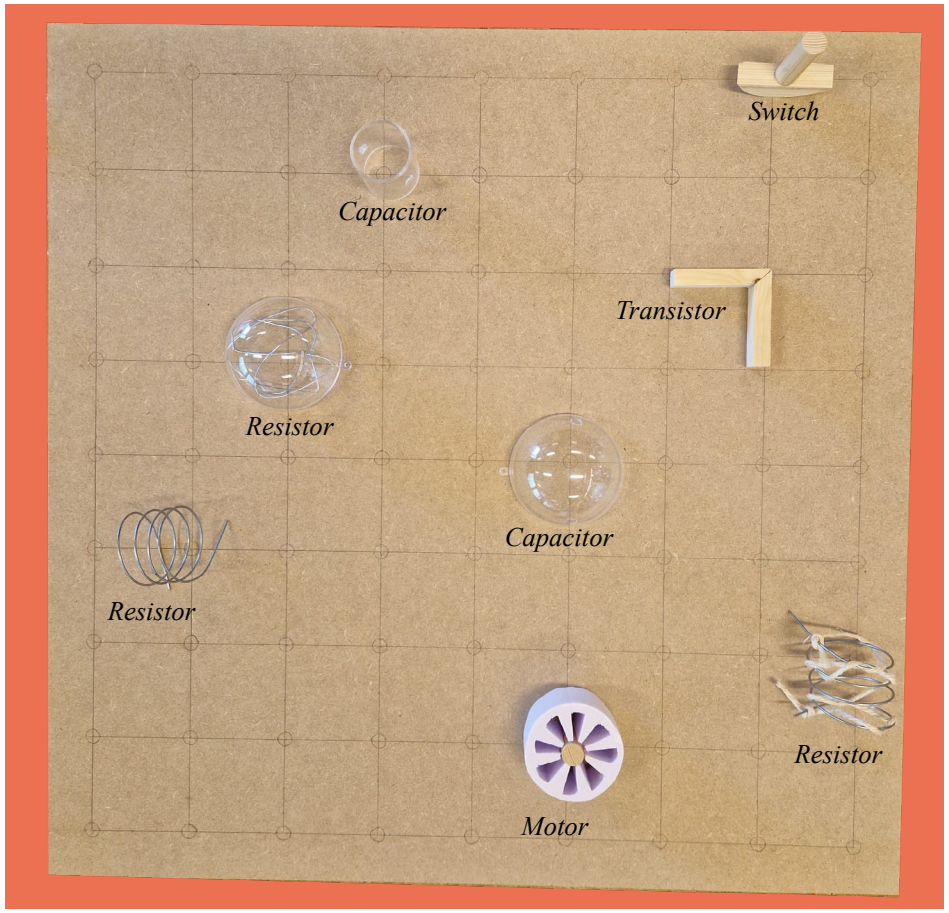


Figure 5B. Iteration components

Third iteration
Our third and final iteration included a multimeter and the vacuum cleaner as main object. We created an installation with which users could interact. We wanted to use the DemoDay to test this demostrator and see how a multimeter could have effect on repair for the general public. Our stand was made in a Repair Café setting to convey a full experience for the users.

Interviews

We conducted two formal interviews, one with a volunteer from Repair Café Woensel and one with volunteers from the Repair Café in Utrecht (who will be present during the Repair Café XL event in Den Haag) (Appendix F).

The interview's objective was to see how the volunteers react to our multimeter concept and if they had a use for it in their practice of repair. Furthermore, general questions where asked regarding the background of the volunteers and their specialties. Our goal with these questions where to analyze the difference between the background of the general public and these volunteers and what kind of impact these backgrounds have on repair.

REPAIR CAFÉ SETTING

Figure 6. Demo Day stand

RESULTS

Literature:

From our literature research, we got a baseline idea of what Repair Cafés are about, their importance and what items are frequently brought in for repairs. Postma also states that most of the objects that are brought in for repairs to the Repair Cafés are electronic devices, such as toasters, coffee machines and vacuum cleaners [10].
We decided to focus on vacuum cleaners, not only are they frequently brought in for repairs, but they also contain relatively simple electronics [10]. The repairing process of a vacuum cleaner, according to the repairer that we have made an ethnography of, usually consists of either cleaning the device, resoldering the power cord, or replacing a single electronic component. Besides, vacuum cleaners are large devices, so throwing them away results in a high amount of electronic waste per device. Therefore, we decided to use an actual vacuum cleaner PCB as the example circuit for our final iterations.

Book + general Repair Café facts:

The book “Weggooien? Mooi niet!” [10] explains that repairing products has become less appealing in recent times, as products have become cheaper to produce and thus purchase. This makes it often more expensive to repair a broken product than to throw it away and purchase a new one [10]. This uses up more raw materials and wastes the still functioning/ intact parts of the old product [10]. Repair Cafés want to alleviate this problem by providing free repairs and by teaching the visitors how to repair the products themselves [10]. However, the volunteers are often quite old, and once their generation passes away, their knowledge will be lost with them if we do not intervene.

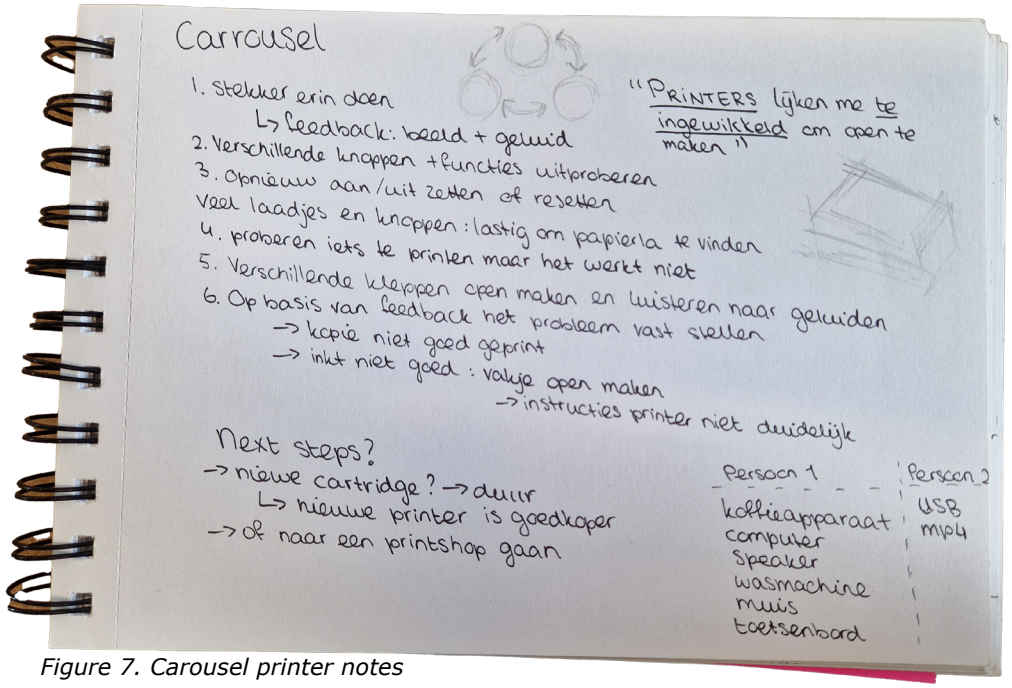


Figure 7. Carousel printer notes

Observational studies:

During our first visit to a Repair Café, we experienced that, even though there were people waiting in line, it was still a small, quiet, almost intimate setting (Appendix E). Multiple elderly volunteers were present, with one of them doing the repairs and the others offering coffee and tea. The visitors were also mostly 40+ and lived close-by, having heard about the Repair Café throught their local newspaper. The volunteer stated that the most frequently brought in items are household electronics, such as vacuum cleaners or coffee machines.

The repairers often see that people want to drop off their products and come back later once it is fixed. However, that is not the premise of the Repair Café. This mentality, and the fact that many visitors still find it hard to understand how the repair works, has led repairers to just work on the repair on their own while explaining to the visitor what they are doing. However, when asked the repairers do want to work together with you to repair the product.

Carousel

By deconstructing a Braun Citromatic ourselves, we found that objects often have a lot of screws to keep all parts together (Appendix D). The construction of the Citromatic was complicated, so we had to make process pictures in order to put it back together.
When we asked others to take apart this Citromatic during the carousel, we found that people are afraid to take apart objects when they are still partially functional, as they do not want to break it apart any further.

When people were asked to take apart a printer, they found the object to be complicated and hard to understand. It had many drawers and buttons, which makes it difficult to understand what part is broken. During their attempt to repair the device, they used trial and error and tried after every step to see if any progress was made, and they carefully listened to see if audio feedback could aid them in the repair.

Ethnography

Our ethnography from the Repair Café visit gave us more detailed information about the way a volunteer goes about a repair process (Appendix F). We found that the repairer that we observed used a step-by-step approach to repairing. First, they plug the device in and try to see if they can turn it on. They listened to any audiovisual feedback that the device gave. It was not the cable that was broken, so they opened up the device. The repairer used a separate magnetic tray where they left screws that had been unscrewed from the device. Now they checked with a multimeter whether the electronic components were in order, and they cleaned any filthy components. WD40 was used to make sure components made smooth contact, which was the solution for both the Citromatic and an electric blanket that the previous visitor brought in. This information allowed us to understand what a repair experience can look like. We also found out what practices are important to teach the users of our demonstrator, such as the use of a multimeter and listening to the feedback of the device.

Another piece of information that was gathered from the ethnography is the importance of multimeters. The reason that the devices were broken could not have been spotted without the multimeter. Its importance for repairs inspired us to use it for our second and third iteration of the prototype. Teaching visitors of our stand how a multimeter works became the main goal of our demonstrator.

Interview:

One of the interviewed repairers from Utrecht remarked a distinction between electronics and electrics (Appendix F). Electronics from his point of view are devices like phones and tablets, where they have complex electronic components and they are hard to repair. Electrics, which is our focus, are simple devices like vacuum cleaners, that have a cord to power a motor and not much else. This distinction helped us to clarify what devices are our focus, as there is a large difference in how difficult they are to repair.

Interviews that have been conducted with people from Repair Cafés in Woensel and Utrecht showed us that they are busy with teaching visitors of the Repair Café XL event about multimeters as well. This perfectly aligns with our plan, so a collaboration will be put in place. They liked our plan to use a model multimeter. They also wanted to people to visit their stands first and use our stand to let the visitors implement their previously gathered knowledge. This showed us that teaching about multimeters is both a relevant topic for Repair Cafés, and that the repairers find it a difficult topic to teach about, thus making our research relevant for the client.

Many of the volunteers have a background in electronics and mechanics. That is why they know so much about repair and usually informal ways of repair, such as completely ripping out the electronics of a vacuum cleaner so it only works on one setting but it works. This background can consist of academical knowledge, but usually it is life experience. This means that they have either worked in a sector where electronics are relevant, or have a hobby where they come in contact with electronics on a daily basis. Especially this life experience is relevant, as it might be a reason why the younger generation lacks this informal repair knowledge.

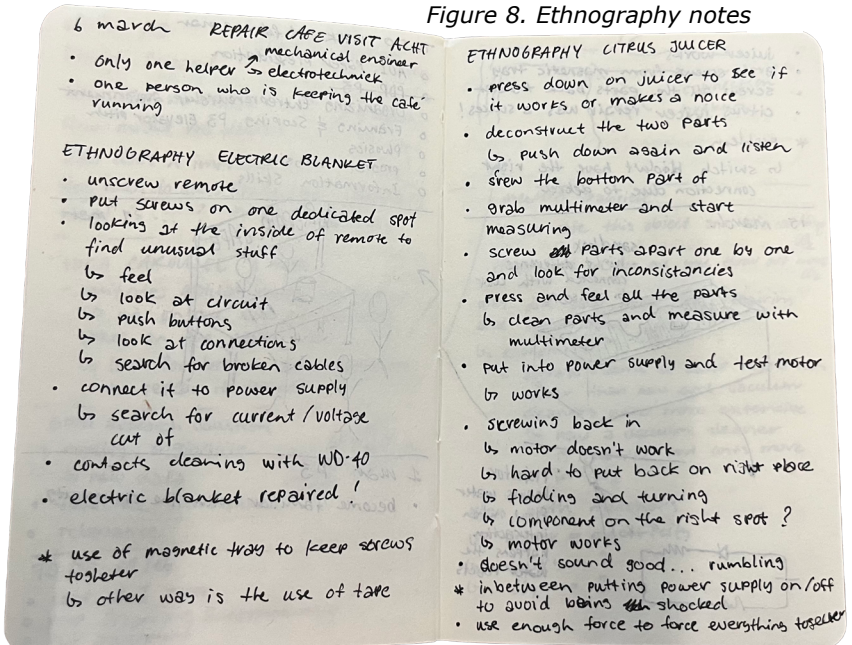


Figure 8. Ethnography notes

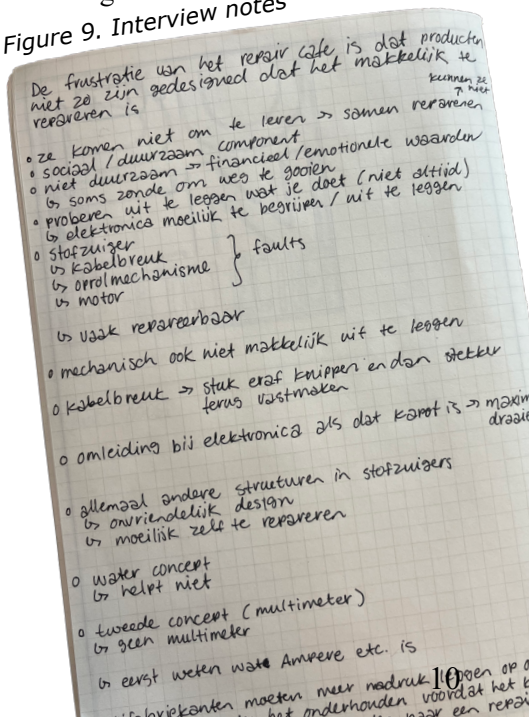


Figure 9. Interview notes

DEMONSTRATOR

Our project aimed to create an interactive installation that effectively teaches repair culture and practices, and highlights the environmental benefits of repairing electronic devices. This section details the iterative process that led to the final design of our demonstrator.

First Iteration: Water Model

For the midterm demo day, we decided on looking for a way to make electronics more approachable for regular people. We decided to use water as a metaphor for current running through wires. We redesigned a simple desk lamp with tubes running from the plug to the light bulb, replacing the electrical wires. This was going to be a demo for our final demonstrator, where we would recreate a vacuum cleaner circuit with the same principle. The goal was to show that electricity is essentially nothing more than energy running through paths and encountering resistance occasionally, just like water.

What we learned?

After presenting the first iteration demonstrator at the midterm Demo Day as our user test, we found mostly positive reactions, with fellow students and coaches appreciating the metaphor. One of the important points of feedback we received during this test was that the prototype could become more interactive, but that the idea of making electronics less scary was a good plan and something we could for certain move forward with. We also completely skipped touching on the environmental impact and importance of repairing with the water model prototype.

Figure 10. Water components

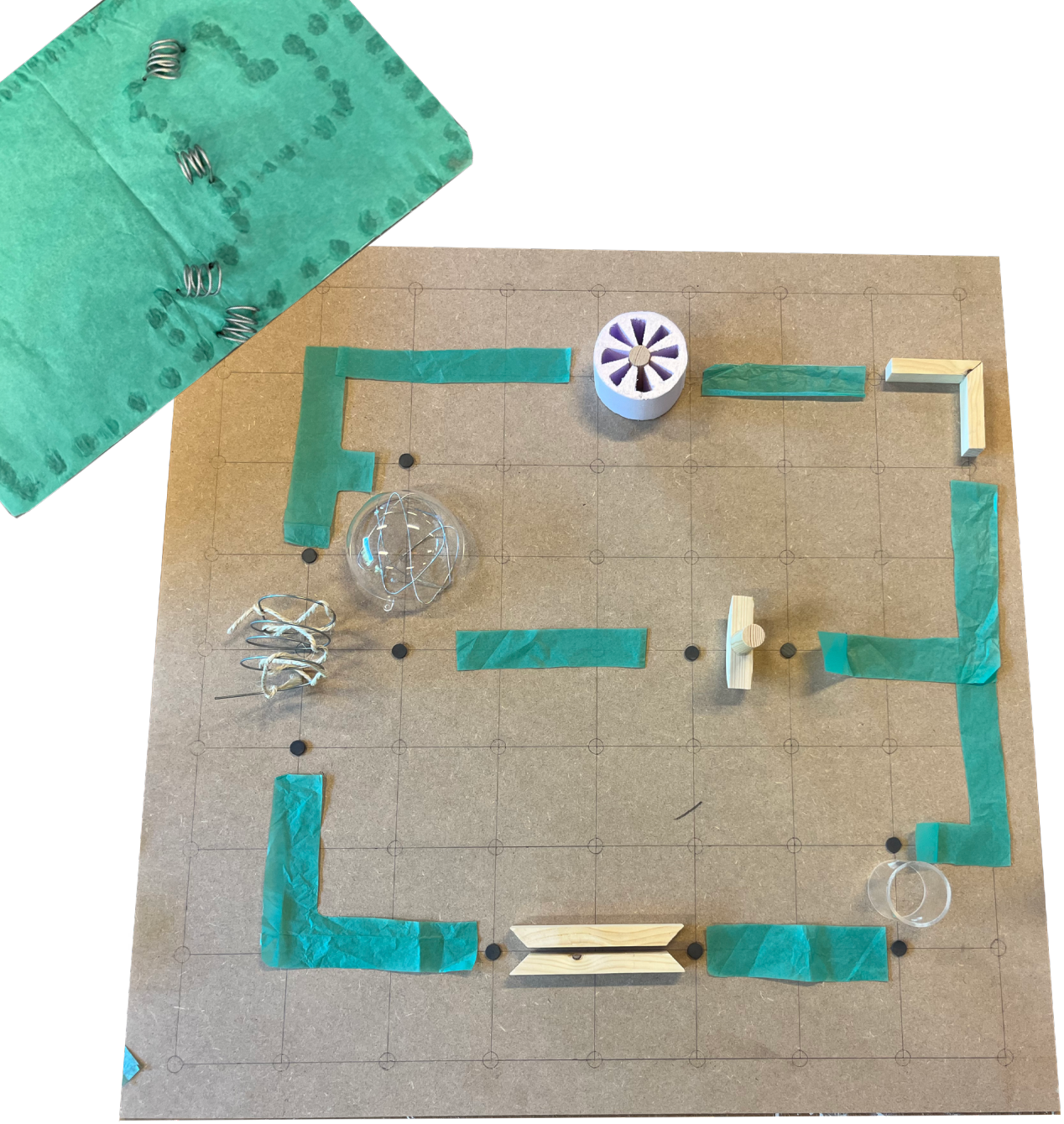


Figure 11. Iteration 2: PCB board

Second Iteration: Grid Model

For our second iteration, we abandoned the water metaphor and started looking for a more flexible way of representing electricity through metaphors. We decided to use abstract objects to represent the components, like using a spring to represent resistors. At this point, the idea was to create some kind of a “puzzle” for the users. The goal was to create a challenge for the user to spot and repair a problem in a circuit, with different difficulty levels using circuits of everyday objects based on complexity. That is the reason a grid system was designed so that circuits could be swapped using the same demonstrator. The environmental impact was going to be communicated to the user with achievements and occasional facts about their actions and their correspondence to real-world data.

What we learned?

The user test for our second iteration led us to the conclusion that not all metaphors are helpful when explaining electronics. The users did understand the metaphor for resistors, and after some help they could understand the motor aswell. However, all other components were unclear. The users gave the feedback that components required explanation. For instance, a larger version of the component with a short description would add to the readability of the components on the board. We also figured out that repairing was way too complex of a concept to teach in such a manner. Repairing, especially electronic repairs, are way too difficult to teach to someone who doesn’t have prerequisite knowledge about electronics and mechanics.

Final Iteration: The FixGrid

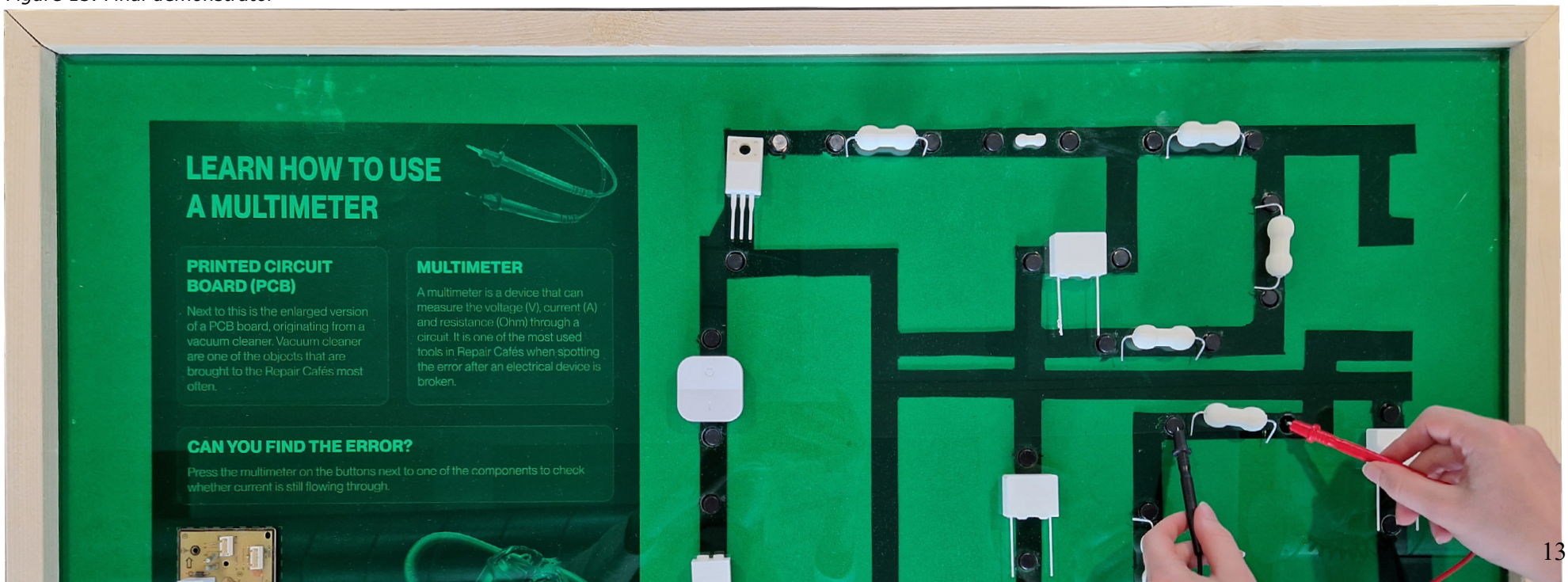
Our final iteration of the demonstrator is essentially a reworked version of the second iteration. At this point, we have decided to focus on a specific product and aspect of repair. The area we wanted to focus on became quite apparent when looking at the ethnography and interviews we conducted with various Repair Café volunteers: Multimeters. Diagnosing and identifying the error in a product is the first and arguably most important step of repair, and this process relies mainly on the use of multimeters, especially with electronics. Even if we can't teach people how to repair their objects, we can at least teach them how to diagnose the error. For the demo day, we also decided to separate interactivity and environmental impact into two separate demonstrators. The main demonstrator is accompanied by a large pile of vacuum cleaner waste with signs showing some statistics about the increase of e-waste ending up in landfills in recent years.

How it works?

Our final demonstrator is an interactive, blown-out replica of a vacuum cleaner's circuit that we opened up for exploration. The goal is to diagnose the error in the circuit by using the multimeter to test each component one by one. The frame of the circuit houses a series of buttons, each aligning with the corresponding control point for the component. The user sees an outline of the circuit, layered with green plexiglass to mimic the color of a circuit, with 3D-printed components on top. The user uses the probes of the multimeter to press the buttons on both sides of the component, to see the value on the multimeter's screen. The buttons are connected to the multimeter using OOCSI [31], allowing real-time data display.

Figure 12. Multimeter model

Figure 13. Final demonstrator



The Pile

We needed to grab the attention of people by the sheer ugliness of the e-waste situation. We gathered 8 vacuum cleaners and a bunch of spare parts and laid them in a pile next to our stand at demo day. We also placed three signs on the pile giving facts about the pile of e-waste they are faced with: “The production of 8 vacuum cleaners costs 548 MJ, more than 5 days of electricity for a household in the US”[3], “In the best scenario where all recyclable parts are recycled, 12.36 kg of this pile still must go to the landfill”[3], and “Manufacturing 8 vacuum cleaners uses 104 L of water, as much as a person drinks in 2 months”[3]. This visual representation effectively highlighted the environmental impact of electronic waste.

What we learned?

On demoday, our last iteration was showcased. After testing the demonstrator, the visitors were overall quite positive, but they did require some instructions on how the demonstrator works. After the visitors used the multimeter to identify the broken component, some were able to correctly state the following steps to repair. This means that a part of the visitors understand that when there is no current flowing through a component, that it is broken. However, this was not the case for everyone, as one of the testers was under the impression that we invented the multimeter. This highlights that the baseline of electr(on)ic repair knowledge varies widely.

Figure 14. Pile of vacuum cleaners

DISCUSSION

Nearing the end of our research, our focus was put on the usage of the multimeter. We overlooked the fact that many people don't understand how a multimeter works or even what it is. We made a simplified version of a multimeter with one setting but a real one has many more. This can be confusing for the user .Therefore an explanation at our stand would have been a valuable addition. However while visiting one of the Repair Cafés, we discovered that there are also other tools, such as a voltage stick , to see where errors occur within a product. These tools where mainly to see if current is going through a wall socket or a cable, not a PCB board.

What we could have added to our research was user testing a real multimeter and the other tools the volunteers used to see if current is flowing through an object. These results could have been compared and integrated into our demonstrator. This might have resulted in a better understandable interaction for the users.

To tackle the problem of the loss of repair knowledge in future generations even more, a further iteration of the concept would be a system that works on its own and can be placed inside community centers. People can go there when they need to repair their broken object. The system will teach them how to repair, so afterwards they can repair their own device.

Furthermore, volunteers at Repair cafés have extensive knowledge about electronics and mechanics and they use many informal practices during repair which the general public does not have. During our user testing, we found that many people find electronics hard to understand, including us. That is showcased when we wanted to draw the vacuum cleaner circuit and could not figure it out completely.

Moreover, based on interviews with Repair Café volunteers it was found that the designs of devices should change to solve this bigger underlying problem. One volunteer mentioned that nowadays there is no way that people can repair their own devices without repair experience. Therefore, all volunteers in Repair Cafés usually have a background in electrical practices, which the general community does not have. For this reason, these practices that are logical for volunteers, will not be understood by the general public.

The core of the problem lies within the consumeristic way of living we are in now. Products need to be designed in a way that repair is easy and accessible for everyone. One of the Repair Café volunteers mentioned that some devices cannot even be opened up because of its design. Besides, when trying to repair the Citromatic ourselves, we found struggles such as many different type of screws and having a hard time putting all electronics back in the device again.

Therefore, the first step should be to make designs more repair friendly. This includes not only making them easy to open up but also to make it easier to put it back together afterwards. To make it even easier, designers could consider adding small explanations and descriptions on the inside of the product which can guide people through their repair.

Figure 15. Current reading method

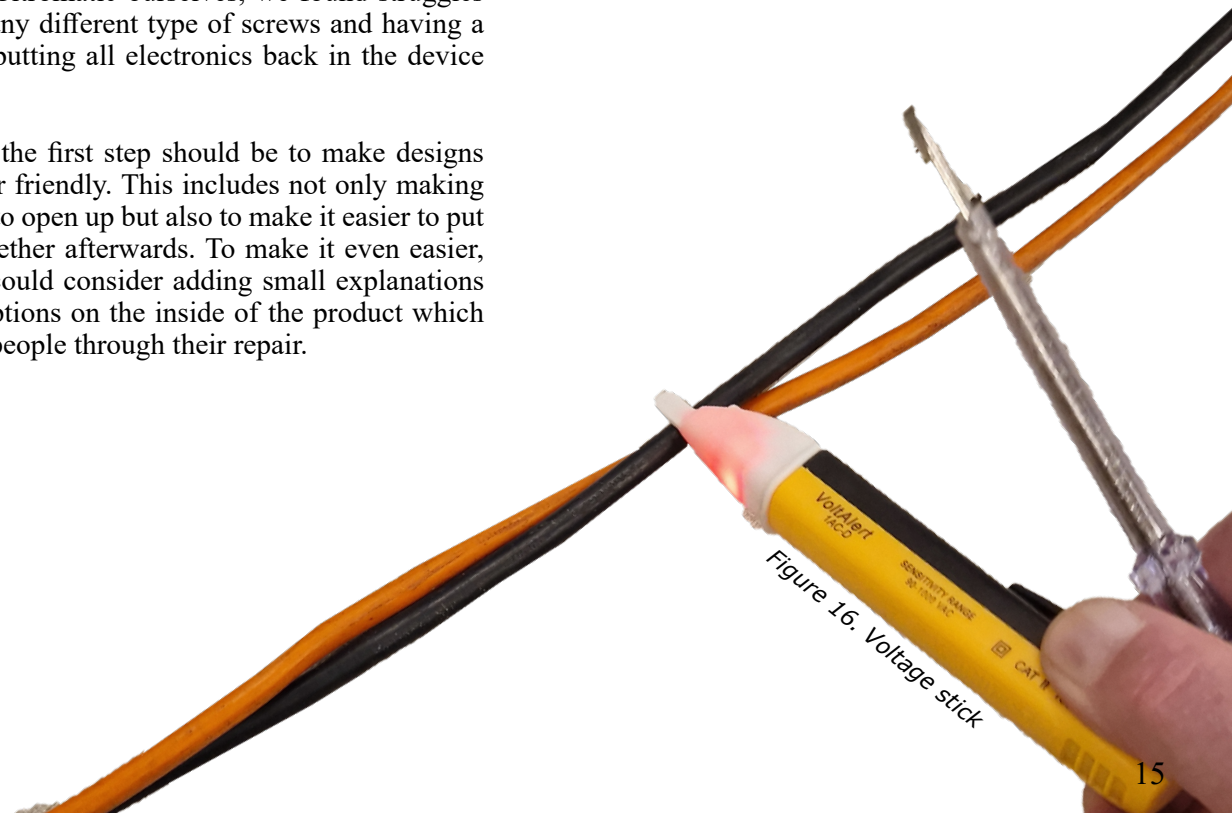


Figure 16. Voltage stick

CONCLUSION

This research has been able to highlight why people are reluctant to repair their electric devices. Both our consumerist society promoting purchasing new devices instead of repairing the old device, and a lack of knowledge and confidence in repairing. With a focus on the latter 2 problems, we studied the practices and struggles of repairing using literature review, ethnography, interviews and user testing.

This research has identified the multimeter as the most important tool for electric and electronic repairs. It has also become apparent, that many people lack knowledge on how to use the multimeter. The third iteration of our demonstrator has highlighted how people are unable to use the multimeter, but using the simplified and enlarged versions of an existing circuit and multimeter allowed people to understand the basics of using a multimeter and to fill in the remaining steps of repairing a device.

These take-aways contribute to teaching people the basics of repairs, as well as enabling further research dedicated to this topic to have an example of how repair education can look like and what specific parts of repairing require education. This research is also valuable, as it showcases what level of repair knowledge people already possess, highlighting the importance of quality repair education.

Furthermore, the lack of reparability in the design of consumer products is showcased through our research. Our ethnography and interviews demonstrate possible solutions and wishes from repairers, such as using the same type of screw throughout the entire design. Some designs do not even use screws everywhere, but choose to glue certain parts, making it impossible to reassemble. If these points were to be implemented in future designs, many more devices can be repaired.

Lastly, this research has also revealed the pressing matter of repair knowledge slowly fading away, due to the older generation slowly passing away. It is not only problematic that the younger generation does not know how to repair, but it is even worse that those who do know are not going to be around much longer. This insight should be an alarming signal for the design world to act fast.

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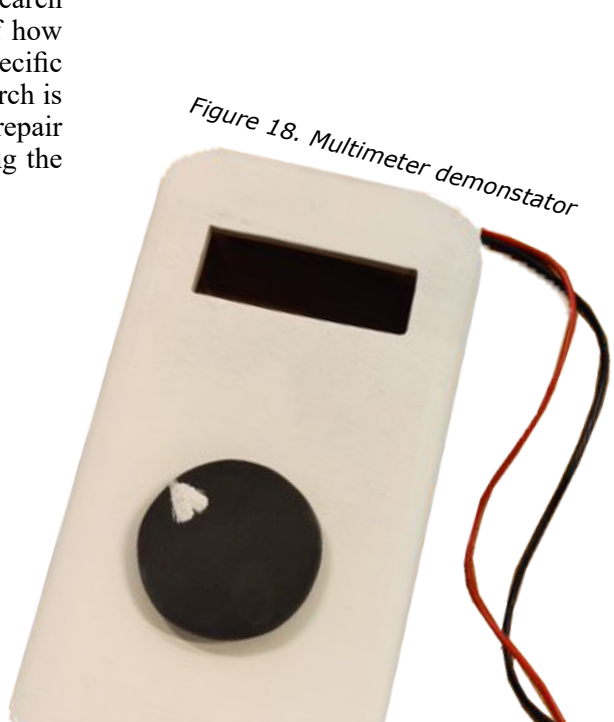

Figure 18. Multimeter demonstator

Figure 17. Multimeter in Repair Café

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AI STATEMENT

For this project, a large language model AI, namely ChatGPT-o4, has been used to aid us in the coding of our demonstrator.

OpenAI. (2023). ChatGPT-o4 [Large language model]. https://chat.openai.com/chat

Besides, Photoshop AI has been used to remove backgrounds in certain photos.

APPENDIX A.
INDICATION OF CONTRIBUTIONS

Mike:
- Repair Café visits
- Interview
- Mid-term demoday physical construction of lamp
- Coding for final demonstrator (LCD)
- Assembly electronics (LCD)
- Creation multimeter model
- Creation metaphoric components
- Writing and presenting midterm and final demoday pitch
- Report: results, conclusion

Lot:
- Repair Café visits
- Interview
- Ethnography
- Mid-term demoday electronics + water element
- Coding final demonstrator (OOCSI, Arduino, ESP, LCD)
- Assembly all electronics final demonstrator
- Creation enlarged PCB (partly)
- Iterative PCB boards
- Creation metaphoric components
- 3D printed elements
- Report: methodolgy, discussion, lay-out

Aydin:
- Visit Repair Café
- Conduct interviews
- Research environmental impact
- Assemble signs and vacuum cleaners
- Construct final structure demonstrator
- Create enlarged PCB
- Edit the final video
- Design poster
- Design logo
- Report: abstract, related works, demonstrator

Suus:
- Repair Café visits
- Interview
- Ethnography
- Research environmental impact
- Pile of vacuum cleaners + signs
- Assembly electronics final demonstrator
- Creation enlarged PCB
- Iterative PCB boards
- Translating the pcb to a circuit diagram
- Creation metaphoric components
- Mid-term demoday electronics + water element
- Narration video Demo Day
- Report: introduction, discussion, acknowledgements, appendix, lay-out

APPENDIX B.
DEMO DAY

Video: https://www.youtube.com/watch?v=lEIKvpIp8I8

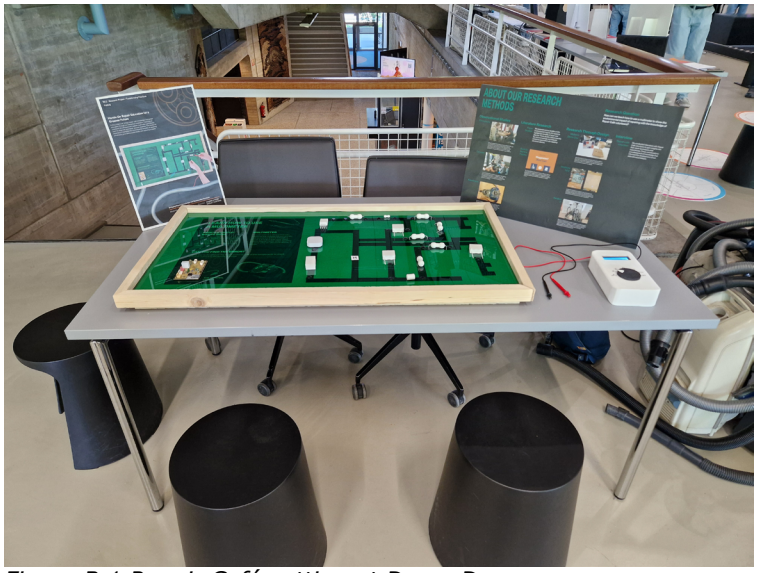


Figure B.1 Repair Café setting at Demo Day

Figure B.2 Demo Day setup

Figure B.3 Demo Day interaction

Figure B.4 Demo Day Poster

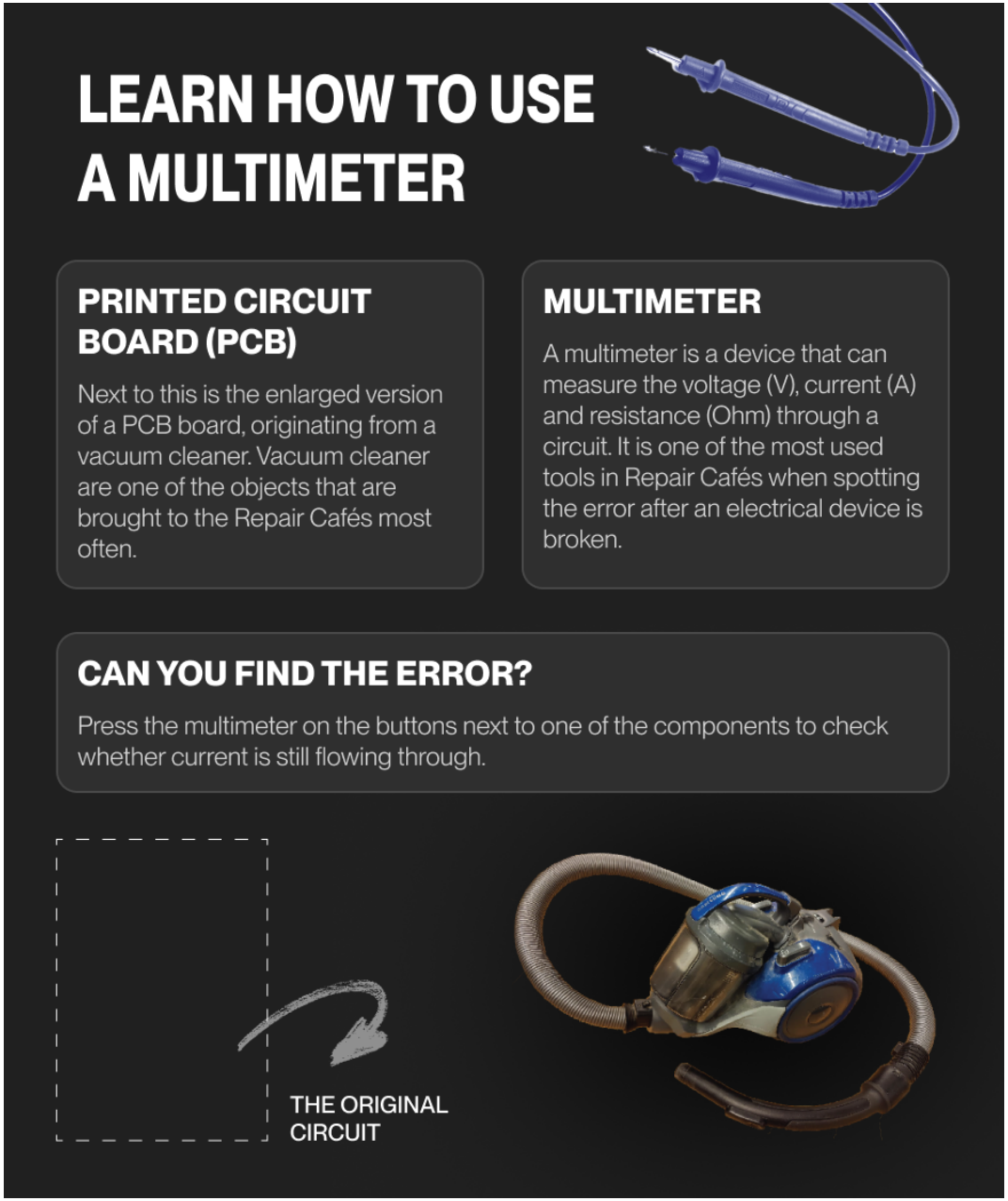


Figure B.5 Demonstrator Poster

ABOUT OUR RESEARCH METHODS

Research Question

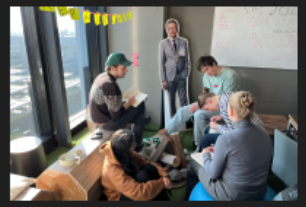
How can we teach how to use a multimeter to show the environmental impact of repairing with the knowledge of Repair Café volunteers?

Observational Studies

Ethnography

Through detailed observations at various Repair Cafés, we documented the practices and techniques used by volunteers to repair electronics. This method provided deep insights into the repair process and the cultural significance of these community-driven repair initiatives.

Carousel



In a controlled setting, students were tasked with opening and examining broken objects to identify faults. This exercise highlighted common obstacles and knowledge gaps, providing valuable feedback for refining our educational prototype.

Experiments

By disassembling a citromatic and a printer ourselves, we identified common challenges and complexities in the repair process. These hands-on experiments informed our understanding of the practical difficulties faced during repairs and helped shape our instructional approach.

Literature Research

Paper Studies

We reviewed various studies on the environmental impacts of e-waste to highlight the benefits of repair over disposal. These studies helped quantify the resource savings and reduced emissions associated with repairing electronic devices.

Book by Martine Postma

We studied Martine Postema's book on Repair Cafés to understand the origins, goals, and impact of the Repair Café movement. This provided a foundational context for our project and insights into the importance of repair culture.

Research Through Design

Midterm Demo Day

We presented our initial prototype during the midterm demo day, gathering valuable feedback from peers and instructors. This event helped us identify strengths and areas for improvement in our design.

Iterations 1 & 2

In the first and second iterations, we conducted user testing to evaluate the usability and effectiveness of our prototype. Feedback from these tests guided significant refinements and enhanced the user experience.

Iteration 3

Based on insights from previous iterations, we developed a refined and final prototype. This version incorporated all the improvements and was designed to be both educational and engaging, effectively teaching repair skills and highlighting environmental impacts.

Interview

Repair café volunteer

We conducted interviews with Repair Café volunteers to gain insights into their repair techniques and experiences. These conversations provided practical knowledge that informed the development of our educational prototype.

Figure B.6 Demo Day Research Poster

THE CONCEPT

Repair Cafés are free meeting places where visitors bring their broken items from home to repair them with volunteer experts.

If you have nothing to repair, you can enjoy a cup of tea or coffee. Or you can lend a hand with someone else's repair job.

POPULAR BROKEN OBJECTS

- Toasters
- Coffee Machines
- Vacuum Cleaners
- Lamp
- Video Player
- Mixer

THE VISITORS

Mainly attended by seniors, where we noticed one teenager with a complex item to fix, some headphones.

THE VOLUNTEERS

- Mostly retired people
- Repairers with a background or interest in repairing
- They enjoy helping people and think it is a good initiative
- They enjoy the company

ABOUT REPAIR CAFES

BY AYDIN GENCHSOY SUUS VAN GOGH MIKE ROELOFS LOT VOGELS

WHY DO PEOPLE NOT REPAIR?

- Scared of damaging the object even further
- Not having any knowledge about electronic circuits
- Intimidated by the complexity of some objects
- Not motivated to repair
  - Takes time and effort and does not always guarantee success
- Not knowing how to find the problem
- Rather buy a brand new object

REPAIR STRUGGLES

- Not knowing where the problem is
- Lots of wires and screws
- Everything is bunched together
- Putting the components back in the correct spot

THE PRACTICES

Use a multimeter to check all components for errors, inspect for any broken connections, and clean any dirty parts that might cause issues.

Figure B.7 Midterm Demo Day Poster

APPENDIX C.
REPAIR CAFÉ VISIT

Questions to ask at the repair café:

- What type of people would visit the event?
- What is the background of the volunteers? What did they study?

The men that helped us studied something like electrical engineering.
Another volunteer studied industrial design.
All volunteers have a technical background.

- Where did they work?

After studying electricial engineering he decided to do a job in the management sector.

- How did they end up as a volunteer at the repair café?
- What products do people bring in most often?

observation: there were a lot of different objects. Almost all of them were electrical objects. For example, a drill and a vacuum cleaner.

- What type of people visit the repair café?

Most of them are elderly. However, not that many people know about repair cafés.

- What are their thought process of repairing anything
- How do they approach a product they are not familiar with?
- How do they spot the error?

They open up the object and use a multimeter to check the voltage at multiple parts.

- Tips & Tricks?
- Are people bringing stuff open to learn about repairing?

Yes most of them are. However, not everyone knows that the idea is really to repair it together. They really tried to explain every step and let us do things ourselves.

- If volunteer works there for a longer period: Do you see a increase or decrease in people visiting the repair café? If yes: What do you think is the reason behind it.

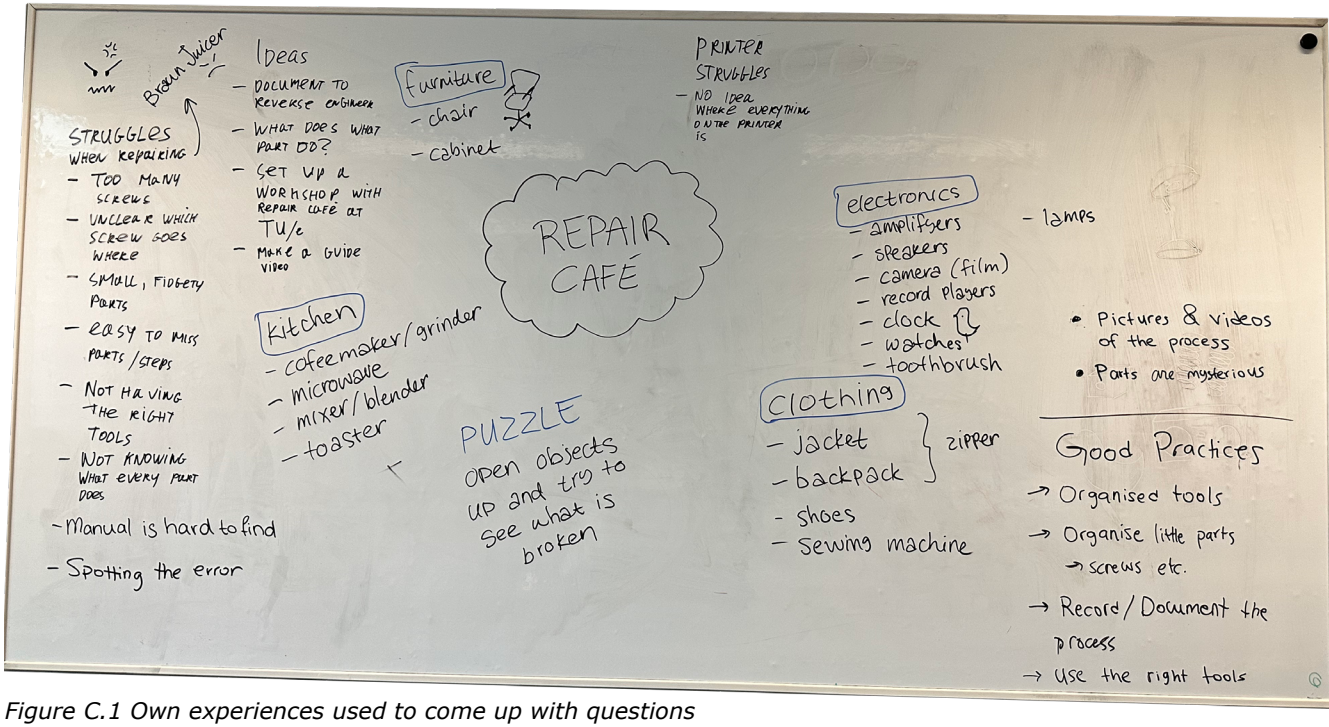


Figure C.1 Own experiences used to come up with questions

APPENDIX D.
OBSERVATIONAL RESEARCH

Opening up the Braun Citromatic ourselves:

Table D.1 Observations while opening up the Braun Citromatic

Idea	Comment
lots of screws	
wires connected to many parts was annoying to handle	
if we didn't make any pictures we wouldn't be able to put it back together	
very dirty from the inside	the dirt could have caused the problem, so try cleaning next time.
parts where squized in the body of the juicer so it was hard to reach certain parts	

Carousel Printer:

Table D.2 Observations during the carousel of the printer

Idea	Quotation
some devices are more complicated than others, making repairing even harder	"Printers seem to complicated to open up"
There are a lot of drawers and buttons which makes it hard to find the right compartments.	
Feedback of sounds was used a lot of times	
lots of trial and error	"lets try printing again, see if it works now"

Carousel printer:

Steps taken:

- try to plug it in
- Pay attention to feedback (sounds and visuals)
- Trying multiple buttons and features
- Try to turn it on/off again
- A lot of drawers and buttons → hard to find the place where to put paper in

- Try to print something but it does not work
- Try to open up multiple drawers and listen to sounds
- Based on feedback trying to figure out the problem
  - Copy was not printed correctly
  - Inked not good: opening it up
  - Instructions of the printer are not clear

Next steps:

- New cartridges? → expensive
  - Buying a new printer might be cheaper
- Try to fix it at a printshop

One of the participants mentioned that he normally does not open objects up to try to fix them but buys a new one instead. If he does open something up, he can not find the problem.

The other participant mentioned that he tries to fix objects such as coffee machines, computers, speakers, washing machines, mice, and keyboards. However, he thinks a printer is too complex.

Carousel Citromatic:

- People are scared to break broken object even more then they already are
- When an object is that broken that even more damage wouldnt be of any significance then they wouldnt have that fear of breaking it even more and would try to repair the object.

APPENDIX E.
REPAIR CAFÉ VISITS ETHNOGRAPHY

Table E.1 Ethnography of Repair Café

Idea	Comment
the volunteers have a background in engineering.	The volunteer studied something like electrical engineering. Another volunteer studied industrial design.
Most objects were electrical.	the most commonly brought objects were household electronics, such as coffee machines, vacuum cleaners,etc. This is likely because people do not understand how these should be repaired.
Most people visiting the repair café are elderly.	Most of them are 40+ and live in the neighborhood of the repair café. Most of them read about it in the newsletter of their neighborhood.
They open up the object and use a multimeter to check the voltage at multiple parts.	By checking if current runs through different parts of the device, the repairer is able to see where the problem is. If current is running through a part, then it is likely still functional.
Not all visitors know the principle is to repair it together.	A volunteer in the repair cafe in Acht told us some people want to drop the object of and pick it up again when it is finished but that is not the idea of the repair cafe, they would redirect these people to other companies who do offer this service. For many elderly people it is hard to understand all the mechanics and electrical parts that is why they often watch and chat with the repairers.
Both repair cafés explained all steps.	At one of them you could help with opening the device. Volunteers at the repair café are used to doing the repair for the people bringing in an object so they just start working on repairing and taking you through the steps via speech. However, when asked they would let you help them figure it out togheter.
wd40 was used for the contact points at the blanket and the citromatic	At the repair cafe in Acht the volunteer was looking for broken connections or spots with lots of debree, WD40 was often the solution for parts that needed a bit of cleaning which help fix the problem.
Vacuum cleaners are brought in a lot	Most of the times the cable is broken or the filter is filthy. These can both be easily fixed
While repairing the citromatic, audio feedback was used from the object	
Not all screws are the same, requiring different tools	the repair café volunteer stated that he wished all screws in a device would be the same, because he now needed to use different screwdrivers to open the device up and screw them back together

APPENDIX F.
INTERVIEW REPAIR CAFÉ VOLUNTEER

Questions:

Algemene vragen:
- Komen mensen naar repair cafés om te leren hoe ze zelf iets kunnen repareren?
- Speelt de zorg om het milieu een rol bij de beslissing om het Repair Café te bezoeken? Of is het meer financieel gerelateerd?
- Wat vind je lastig om mensen te leren over repareren?
- Welke aspecten van repareren vinden mensen het lastigste om te begrijpen?
- Merk je dat mensen "bang" zijn voor electronica?
- Merk je dat mensen niet begrijpen hoe electronica werken? Bijvoorbeeld hoe stroom werkt? Of een multimeter?

Stofzuigers:
- Voor ons project hebben we besloten om te focussen op stofzuigers.
-
- Welke componenten van stofzuigers moeten het vaakst gerepareerd worden?
- Zijn stofzuigers meestal repareerbaar?
- Zijn er struggles met het uitleggen van hoe je een stofzuiger repareerd?
- Zijn verschillende stofzuigers erg verschillend van binnen (qua electronica) of zijn ze vergelijkbaar?

Concept:
Een interactief systeem waarin het circuit van een stofzuiger wordt getoond. Op het circuit staan interactieve fysieke elementen die de electronische componenten van het circuit representeren. De stroom die door het circuit loopt wordt gerepresenteerd door water.

- Verwacht je dat mensen een elektronisch circuit begrijpen na het zien van een visuele representatie?
- Wat vind je van het gebruik van water als representatie van stroom?

Concept:
De installatie is een extra grote, vereenvoudigde weergave van een circuit waarmee deelnemers een interactie kunnen aangaan. Het centrale punt van de installatie is de multimeter, aangezien wij constateerden dat dit object een veelgebruikt instrument is in reparatiecafés.

Wat willen wij meenemen in de installatie:
- Weergave van een multimeter: een centraal onderdeel van de tentoonstelling. Deze tool begeleidt bezoekers bij het diagnosticeren en repareren van veelvoorkomende circuitfouten.
- Fysieke componenten: extra grote objecten van een typisch elektronisch apparaat (stofzuiger), elk object vertegenwoordigt een ander onderdeel van een circuit (bijvoorbeeld weerstanden, condensatoren).
- Verhaal over ecologische duurzaamheid: een afvalberg die tijdens het repareren steeds kleiner wordt. Bovendien, start er na het voltooien van de reparatie een video die laat zien welke impact je hiermee gemaakt hebt.

- Wat denken jullie van dit concept?
- Denk je dat dit mensen helpt om te begrijpen hoe ze een kapot apparaat moeten repareren?
- Als jullie toegang zouden hebben op zo'n installatie zouden jullie dit dan kunnen/willen gebruiken in het repair cafe om mensen te helpen met uitleggen?
- Wat zouden de pluspunten zijn van deze installatie in een repair cafe?

Answers:

- De frustratie van het repair café is dat producten niet zo zijn ontworpen dat het makkelijk te repareren is.
- De bezoekers komen niet om te leren, ze kunnen niet samen repareren.
- Het weggooien van producten is zonde, en er hangen vaak financiële/emotionele waarden aan.
- Het is vaak lastig om electronica uit te leggen terwijl je bezig bent.
- De meest voorkomende problemen bij een stofzuiger zijn kabelbreuk, het oprolmechanisme dat breekt of de motor. Dit allemaal is repareerbaar.
- Mechanica is ook moeilijk om uit te leggen.
- Bij kabelbreuk; knip een stuk eraf en zet de stekker er weer aan.
- Je kunt een omleiding maken in electronica als die kapot is. je zet hem dan permanent op stand maximaal.
- Design van stofzuigers is onvriendelijk en moeilijk zelf te repareren.
- Ze verwachten dat het water concept niet effectief is.
- De multimeter is waarschijnlijk te moeilijk voor mensen.
- Fabrikanten moeten nadruk leggen op onderhoudbaarheid van producten.

Consent form:

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Informatieblad voor onderzoek "Repair Cafés"

1. Inleiding

U bent gevraagd om deel te nemen aan het onderzoek "Repair Cafés", omdat u actief bent bij een of meerdere repair cafés in Eindhoven.

Deelname aan dit onderzoek is vrijwillig: u besluit zelf of u mee wilt doen. Voordat u besluit tot deelname, willen wij u vragen de volgende informatie door te lezen, zodat u weet waar het onderzoek over gaat en wat er van u verwacht wordt. Op basis van die informatie kunt u middels de toestemmingsverklaring aangeven of u toestemt met deelname aan het onderzoek.

U bent natuurlijk altijd vrij om vragen te stellen aan de onderzoeksleider via s.m.c.v.gogh@student.tue.nl, of deze informatie te bespreken met voor u bekenden.

2. Doel van het onderzoek

Dit onderzoek wordt geleid door Suus van Gogh.
Het doel van dit onderzoek is om inzichten te krijgen in hoe vrijwilligers in repair cafés bezoekers helpen om meer te leren over repareren. Bovendien, willen we feedback over een concept dat hier aan bij zou kunnen dragen.

3. Wat houdt deelname aan de studie in?

U neemt deel aan een onderzoek waarbij we informatie zullen verzamelen door: een interview.

Wij vragen u 1 keer op locatie te komen zodat wij u kunnen interviewen over repair cafés.

- U te interviewen over repair café handelingen, reparaties van stofzuigers en een design concept en uw antwoorden te noteren

Dit onderzoek geschiedt volledig anoniem, en de uit het onderzoek verkregen gegevens zullen niet tot u herleidbaar zijn.

U ontvangt voor deelname aan dit onderzoek geen vergoeding.

4. Potentiële risico's en ongemakken en intrekken van toestemming

Er zijn geen fysieke, juridische of economische risico's verbonden aan uw deelname aan deze studie. U hoeft geen vragen te beantwoorden die u niet wilt beantwoorden. Uw deelname is vrijwillig. Dit betekent dat u uw deelname op elk gewenst moment mag stoppen door dit te melden bij de onderzoeker. U hoeft niet uit te leggen waarom u wilt stoppen met deelname aan het onderzoek. Het stopzetten van deelname heeft geen nadelige gevolgen voor u.

Als u tijdens het onderzoek besluit om uw medewerking te staken, zullen de gegevens die u reeds hebt verstrekt tot het moment van intrekking van de toestemming in het onderzoek gebruikt worden.
Wilt u stoppen met het onderzoek, of heeft u vragen en/of klachten? Neem dan contact op met de onderzoeksleider via s.m.c.v.gogh@student.tue.nl.

5. Vertrouwelijkheid van gegevens

De ruwe en bewerkte onderzoeksgegevens worden bewaard tot juli 2024. Uiterlijk na het verstrijken van deze termijn zullen de gegevens worden verwijderd. De onderzoeksgegevens worden indien nodig (bijvoorbeeld voor een controle op wetenschappelijke integriteit) en alleen in anonieme vorm ter beschikking gesteld aan personen buiten de onderzoeksgroep.

Dit onderzoek is beoordeeld en goedgekeurd op 20-10-2023 door de ethische toetsingscommissie van de Technische Universiteit Eindhoven.

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Toestemmingsformulier voor deelname volwassene

Door dit toestemmingsformulier te ondertekenen erken ik het volgende:

1. Ik ben voldoende geïnformeerd over het onderzoek door middel van een separaat informatieblad. Ik heb het informatieblad gelezen en heb daarna de mogelijkheid gehad vragen te kunnen stellen. Deze vragen zijn voldoende beantwoord.

2. Ik neem vrijwillig deel aan dit onderzoek. Er is geen expliciete of impliciete dwang voor mij om aan dit onderzoek deel te nemen. Het is mij duidelijk dat ik deelname aan het onderzoek op elk moment, zonder opgaaf van reden, kan beëindigen. Ik hoef een vraag niet te beantwoorden als ik dat niet wil.

Naam Deelnemer:

Handtekening:

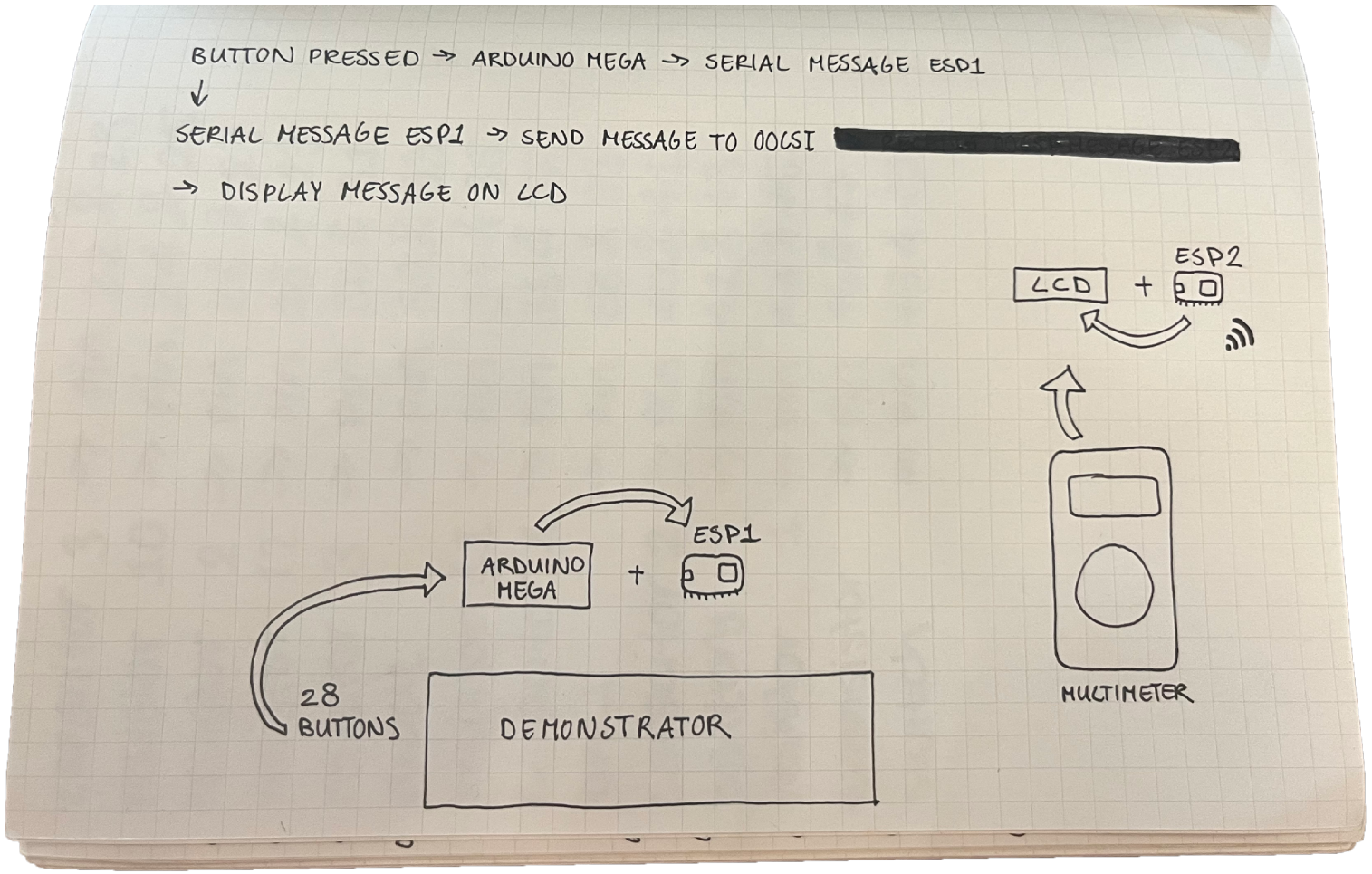
Datum:

Naam Onderzoeker:

Handtekening:

Datum:

APPENDIX G.
CODE



ARDUINO_SERIAL_READ

```
#include <SoftwareSerial.h>

SoftwareSerial SUART(3, 2);

void setup()
{
  Serial.begin(9600);
  SUART.begin(9600);
  for (int i = 4; i < 30; i++) {
    pinMode(i, INPUT_PULLUP);
  }
}

void loop() {
  for (int i = 4; i < 30; i++) {
    int buttonState = digitalRead(i);
    // SUART.println(buttonState);

    bool pressed = (buttonState == LOW); // Assuming pressed is LOW, change if r

    if (pressed) {
      String str1 = "B" + String(i) + "_" + "ON";
      SUART.println(str1);
      Serial.println(str1);
    } else {
      String str2 = "B" + String(i) + "_" + "OFF";
      SUART.println(str2);
      Serial.println(str2);
    }

    // SUART.println(pressed);
    delay(50);
  }
  Serial.println("----");
  // delay(1000);
}
```

LCDtoOOCSIcode.ino | LCD.ino | OOCSI_WiFi.ino | processOOCSI.ino

```
#include <OOCSI.h>

OOCSI oocsi;

void setup(){
  setupOOCSI();
  setupLCD();
  processOOCSI();
}

void loop(){
  oocsi.check();
}
```

LCD CODE

LCDtoOOCSIcode.ino | LCD.ino | OOCSI_WiFi.ino | processOOCSI.ino

```ino
#include <OOCSI.h>

OOCSI oocsi;

void setup(){
  setupOOCSI();
  setupLCD();
  processOOCSI();
}

void loop(){
  oocsi.check();
}
```

LCDtoOOCSIcode.ino | LCD.ino | OOCSI_WiFi.ino | processOOCSI.ino

```ino
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

// LCD address and dimensions (change address if necessary)
#define I2C_ADDR    0x27
#define LCD_COLUMNS 16
#define LCD_ROWS    2

// Initialize the LCD
LiquidCrystal_I2C lcd(I2C_ADDR, LCD_COLUMNS, LCD_ROWS);

void setupLCD(){
  // Set up the LCD
  lcd.init();
  lcd.backlight();
  lcd.clear();

  lcd.print("Connecting to Wifi");

  // Initialize serial communication
  Serial.begin(115200);
  Serial.println("Setup LCD ESP");
}
```

LCDtoOOCSIcode.ino | LCD.ino | OOCSI_WiFi.ino ● | processOOCSI.ino

```ino
#include <WiFi.h>
const char* ssid = "iotroam";
const char* password = "V29GlNOcp2";
const char* oocsiServer = "oocsi.id.tue.nl";
const int oocsiPort = 80; // Port for non-secure WebSocket (WS)

// OOCSI channel
const char* channel = "L2C_test";


void setupOOCSI(){
  // Connect to Wi-Fi
  Serial.println("Connecting to WiFi...");
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.println("Connecting to WiFi...");
  }
  Serial.println("Connected to WiFi");

   lcd.print("Connected to Wifi");

  // Initialize OOCSI
  Serial.println("Connecting to OOCSI...");
  oocsi.connect("myLCDDevice", oocsiServer, ssid, password, processOOCSI);

  // Subscribe to the channel
  Serial.println("Subscribing to L2C_test");
  oocsi.subscribe(channel);

  // Allow time for OOCSI to connect
  delay(1000);
}
```

LCDtoOOCSIcode.ino | LCD.ino | OOCSI_WiFi.ino ● | processOOCSI.ino

```ino
void processOOCSI() {
  // Get the message
  String receivedMessage = oocsi.getString("message", "No message");

  // Clear the LCD and display the message
  lcd.clear();
  lcd.print(receivedMessage);

  // Print the message to the serial monitor for debugging
  Serial.print("Received message: ");
  Serial.println(receivedMessage);
}
```

ESP CODE

FINAL_CODE_DEMODAY.ino | OOCSI_WiFi.ino | readSerial.ino | screenDisplay.ino

```ino
#include <SoftwareSerial.h>
#include <OOCSI.h>

const int numButtons = 29;
bool buttonStates[numButtons];

OOCSI oocsi;
EspSoftwareSerial::UART myPort;

String textDisplay;

void setup() {
  Serial.begin(9600);
  myPort.begin(9600, SWSERIAL_8N1, 12, 14, false);
  setupOOCSI();

  for (int i = 3; i < numButtons; i++) {
    buttonStates[i] = false;
  }
}

// Main loop to read serial data and send OOCSI messages
void loop() {

  readSerial();
  screenDisplay();

  // Check OOCSI messages
  oocsi.check();

}
```

FINAL_CODE_DEMODAY.ino | OOCSI_WiFi.ino | readSerial.ino | screenDisplay.ino

```ino
#include <WiFi.h>

// Wi-Fi credentials
const char* ssid = "iotroam";
const char* password = "31pPvp9JvO";

// OOCSI credentials
const char* oocsiServer = "oocsi.id.tue.nl";
const char* oocsiName = "RC2_Button";
const char* oocsiChannel = "L2C_test";

// Function to setup OOCSI communication
void setupOOCSI() {
  // Connect to Wi-Fi
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.println("Connecting to WiFi...");
  }
  Serial.println("Connected to WiFi");
  Serial.println(WiFi.macAddress());

  // Connect to OOCSI server
  oocsi.connect(oocsiName, oocsiServer, ssid, password);
}
```

ESP CODE

FINAL_CODE_DEMODAY.ino | OOCSI_WiFi.ino | readSerial.ino | screenDisplay.ino

```
void readSerial() {
  String input;
  if (myPort.available()) {
    input = myPort.readStringUntil('\n');  // Read the input from Serial2 until
    // Serial.println("input is: " + input);
    input.trim();  // Remove any leading or trailing whitespace

    int index_input = input.indexOf('_');
    String numberStr = input.substring(1, index_input);
    String status = input.substring(index_input + 1);

    int index = numberStr.toInt();

    bool isOn = false;

    if (index < numButtons) {
      if (status == "ON") {
        buttonStates[index] = true;
        Serial.println("Buttonstates updated");
      } else if (status == "OFF") {
        buttonStates[index] = false;
        Serial.println("Buttonstates updated (2) ");

      } else {
        buttonStates[index] = false;
        Serial.println("Buttonstates updated (3) ");
      }
    }
  }
}
```

FINAL_CODE_DEMODAY.ino | OOCSI_WiFi.ino | readSerial.ino | screenDisplay.ino

```
void screenDisplay() {

// capacitor 10
  if ((buttonStates[22] == true) && (buttonStates[23] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "1 A").sendMessage();
  } else if ((buttonStates[22] == true) && (buttonStates[23] == false)) {
    oocsi.newMessage(oocsiChannel).addString("message", "1 A").sendMessage();
  } else if ((buttonStates[22] == false) && (buttonStates[23] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "1 A").sendMessage();
  }
// resistor 10
  if ((buttonStates[24] == true) && (buttonStates[25] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0.5 A").sendMessage();
  } else if ((buttonStates[24] == true) && (buttonStates[25] == false)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0.5 A").sendMessage();
  } else if ((buttonStates[24] == false) && (buttonStates[25] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0.5 A").sendMessage();
  }
// resistor 2
  if ((buttonStates[26] == true) && (buttonStates[27] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "1.4 A").sendMessage();
  } else if ((buttonStates[26] == true) && (buttonStates[27] == false)) {
    oocsi.newMessage(oocsiChannel).addString("message", "1.4 A").sendMessage();
  } else if ((buttonStates[26] == false) && (buttonStates[27] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "1.4 A").sendMessage();
  }
// resistor 12
  if ((buttonStates[28] == true) && (buttonStates[29] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0.7 A").sendMessage();
  } else if ((buttonStates[28] == true) && (buttonStates[29] == false)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0.7 A").sendMessage();
  } else if ((buttonStates[28] == false) && (buttonStates[29] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0.7 A").sendMessage();
  }
```

ESP CODE

FINAL_CODE_DEMODAY.ino | OOCSI_WiFi.ino | readSerial.ino | screenDisplay.ino

```
// resistor 3
  if ((buttonStates[30] == true) && (buttonStates[31] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "1.9 A").sendMessage();
  } else if ((buttonStates[30] == true) && (buttonStates[31] == false)) {
    oocsi.newMessage(oocsiChannel).addString("message", "1.9 A").sendMessage();
  } else if ((buttonStates[30] == false) && (buttonStates[31] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "1.9 A").sendMessage();
  }
// diode
  if ((buttonStates[32] == true) && (buttonStates[33] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0.3 A").sendMessage();
  } else if ((buttonStates[32] == true) && (buttonStates[33] == false)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0.3 A").sendMessage();
  } else if ((buttonStates[32] == false) && (buttonStates[33] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0.3 A").sendMessage();
  }
// resitor 11
  if ((buttonStates[34] == true) && (buttonStates[35] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "1.1 A").sendMessage();
  } else if ((buttonStates[34] == true) && (buttonStates[35] == false)) {
    oocsi.newMessage(oocsiChannel).addString("message", "1.1 A").sendMessage();
  } else if ((buttonStates[34] == false) && (buttonStates[35] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "1.1 A").sendMessage();
  }
// capacitor 1
  if ((buttonStates[36] == true) && (buttonStates[37] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0.5 A").sendMessage();
  } else if ((buttonStates[36] == true) && (buttonStates[37] == false)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0.5 A").sendMessage();
  } else if ((buttonStates[36] == false) && (buttonStates[37] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0.5 A").sendMessage();
  }
```

FINAL_CODE_DEMODAY.ino | OOCSI_WiFi.ino | readSerial.ino | screenDisplay.ino

```
// DAC1
  if ((buttonStates[38] == true) && (buttonStates[39] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0.4 A").sendMessage();
  } else if ((buttonStates[38] == true) && (buttonStates[39] == false)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0.4 A").sendMessage();
  } else if ((buttonStates[38] == false) && (buttonStates[39] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0.4 A").sendMessage();
  }
// capacitor 2
  if ((buttonStates[40] == true) && (buttonStates[41] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0").sendMessage();
  } else if ((buttonStates[40] == true) && (buttonStates[41] == false)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0").sendMessage();
  } else if ((buttonStates[40] == false) && (buttonStates[41] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0").sendMessage();
  }
// battery
  if ((buttonStates[42] == true) && (buttonStates[43] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "3 A").sendMessage();
  } else if ((buttonStates[42] == true) && (buttonStates[43] == false)) {
    oocsi.newMessage(oocsiChannel).addString("message", "3 A").sendMessage();
  } else if ((buttonStates[42] == false) && (buttonStates[43] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "3 A").sendMessage();
  }

// resistor 1
  if ((buttonStates[44] == true) && (buttonStates[45] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0").sendMessage();
  } else if ((buttonStates[44] == true) && (buttonStates[45] == false)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0").sendMessage();
  } else if ((buttonStates[44] == false) && (buttonStates[45] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0").sendMessage();
  }
// transistor
  if ((buttonStates[46] == true) && (buttonStates[47] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0.5 A").sendMessage();
  } else if ((buttonStates[46] == true) && (buttonStates[47] == false)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0.5 A").sendMessage();
  } else if ((buttonStates[46] == false) && (buttonStates[47] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "0.5 A").sendMessage();
  }
// switch
  if ((buttonStates[48] == true) && (buttonStates[49] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "3 A").sendMessage();
  } else if ((buttonStates[48] == true) && (buttonStates[49] == false)) {
    oocsi.newMessage(oocsiChannel).addString("message", "3 A").sendMessage();
  } else if ((buttonStates[48] == false) && (buttonStates[49] == true)) {
    oocsi.newMessage(oocsiChannel).addString("message", "3 A").sendMessage();
  }
}
```