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Master's Thesis
Academic Year 2024

Tsugi: Exploring the Interactions among Humans, Artefacts, and the Environment through Repair

Keio University
Graduate School of Media Design

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A Master's Thesis
submitted to Keio University Graduate School of Media Design
in partial fulfillment of the requirements for the degree of
Master of Media Design

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Abstract of Master's Thesis of Academic Year 2024

Tsugi: Exploring the Interactions among Humans, Artefacts, and the Environment through Repair

Category: Design

Summary

This research will focus on exploring the possible interaction among humans, artefacts and the environment so that people's right to repair can be enhanced. Repair is often considered a sustainable approach to expanding products' lifespan or enforcing the emotional attachment towards the artefacts. However, in this research, repair is mainly treated as a dynamic process that negotiates at various levels so that the artefacts can be contingently stable within their ecology. By conducting a literature review, auto-ethnography, ethnography, workshop, and survey, a wide range of insights towards repair experience was collected, and the current design for repair principles was examined. This would inform a potential design guideline that not only focuses on product design but also considers the collective system of repair, such as the life cycle and context of products, from the aspect of designing a better repair experience, which would also enhance people's right to repair.

Keywords:

repair, right to repair, design for repair, repair experience, human artefact interaction

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Chapter 1
Introduction

1.1. Research Background

In recent years, sustainability has emerged as a critical global concern, prompting a renewed focus on the lifecycle of products. The "right to repair" movement has gained momentum, particularly in European countries, advocating for consumers' ability to repair their devices [1]. This shift in focus has led to a transition from eco-design, which primarily considers environmental impact during the production phase, to a circular economy approach that emphasizes the entire lifecycle of a product, including repair and reuse [2].

A notable example of industry engagement with sustainability demonstrates the growing industry interest in sustainable practices. Take the fashion industry as an example, Zara recently introduced "Home Repair," a program aimed at empowering consumers to repair their clothing through sharing several videos of mending clothes at home [3]. UNIQLO also launched RE.UNIQLO Studio as a sustainable approach, which offers a variety of clothing repair and recycling services in stores, such as mending, embroidery, and sashiko [4]. Similarly, Patagonia has pioneered various initiatives, such as the mail-in repair service, DIY repair and care guides, and the Worn Wear program, which encourages repair and reuse which extends the lifespan of its products [5].

However, traditional design practices often prioritize novelty and planned obsolescence, leading to the premature disposal of perfectly functional products. As Shedroff [6] points out, designers are frequently taught to create new products, even when existing ones are still viable. This approach, coupled with the intentional design of products to fail, as explored in Slade's [7] book "Made to Break," perpetuates a culture of consumption and waste. Moreover, the design of products can limit repair possibilities [8].

The resistance to accessible and affordable repair is understandable from a business perspective, as Perzanowski [9] highlights in the book "Right to Repair," the potential threat that accessible and affordable repair poses to the business models of many consumer goods companies. These companies often rely on short product lifespans to drive sales and profits. To counteract this, Munten et al. [10] suggest that manufacturers can leverage product repairability as a positive brand attribute, particularly when perceived product reliability is low.

From a perspective of empowering individuals to challenge consumerist norms, by engaging in repair practices, individuals can not only extend the lifespan of their products but also foster a sense of community and environmental responsibility. Houston [8] argues that repair can address concerns about alienation from technology, wasteful consumption, and environmental damage.

In light of these complex factors, understanding the relationships between design, repair, and consumer behaviour is essential. Developing practical guidelines for designing better repair experiences can contribute to a more sustainable future, empowering consumers to make informed choices and prolong the life of their products.

1.2. Research Objective

This research aims to contribute to the field of design for repair by shifting the focus from traditional aspects such as product design, sustainability, and emotional attachment to a more holistic approach that centres on human-artefact interaction. By delving into the dynamics of this interaction, this research seeks to improve the right to repair and enhance the overall repair experience.

To achieve this objective, the following research questions will be addressed:

- How do humans and artefacts interact in the repair process?
  - This question seeks to understand the cognitive, physical, and emotional factors that influence the repair process by mapping out the relationship and interactions of human-artefact.
  - It aims to identify the challenges and opportunities that arise from the interaction between humans and artefacts during repair.

  - The finding of this question would become the foundation of the updated version Design for Repair guideline.

- From a designer's perspective, does the guideline of Design for Better Repair Experience help design a more repairable product?
  - This question explores the role of design in shaping the repair experience.
  - It aims to identify design limitations, strategies and possibilities that can enhance the accessibility, affordability, and satisfaction of repair.

- From a user perspective, does the design example of the guideline which considers the repair experience make people more willing to repair?
  - This question investigates the impact of the design example of the Design for Better Repair Experience guideline on user behaviour and attitudes towards repair.
  - It aims to determine whether the relevant design interventions can motivate people to choose repair over replacement.

By addressing these research questions, this study will contribute to a deeper understanding of the human-artefact relationship in the context of repair and provide valuable insights for designers, manufacturers, and policymakers. Ultimately, this research seeks to foster a more repair-oriented society by promoting a design approach that prioritises the repair experience.

1.3. Research Methodology

This research employs a mixed-methods approach, combining both qualitative and quantitative research methods to gain a comprehensive understanding of repair experiences and to develop an updated framework for Design for Repair. In terms of data collection, the research will be done as follows:

- Literature Review: A comprehensive review of existing literature on repair, including academic articles, industry reports, and design guidelines, will be conducted to establish a theoretical foundation.

- Auto-Ethnography: The researcher will document their personal experiences with repair, including challenges, successes, and emotional responses. This will provide first-hand insights into the repair process.

- Ethnographic Study: An ethnographic study will be conducted within a repair community to observe and document the social and cultural aspects of repair. This will involve participant observation, interviews, and artefact analysis.

- Creative Repair Workshop: A workshop will be organized to encourage participants to engage in creative repair activities. This will provide opportunities to observe and document innovative approaches to repair.

- User Survey: A survey will be administered to a diverse group of participants to gather quantitative data on their repair experiences, attitudes, and preferences.

To analyse the collected data and gain useful insight, the following methodology will be used:

- Thematic Analysis: Qualitative data from auto-ethnography, ethnographic study, and workshop observations will be analysed using thematic analysis to identify recurring themes and patterns.

- Quantitative Analysis: Quantitative data from the user survey will be analysed using statistical methods to identify trends and correlations.

Based on the insights gained from the data analysis, a new framework for Design for Repair will be developed. This framework will focus on the human-artefact interaction aspects of repair, considering the entire lifecycle of a product, from design to disposal, to create a better repair experience. The updated design for repair will be examined by designer interviews, and Designers will be interviewed to evaluate the effectiveness of the Design for Repair principles in guiding the redesign process and to identify any challenges or limitations. On the other hand, a case study involving the redesign of a fan will be conducted to illustrate the application of the new Design for Repair framework. The redesigned fan will be evaluated through User Interviews, and users will be interviewed to assess their

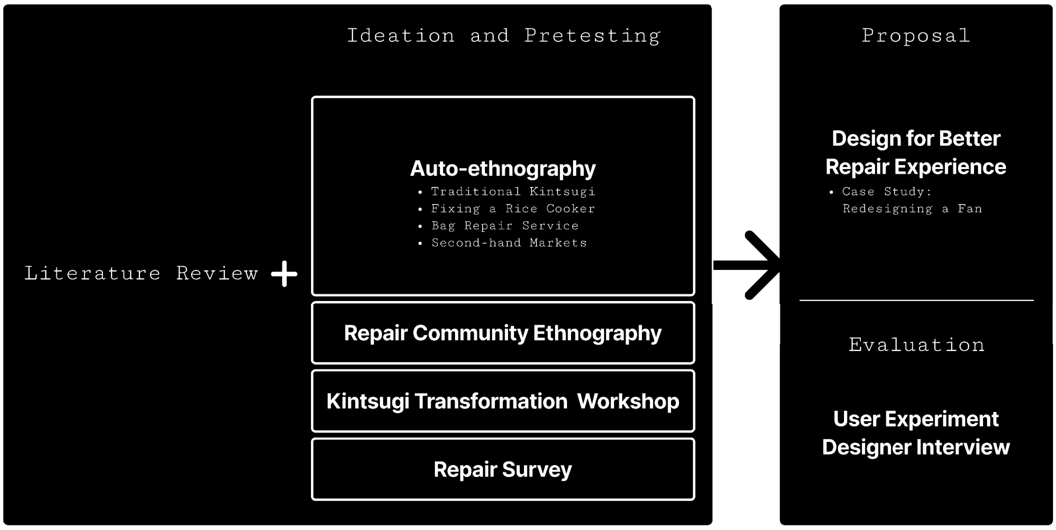


Figure 1.1 Thesis Structure

experiences with the redesigned fan, including ease of repair, perceived quality, and overall satisfaction.

By combining these research methods, this study aims to provide a comprehensive understanding of repair experiences and to develop a practical framework for designing products that are more repairable and sustainable.

1.4. Thesis Structure

This thesis (Figure 1.1) investigates the human-artefact interaction within the context of repair, aiming to improve the right to repair through a more holistic approach to design. By focusing on the repair experience, this research seeks to develop a framework for Design for a Better Repair Experience.

Chapter 2: Literature Review and Related Works

This chapter establishes the theoretical foundation for the research. It explores the concept of repair, the human-artefact interaction during repair, and the factors influencing repairability. Additionally, it delves into the field of Design for Repair, reviewing existing frameworks and methodologies.

Chapter 3: Design Process

This chapter outlines the design process employed in this research. It begins with a series of exploratory studies, including auto-ethnography, a Kintsugi Transformation workshop, an ethnographic observation of a repair community, and a user survey. These studies provide insights into the motivations, challenges, and experiences of repair. Based on these findings, a new framework for Design for Repair is developed, emphasizing the importance of the repair experience. A case study involving the redesign of a fan demonstrates the application of this framework.

Chapter 4: Evaluation and Results

This chapter presents the results of the prototype testing, including user experiments and expert interviews. The user experiments evaluate the impact of the redesigned fan on user experience, while the expert interviews assess the effectiveness of the proposed Design for Repair principles.

Chapter 5: Discussion and Conclusion

This chapter discusses the implications of the research findings, highlighting the potential to improve people's right to repair through a more human-centred approach to design. It also acknowledges the limitations of the study and suggests directions for future research.

By combining theoretical analysis, empirical research, and design practice, this thesis contributes to a deeper understanding of the human-artefact relationship in the context of repair and provides practical insights for designers, manufacturers, and policymakers.

Chapter 2
Literature Review and Related Works

2.1. What is Repair?

According to the Cambridge Dictionary, Repair is "to put something that is damaged, broken, or not working correctly, back into good condition or make it work again" [11] (Figure 2.1). However, the definition of repair and its differentiation between repurposing and upcycling are hard to define because of the diverse context. To better clarify the terminology, we first need to understand the interactions between humans and artefacts which lead to breakage and repair.

2.1.1 Human-Artefact Interaction through Repair

The Human-Artifact Model [12] and artefact ecologies dynamics [13]were one of the aspects used to illustrate the complex interactions not only between humans and artefacts but also between artefacts and artefacts. There are three stages, stable, unsatisfactory, and excited, within the artefact ecology, which indicates the over time changing relationship of artefacts [13]. In the stable stage, the artefacts are fitted into the ecology and explored for possible usage. If tensions are caused due to the mismatched expectations of motivation and function, the ecology would develop into the unsatisfactory stage, which would eventually evolve to the excited stage, while a new artefact is added, and the artefact would be explored with all levels of activities development [13]. While the tensions within the ecology are not always associated with physical damage, the model can help us visualize interactions at both macro and micro levels, especially when considering the various strategies for addressing system damage, such as reliability, redundancy, repair, or replacement [14]. The tensions caused by breakage and its

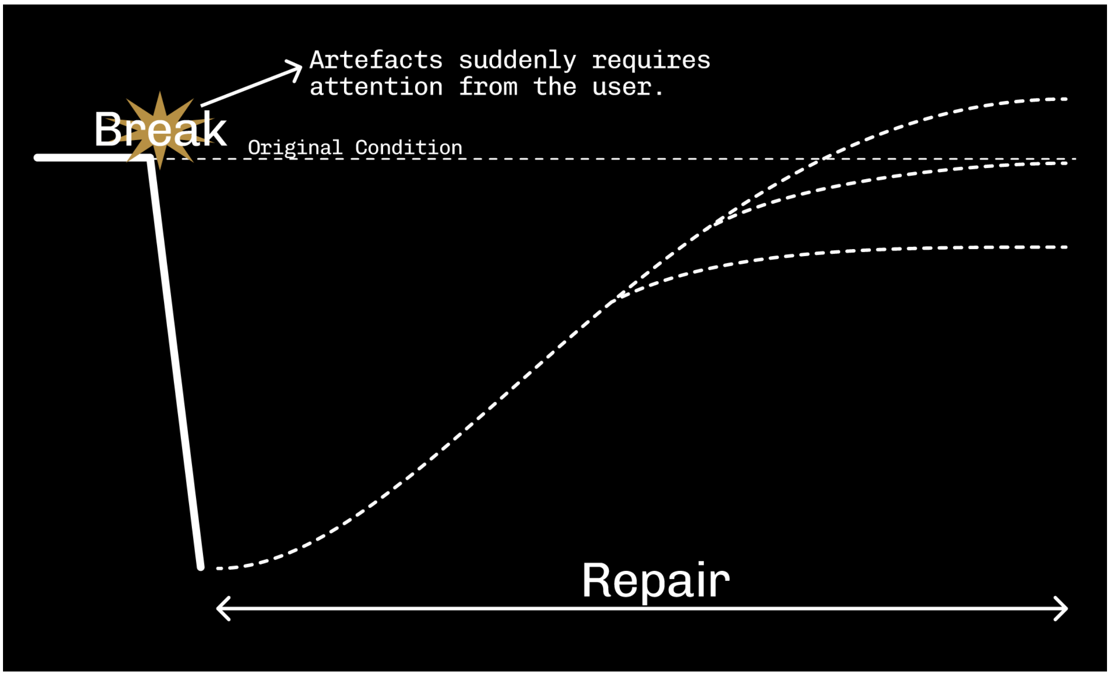


Figure 2.1 The artefacts' condition before and after repair.

relevant repair activities keep the artefact in the ecology could be spotted in both the macroscopic scale, which is the interactions and relationships between artefacts, and the microscopic scales, which are inside the artefacts between parts and parts. The "double dance of agency" [15] describes the intricate relationship between humans and machines, which could also be applied to humans and artefacts. Both possess agency, meaning they can independently act, make decisions, and influence their environment. Importantly, their agency is interconnected. Human actions determine how machines function, while machine actions in turn shape human behaviour and choices. This dynamic interaction is constantly evolving, with both humans and machines adapting and learning from each other over time. From the human perspective, when a ready-to-hand artefact breaks, it suddenly requires attention [16] because of the sudden increase in friction and people would confront the *thingness* of the artefact, since the relation between human and artefact changes momentarily [17]. Then, a decision of repairing or not would be made by the human [18]-normally by a consumer [19]-based on the use value, the assertion of the good's value under the human needs [20]. In other words, if peo-

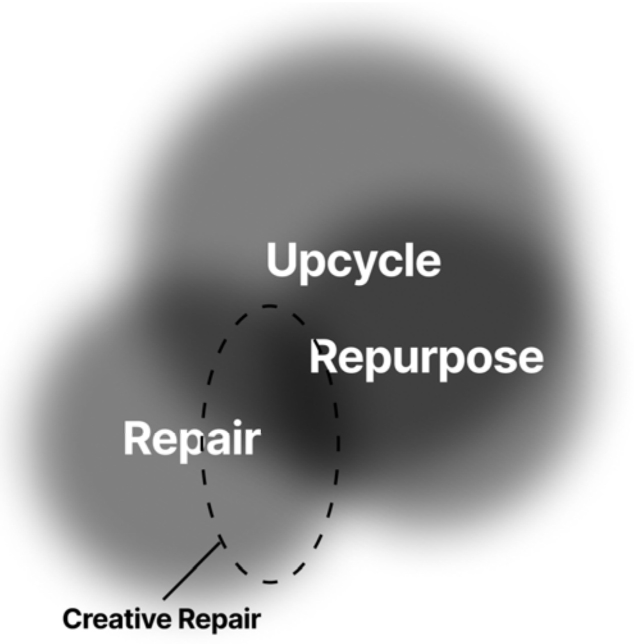


Figure 2.2 The diagram of repair, upcycle and repurpose

ple have concerns about slowing down the new resource usage and allowing more resource recreation time, repair is the strategy for recovering product value [19] and contributing to the ecology of care [21].

The repair activity not only refers to the mending or reconditioning of an artefact to restore its form or function [9] but also an act of creativity [22], an extension of making or a form of design-in-use [23], which explore the alternative use of technology or artefact. Since repair does not have to be an exact restoration, which means that the outcome could be variate, improvisation and innovation [24]. Hence, some of them could also be upcycling or repurposing (Figure 2.2), due to the increasing value or the change of main function after repair [25]. Therefore, repair could also be likened to Ingold's Making as a process of becoming [26], or Freud's notion of a death instinct [24], that an artefact would never finish repairing, and repair should be considered as an ongoing process, which includes patching, reconfiguring, interpolating and reassembling the setting from previously existing forms [27].

On the other hand, sharing the same aspect with making as the dynamic interplay between humans and materials. [26], repair is also a social practice that builds valuable skills, such as analytic reasoning, strategic thinking, and creativity [9], since disconnection produces learning, adaptation and improvisation that makes the new solutions [24]. Additionally, repair contributes to the design of a new pathway for the artefact [21], by helping us develop a more complete understanding of how a device operates, creating relationships, enriching our awareness of the world around us and shaping it. [9] [26]. Thus, Repair empowers us by making us freer, more autonomous, and more in control of the world we live in [9]. Hence, repair is essential for people's ownership of the artefact [9] [28].

2.1.2 Right to Repair

The "right to repair" is defined as the users' right to make decisions on their products, especially empowering individuals through having the freedom to modify and repair, ability to repair or better accessibility to repair service [9,29–32], which is also an essential aspect to interpret people's ownership of artefacts [9]. The growing recognition of the right to repair, as reflected in the ongoing dialogue, is driving a more sustainable and user-centric approach to technology, while also inspiring innovative methods of resistance, such as reverse-engineering devices, bypassing technological locks, and sharing repair knowledge despite corporate opposition [9, 31]. In recent times, the debate has extended to legal proceedings, regulatory bodies, and legislative halls. Repair advocates are now focused on overturning laws that impede their ability to fix devices [9].

Grass-roots Advocacy Community of Right to Repair Movement

The Right to Repair movement boasts several key advocates. Organizations like Repair Café, The Repair Association (repair.org), The Restart Project, and iFixit are all fighting for the "Right to Repair." They tackle planned obsolescence by advocating for easier access to spare parts, repair manuals, and diagnostic tools.

Inspired by the local design exhibition's emphasis on repair and creative reuse, Martine pioneered the world's first Repair Café, hosted in a movie theatre lobby in Amsterdam [33]. This innovative concept aligns with the global Repair Café movement, supported by the Repair Café Foundation [34]. This movement encourages community-led repair events, where volunteers share their skills to mend broken items, thereby reducing waste and promoting sustainable practices. Repair Cafés, typically situated in neighbourhoods, provide a platform for individuals to gather and collaboratively repair a diverse range of household items, including electrical and mechanical devices, bicycles, clothing, and more. These events, often held at fixed locations, are organized by dedicated volunteer repairers [35].

Compared to the Repair Café movement, which focuses on community-based repair initiatives, organizations like the Repair Association (repair.org) [36] play a crucial role in advocating for consumers' rights to repair their own electronic devices. This US-based non-profit champions legislative efforts to secure access to repair information, parts, and tools, empowering individuals to fix their gadgets and promoting a more sustainable consumption model. Their work aligns with the goals of the Digital Right to Repair Coalition, further solidifying their position as a leading advocate for consumer rights in the repair landscape.

While the Repair Association advocates for legislative changes to make repair more accessible, iFixit takes a different approach. iFixit [33, 37] empowers people to repair their own devices by providing comprehensive online resources. Their website offers free repair guides, parts, and tools for a wide range of products. This challenges restrictions imposed by manufacturers who may prefer consumers to replace broken devices rather than fix them. iFixit's philosophy aligns with the "Repair Manifesto" which states that if you can't fix it, you don't own it [38]. By promoting DIY repairs, iFixit contributes to a more sustainable consumption model and reduces electronic waste.

The Restart Project [39], a UK-based non-profit, advocates for extending the lifespan of electronic devices and making repairs more accessible. By organizing community repair events, providing training, and building repair directories, they empower individuals to fix their own devices, reducing electronic waste and conserving resources. The Restart Project's mission aligns with the broader goal of transitioning from a throwaway culture to a repair-oriented society. They actively campaign for policies that support the Right to Repair, aiming to influence both government regulations and industry practices to promote more sustainable and repairable products.

These organizations collectively form a multifaceted front in the fight for the

Right to Repair. By engaging communities, advocating for legislation, and providing resources, they empower consumers and independent repair shops to fix their electronics and appliances, rather than being forced into costly replacements. This approach promotes a more sustainable future by reducing electronic waste and fostering a culture of repair. As the Right to Repair movement continues to gain momentum, these organizations, alongside many others, are actively working to create a more sustainable and equitable future.

Top-down Policy Implementation of Right to Repair

The grass-roots movement for the right to repair has gained significant momentum in recent years, driven by concerns over product longevity, environmental impact, and consumer choice. This section delves into the evolving landscape of right-to-repair legislation and policies across various countries.

The European Union (EU) has been at the forefront of this movement, introducing regulations to facilitate product repair and extend product lifespans. In 2023, the EU introduced a new regulation on the "right to repair," aimed at reducing repair costs and promoting a circular economy [1]. This regulation covers a wide range of products and includes provisions for easier access to spare parts and repair information, as well as prohibitions on practices that deliberately hinder repair. The UK has also taken steps to promote the right to repair through its eco-design regulations. These regulations mandate the availability of spare parts for certain product categories, making it easier for consumers and professional repairers to extend the life of their devices [40]. Furthermore, France has introduced a product repairability index, which provides consumers with information about the repairability of various products. This index is intended to encourage manufacturers to design more repairable products and empower consumers to make informed choices [41].

While the EU has made significant strides in the right to repair, the United States has also taken steps to address this issue. The Massachusetts Motor Vehicle Owners' Right to Repair Act, which requires carmakers to provide independent repair shops with access to diagnostic tools, has set a precedent for the broader right-to-repair movement [33]. Additionally, the U.S. Copyright Office has recognized the importance of consumer repair rights and has clarified that copyright law does not prevent consumers from repairing their own devices. However, challenges remain in the U.S., particularly in the area of electronics repair. Green standards have become easier for manufacturers to meet, potentially hindering efforts to promote product longevity and reduce electronic waste [42].

While there is a growing global movement to recognize and protect consumers' rights to repair their own products, Japan faces unique challenges due to its specific legal framework [43]. The Japanese legal landscape presents a complex interplay of regulations that both facilitate and hinder the right to repair. While the Antimonopoly Act (独占禁止法) offers some protection for third-party repair services, as seen in cases involving elevator parts and printer cartridges, other laws, such as the Radio Law (電波法), pose significant barriers. The Radio Law, designed to regulate radio waves, imposes strict requirements on the modification of devices, effectively limiting repairs to manufacturers or their authorized service providers. Conversely, the Fair Trade Commission's (公正取引委員会)guidelines and the Appliance Fair Trade Council's(全国家庭電気製品公正取引協議会) regulations offer some consumer protections, including minimum parts retention periods. However, these measures are often voluntary and do not provide the same level of consumer protection as the legislative mandates found in Europe. In conclusion, while Japan has made strides in protecting the right to repair through antitrust law, comprehensive legal protections comparable to those in the EU remain elusive. The interplay between intellectual property rights, consumer protection laws, and industry self-regulation continues to shape the landscape of product repair in Japan [43].

The right to repair debate involves a complex interplay of consumer rights, manufacturer interests, and public policy. Proponents argue for increased consumer choice, reduced electronic waste, and lower repair costs, while opponents raise concerns about product safety, security, and innovation.

As technology continues to evolve, particularly with the rise of the Internet of Things (IoT), the right to repair becomes increasingly important. IoT devices present unique challenges due to their complex software and hardware components. It is crucial to consider the implications of these devices on repair, maintenance, and sustainable development [30].

To fully realize the benefits of the right to repair, it is essential to consider not only legal frameworks but also the practical aspects of repair. This includes studying the design and use of products, as well as the skills and knowledge required for repair [27,44]. By fostering a culture of repair and empowering consumers, we can create a more sustainable and equitable future.

2.2. Repairability of Artefacts

2.2.1 Negotiation in the Process of Repair

The process of repair is a complex interplay of technical, social, and cultural factors. It involves a series of negotiations and decision-making, often collaborative in nature. As Rosner argues, "maintenance, care, and repair are negotiated – often collaboratively – in use and the meaning-making associated with use, rather than the meanings pre-specified by designers" [45]. This negotiation includes the identification of breakdown, collaborative definitions of worth, and the gendered stakes of repair [45].

Marie Lefebvre further breaks down the repair process into five distinct stages: pre-decision, decision, preparation, repair, and post-repair [46]. The pre-decision and decision stages involve the prosumer's assessment of the item and their own capabilities. Research by Lundberg et al. suggests that consumers often feel most confident repairing textiles and bicycles, and their willingness to develop repair skills is influenced by factors such as education, previous experience, and environmental concerns [47]. Additionally, Scott's study on repair motivation highlights the impact of market, product, and consumer factors on repair propensity [48].

The preparation and repair stages involve the practical aspects of the repair process. Hielscher identifies several types of repair acts, ranging from quick fixes to complex repair projects [35]. These acts often involve diagnosing, fixing, and integrating components. Maestri's research emphasizes the importance of resourcefulness, adaptation, and quality in self-repair practices [23]. People often find innovative ways to reuse materials and modify objects to suit their needs, demonstrating the creative potential of repair.

The post-repair stage involves the assessment of the repair outcome. Graham highlights various possibilities, including bodged jobs, upgrades, cannibalization, and complete rebuilds [24]. Jung introduces the concept of "repairedness," which refers to the negotiated outcome of the repair process [49].

Overall, the literature suggests that repair is a dynamic multifaceted activity with significant social, cultural, and environmental implications. It is a process that involves both technical skills and creative problem-solving. As Graham argues, "Maintenance and repair is an ongoing process, but it can be designed in many different ways in order to produce many different outcomes and these outcomes can be more or less efficacious: there is, in other words, a politics of repair and maintenance" [24].

2.2.2 Factors of Repairability

Repairability, the ability of a product to be repaired, is influenced by a complex interplay of economic, technical, psychological, and infrastructural factors. Understanding these factors is crucial for promoting sustainable consumption and reducing electronic waste.

Economic Factors

Economic factors play a significant role in influencing repair decisions. The cost of repair, including parts, labour, and service fees, often outweighs the perceived value of a repaired product, especially when compared to the cost of a new replacement [9, 50–53]. Additionally, the lack of economic incentives for repair and reuse hinders the development of a sustainable repair ecosystem [51].

Technical Factors

Product design significantly impacts repairability. Features like glued components, proprietary parts, and complex disassembly processes can make repairs difficult and time-consuming [9,50,51]. The availability of spare parts and repair manuals is also crucial for enabling repairs [9,31,54,55]. Moreover, although there are several standardized repairability assessment methods, such as EN 45554 [56], the lack of assessment methods for other product categories, particularly for mechanical products, hinders the development of repairable products [55].

Psychological Factors

Consumer attitudes and perceptions play a significant role in repair decisions. While consumers may be open to repairing their devices, factors such as the perceived cost-effectiveness of repair, the quality of repaired products, and social norms can influence their choices [9, 31, 51, 52, 57, 58]. Manufacturers often prioritize technological advancements and aesthetic appeal over repairability, leading to products that are difficult to repair [59]. Also, existing repairability assessment methods often focus on design rather than the actual repair experience [55].

Infrastructural Factors

The availability of repair services and skilled technicians is essential for promoting repairability. However, limitations in repair infrastructure, such as the lack of accessible repair shops and the high cost of repair services, can discourage consumers from repairing their devices [9, 50, 51, 53]. Additionally, legal and regulatory barriers, such as restrictive repair practices and copyright laws, can hinder the development of a thriving repair ecosystem [51].

In conclusion, addressing the complex interplay of economic, technical, psychological, and infrastructural factors is essential while discussing the repairability of a product. By offering a better repair experience and reducing the friction in the repair process through designing products that are easy to repair, providing accessible repair services, and fostering a supportive regulatory environment, we can encourage consumers to repair rather than replace their devices.

2.3. Design for Repair

2.3.1 Design for X

Design for X (DfX) is a strategic approach to product development that aims to optimize various aspects of a product's lifecycle, including design, manufacturing, assembly, testing, service, and disposal. By integrating specific design considerations into the early stages of the product development process, DfX seeks to enhance product quality, reduce costs, accelerate time-to-market, and improve overall product performance. This holistic approach has evolved from its origins in manufacturing efficiency to encompass a broader range of concerns, such as environmental impact, supply chain sustainability, and product serviceability. [60–62]

2.3.2 Design for Repair Development

Design for Repair (DfR) is a proactive approach to product design that prioritizes the ease of repair and maintenance. By incorporating repairability into the design process, manufacturers can extend the lifespan of products, reduce waste, and minimize environmental impact. This strategy aligns with the growing global emphasis on sustainable design and consumption. Repair is an integral part of our daily lives, yet it is often overlooked in product design [63]. DfR challenges this conventional approach by considering repairability as a core design criterion. By employing modular components, standard connectors, and easily accessible parts, products can be more readily repaired, leading to reduced costs, lower environmental impact, and enhanced customer satisfaction [64]. Mead's insightful analysis in [18] underscores the interconnectedness of design and repair. While design creates a blueprint for production, repair engages with individual objects, demanding a deep understanding of their construction and functionality. Both designers and repairers share a common goal: to solve problems and extend the life of products. However, they approach these challenges from different perspectives, highlighting the importance of empathetic design that considers the entire product lifecycle, from creation to disposal.

Design for Repair (DfR) and Design for Maintenance (DfM) are closely related strategies that aim to improve product longevity and reduce environmental impact. While DfR prioritizes the ease of repairing broken components, DfM focuses on minimizing the effort and cost associated with regular maintenance. Both approaches can involve self-repair by end-users or professional repair by manufacturers or third-party service providers [65]. As Mead [18] observes, many modern products, such as cars, appliances, and electronics, are designed more for maintenance than for repair. This often involves replacing entire modules or assemblies, rather than fixing individual components. While professional repair services can be efficient, they can also be costly and time-consuming. Self-repair, on the other hand, empowers users to take control of their devices and can be a more sustainable and affordable option. However, it requires products to be designed with repairability in mind.

The Role of the User in DfR

User motivation and barriers significantly influence repair decisions. Huang et al. [66] found that factors such as the availability of repair parts, tools, and guidelines impact consumers' future purchasing behavior. Terzioglu [67] introduced the Repair Motivation and Barriers (RMB) model, highlighting the interplay of technical, emotional, and value-related factors in shaping repair decisions. Renske van den Berge et al. [68] demonstrated that clear fault indications can significantly increase users' willingness to repair by boosting perceived self-efficacy.

Facilitated Do-It-Yourself Repair (FDR) [69] emerges as a promising approach to empower users and promote sustainable consumption. By providing clear instructions, tools, and support, companies can encourage users to engage in repair and upgrade activities. This can lead to increased customer loyalty, positive brand perception, and reduced environmental impact. However, implementing FDR requires careful consideration of several challenges. Designing repairable products, providing effective user education, and addressing potential stigmas associated with repair are crucial steps. By striking the right balance between user autonomy and guided support, companies can create a positive and empowering repair experience.

Design Strategies for DfR

Designing products for repair requires a holistic approach that considers both product design and consumer behavior. Mead [18] highlights the challenge of anticipating and designing for specific repair scenarios. Rosner [45] emphasizes the importance of understanding the broader context of use, including material, economic, and cultural factors.

Chamberlain [70] outlines key design principles for repairable products, such as modularity, removable batteries and screens, standard fasteners, and clear repair manuals. These principles align with the work of iFixit, which has established a reputation for promoting repairability through analysis and advocacy.

Roskladka's review [19] emphasizes the importance of considering both product design and consumer preferences. While physical aspects like modularity and spare part availability are crucial, understanding consumer behavior and preferences is equally important. By analyzing product usage data, manufacturers can design products that are not only repairable but also desirable to consumers.

Pozo-Arcos et al. [71] highlight the importance of clear and accessible repair information, including detailed fault diagnosis procedures. Kilic et al. [31] emphasize the role of online communities and manufacturer support in facilitating repair. By providing clear instructions, tools, and troubleshooting guidance, manufacturers can empower users to undertake repairs independently. However, Lee [72] notes that factors such as access to repair services, cost, and trust in repair providers can also influence consumer decisions on repair.

Implications for Industry and Policy

The successful implementation of DfR requires a multi-stakeholder approach, involving OEMs, service providers, and consumers. As Roskladka [19] highlights, OEMs play a pivotal role in shaping product design and repair strategies. By prioritizing modularity, standardized components, and accessible repair documentation, manufacturers can significantly enhance product repairability. Saidani [32] explores the potential implications of DfR across various industries:

- Electronics: Design for disassembly and modularity are essential for enabling consumer-led repairs.
- Biomedical Devices: Strict quality regulations are necessary to ensure the safety and reliability of repaired devices.
- Apparel: Providing clear information on repair and disposal can empower consumers to make more sustainable choices.

Government policies and regulations can play a crucial role in promoting DfR. As mentioned in 2.1.2, Right-to-repair legislation, which grants consumers the legal right to repair their devices, can incentivize manufacturers to design products with repairability in mind. Additionally, developing standardized repairability metrics and certifications can help consumers make informed choices and encourage manufacturers to prioritize repair-friendly designs.

DfR Implication Examples

A compelling example of design exploration for DfR comes from The Agency of Design's "Design Out Waste" project [73]. Focusing on electrical products, this initiative explored alternative approaches to product lifecycles that prioritize repairability and minimize waste. Through research and product dissections, the project revealed the limitations of current recycling methods for complex electronics. It then presented three toaster prototypes, each showcasing a different DfR strategy: The Realist focused on robust materials and easy disassembly, The Pragmatist prioritized replaceable modules, and The Optimist explored innovative biomimetic materials designed for easy disassembly and recomposition. This project demonstrates how design exploration can push the boundaries of DfR, fostering creative solutions that benefit both consumers and the environment.

Patagonia's return and repair policy exemplifies service design for DfR [5]. Their website offers clear instructions and resources to facilitate product repair, extending the lifespan of their garments. Customers can easily access repair guides, order replacement parts, and even find authorized repair shops near them. This user-friendly approach empowers customers to actively participate in DfR by repairing their Patagonia gear instead of simply discarding it. This not only reduces waste but also fosters customer loyalty by demonstrating the brand's commitment to product sustainability and responsible consumption.

Kibu [74] provides a unique example of rethinking manufacturing through implementing 3D printing in DfR. Their children's headphones are built with repairability in mind, utilizing 3D-printed components. This allows for on-demand, local batch manufacturing, minimizing the environmental impact associated with traditional production methods. Furthermore, the modular design with 3D-printed parts enables easy replacement of broken components, extending the lifespan of the headphones and reducing electronic waste. This innovative approach demonstrates how 3D printing can not only streamline production but also foster sustainable design practices by facilitating repairs throughout a product's lifecycle.

Fairphone [75] serves as a prime example of Extended Electronic Equipment Producer Responsibility (EPR) in DfR. Their smartphones are designed with modularity in mind, allowing users to easily replace components like batteries and screens. This aligns with Amend et al.'s research [76], which suggests that users are more likely to attempt repairs when products are perceived as self-repairable. Additionally, Fairphone provides comprehensive repair guides and readily available replacement parts, further enhancing the user experience. This holistic approach, encompassing product design and readily available repair resources, exemplifies successful EPR in practice and promotes the extension of smartphone lifespans, thereby reducing e-waste and promoting more sustainable consumption habits.

The integration of Design for Repair (DfR) into the product design process is crucial for achieving sustainable consumption. By prioritizing repairability, manufacturers can extend product lifespans, reduce waste, and minimize environmental impact. This literature review highlights the importance of user motivation and barriers in repair decisions, the potential of facilitated Do-It-Yourself Repair (FDR), the role of design strategies in promoting repairability, and the potential direction of implications in the industry. While challenges remain, such as designing for diverse repair scenarios and addressing consumer perceptions, future research should focus on designing a better repair experience through systems thinking and user-centred design. By embracing DfR and fostering a culture of repair, we can create a more sustainable and resilient future for our products and planet.

Chapter 3
Design Process

3.1. Overview of Design Process

This design process (Figure 3.1) is divided into two distinct stages, first, Ideation and Pretesting, and second, Proposal.

Ideation and Pretesting

This initial phase focuses on gathering and analysing information about repair experiences. It comprises four key components:

- Auto-ethnography: This involves personal reflection on repair experiences, such as traditional Kintsugi, fixing a rice cooker and repairing a bag, as well as exploring second-hand markets.

- Repair Community Ethnography: This delves into a repair community in London, studying the community repair approach.

- Kintsugi Transformation Workshop: This hands-on workshop allows for a deeper understanding of repair processes and the transformative potential of repair.

- Repair Survey: This quantitative research tool collects data on people's repair experiences and attitudes.

Proposal

Building on the insights gained from the previous Literature Review and the Ideation and Pretesting stage, the Proposal stage focuses on developing a design for a better repair experience. The case study, Redesigning a Fan, demonstrates

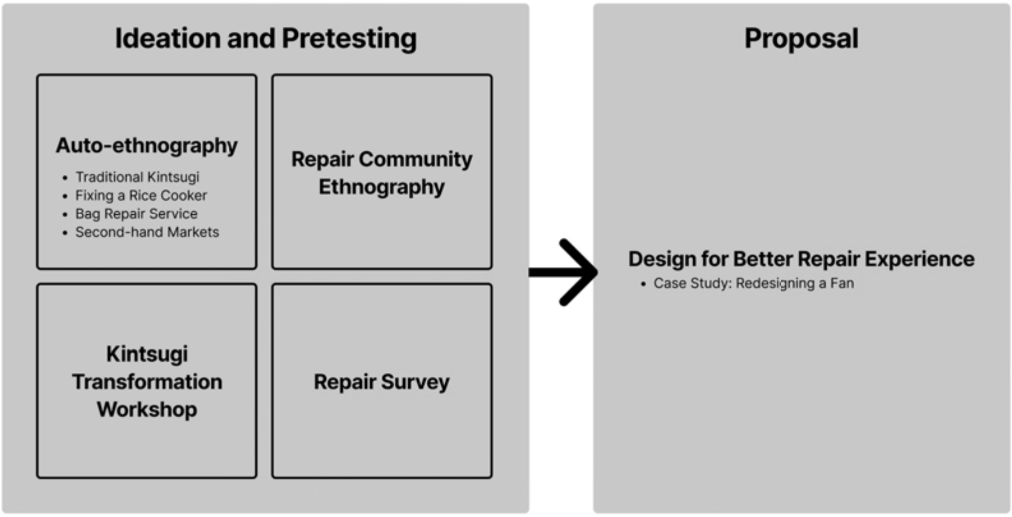


Figure 3.1 Overview of Design Process

how the principles and insights derived from the previous stage can be applied to create a more repairable and sustainable product.

By combining qualitative and quantitative research methods, this design process aims to create a comprehensive understanding of repair practices and to develop innovative design solutions that promote repair and sustainability.

3.2. Ideation and Pretesting

3.2.1 Auto-ethnography: Repair from a User Perspective

To gather a general idea and concept of the repair experience from a user perspective, the following four auto-ethnographies were done as a record of observation, which includes traditional kintsugi practice, rice-cooker repairing, bag repair service, and repair, resale and aftermarket.

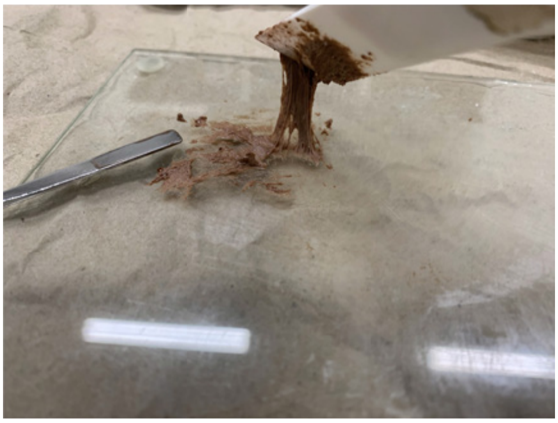


Figure 3.2 The urushi and wheat flour mixture for Kintsugi

Traditional Kintsugi Practice

Kintsugi is a traditional Japanese craftsmanship that uses urushi lacquer (Figure 3.2) to mend the breakage areas on pottery. In this Kintsugi practice, a plate with a crack was repaired and the process, interaction and feeling were recorded.

The clatter of porcelain against the tile, a sharp, sudden sound that pierced the quietude of my kitchen. A familiar scene, one that had played out countless times before. A broken dish, a symbol of both fragility and resilience. As I gazed upon the shattered fragments, a sense of disappointment washed over me, a fleeting moment of frustration. But then, a different thought emerged, and a spark of curiosity ignited within me.

I had always been drawn to the concept of wabi-sabi, the Japanese aesthetic that celebrates imperfection and transience. The idea of embracing flaws, of finding beauty in brokenness, resonated deeply with me. And so, I decided to embark on a journey of Kintsugi, the ancient Japanese art of repairing broken pottery with gold or silver lacquer(Figure 3.4).

The process was a meditation, a slow and deliberate double dance of agency with the fragments. Each step, from cleaning the pieces to applying the urushi lacquer(Figure 3.3), which required patience and precision, was informed by the broken shape of the pieces and the human made the decision and took the action of repair. As I worked, I couldn't help but ponder the nature of repair and renewal. Was I simply fixing a broken object, or was I transforming it into something more?

Figure 3.3 The crack after filling with several layers of urushi

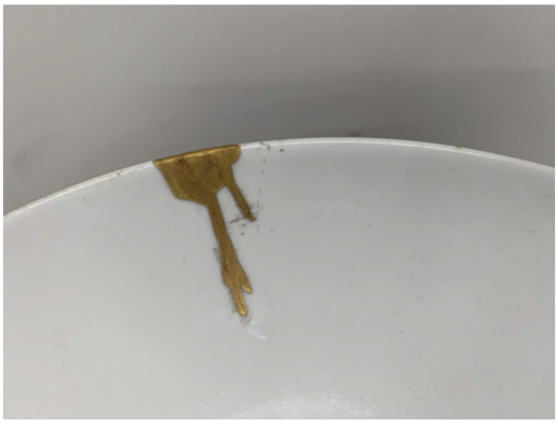


Figure 3.4 Final result of the Kintsugi process

The contrast between traditional Kintsugi and modern methods, which often employ epoxy resin, became apparent. While the latter may offer a quicker and more durable solution, it sacrifices the vessel's original function. Traditional Kintsugi, on the other hand, preserves the object's purpose, highlighting its history and the marks of time.

A question arose: Is it worth the time, effort, and materials to repair a broken dish? The answer, for me, was a resounding yes. The value of an object lies not only in its utility but also in its story. By repairing the broken dish, I was not merely restoring it to its original state but imbuing it with a new narrative, a

Figure 3.5 Before and after repair of the Tatung rice cooker

testament to its resilience and the human touch.

A Cross-Cultural Repair: Fixing a Taiwanese Rice Cooker in the UK

The Tatung rice cooker, a ubiquitous household appliance in Taiwan, is more than just a kitchen tool; it's a cultural symbol deeply embedded in Taiwanese daily life. Its reliability and simplicity have made it a beloved companion for many Taiwanese people, often travelling with them to foreign countries. However, when my Tatung rice cooker encountered a mechanical issue in the UK, it presented a unique challenge: a cross-cultural repair endeavour. The dent in the bottom of the rice cooker, seemingly a minor issue, had significant consequences. It not only affected the stability of the appliance but also compromised its steaming function, a crucial feature for many Taiwanese culinary traditions. The challenge of repairing it was compounded by its Taiwanese origin, making it difficult to find a local repair service with the necessary knowledge and parts.

Given the limitations of professional repair services, I embarked on a DIY repair journey. This involved acquiring the necessary tools, sourcing replacement parts, and consulting online manuals and tutorials. However, I soon discovered that the design of my UK-version Tatung rice cooker differed slightly from the Taiwanese models, particularly in terms of voltage and component placement, which was influenced by the context of the rice cooker used since the plug and repair support of the rice cooker were different from Taiwan.

Despite these challenges, I was able to successfully repair the rice cooker. This experience highlighted three essential factors for successful DIY repair:

- Repairable Design: The rice cooker was designed with repairability in mind, meaning that its components and parts were accessible and replaceable. This is a crucial aspect of sustainable design, as it extends the lifespan of products and reduces electronic waste.

- Appropriate Tools: Having the right tools, such as a suitable screwdriver, was essential for efficient and safe repair. The availability of affordable and versatile tools empowers individuals to take control of their repairs.

- Accessible Knowledge: Online manuals, tutorials, and repair communities provide valuable knowledge and skills. These resources democratize repair, making it accessible to people of all backgrounds and technical expertise.

Repairing my Tatung rice cooker was more than just a practical task; it was a cultural and technical challenge. It underscored the importance of repairable design, accessible tools, and shared knowledge in promoting sustainable practices and empowering individuals to take control of their belongings. As we move towards a more circular economy, it is crucial to prioritize repair and reuse, and to challenge the throwaway culture that dominates many societies. By repairing our broken appliances, we not only extend their lifespan but also contribute to a more sustainable future.

A Reflection on Sending a Bag Back to its Repair Service

The worn bag(Figure3.6), a canvas of my father's daily life, had finally reached its breaking point. Its once sturdy strap, frayed and torn, bore witness to countless journeys carrying the tablet, each stitch a testament to its enduring presence. As a dutiful daughter, I took on the task of reviving this cherished companion.

Figure 3.6 Before and after the repair service of the bag

The process, however, was far from straightforward. We had to entrust the bag to the hands of its original creator, Ichizawa Hanpu [3], a renowned canvas bag company in Kyoto. With a mix of hope and trepidation, we packed the broken bag, along with a heartfelt plea and detailed photographs of the damage, and sent it off on its solitary journey.

Days turned into weeks as we anxiously awaited news. A payment request arrived after a phone call checking the details of the repair process, a stark reminder of the cost of nostalgia. Yet, the price seemed modest compared to the sentimental value attached to the bag. It was more than just an accessory; it was a repository of memories, a silent witness to countless moments, big and small.

A month later, the repaired bag returned, rejuvenated and ready to serve once more. The torn strap was seamlessly replaced, and the worn fabric was refreshed. It was as if time had turned back, erasing the marks of its arduous journey.

As I held the repaired bag, a sense of satisfaction washed over me. It was not just the physical restoration that mattered, but the emotional journey it had taken. The repair process, though arduous and uncertain with a possible language barrier, had strengthened our bond with the bag, making it even more

Figure 3.7 Recycle shop in Japan and its repair and maintenance area

cherished. It was a testament to the enduring power of craftsmanship and the value of preserving the past.

A Journey into the World of Repair, Repurpose and Second-hand Markets

My academic journey has been a fascinating exploration of the concept of repair and the often-overlooked pathways that products take beyond the traditional waste disposal route. To delve deeper into this topic, I embarked on a global quest, visiting diverse second-hand shops and markets, from the bustling streets of Tokyo to the quaint boutiques of European cities.

In Japan, I was particularly struck by the prevalence of recycle shops(Figure3.7). These establishments offer a wide range of second-hand goods, from clothing and furniture to electronics. Many of these items undergo minor repairs and maintenance before being resold, demonstrating a strong commitment to extending product lifespans. Compared to the research in Spain, states that the most frequently repaired and purchased second-hand items in Spain are vacuum cleaners, heaters, toasters [51], there seems to be more washing machines, ovens, microwaves

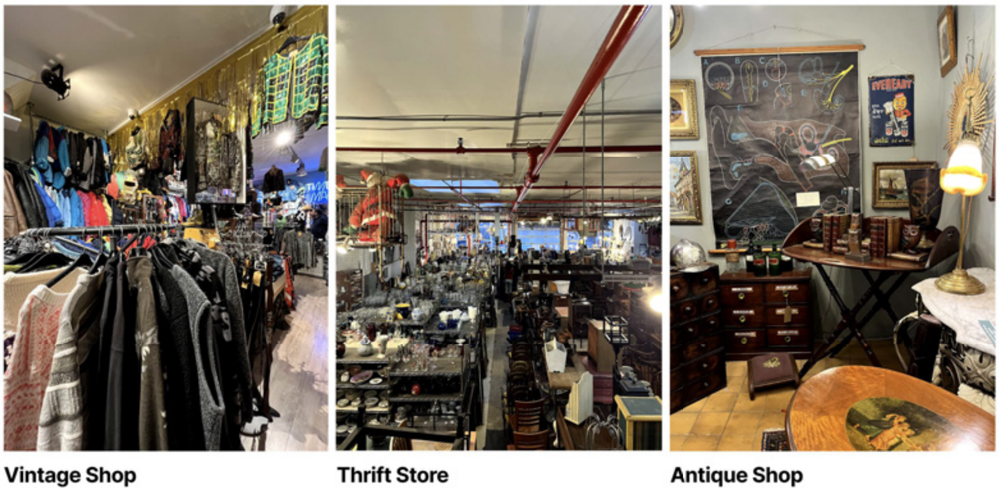


Figure 3.8 Difference between vintage, thrift, antique shop

and refrigerators being sold in the recycle shops in Japan.

Beyond Japan, I encountered a rich tapestry of second-hand commerce (Figure3.8, 3.9), each with its unique approach to repair and reuse:

- Vintage Shops: These curated collections often feature high-quality, pre-loved items, sometimes with minor repairs or alterations.
- Thrift Stores: These stores offer a more diverse range of donated goods, often at affordable prices. Some thrift stores even have designated repair sections, where volunteers mend clothing and other items.
- Antique Shops: These shops specialize in historical artefacts, many of which have been repaired and restored over the years.
- Charity Shops: These shops sell donated items to raise funds for charitable causes. Similar to thrift stores, they may offer repair services or sell items that have been repaired.
- Flea Markets: These informal markets offer a chaotic but exciting shopping experience, where individuals sell a variety of second-hand goods, often with unique stories and histories of repair and reuse.

Figure 3.9 Flea Markets in Different Country

Figure 3.10 Worker-suits sold in vintage shops after repair or remake

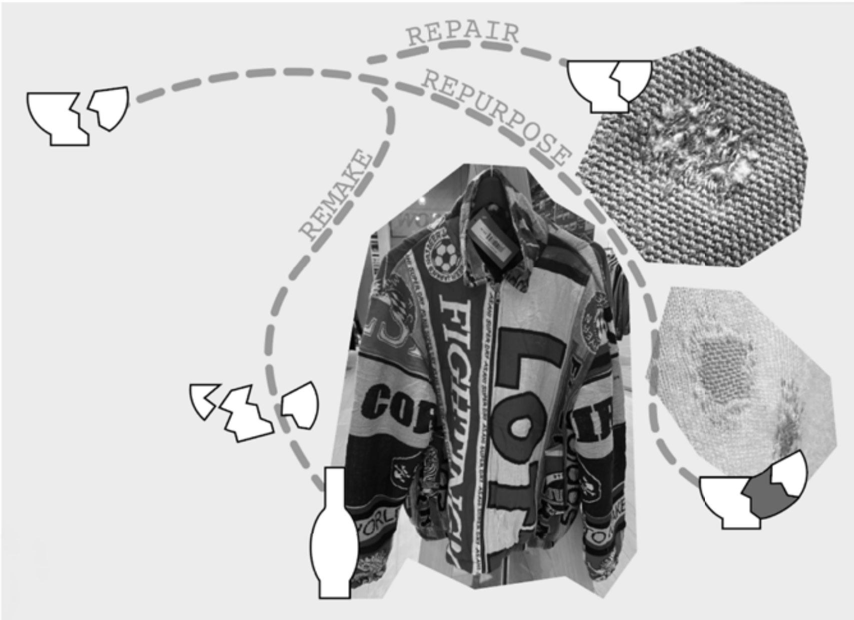


Figure 3.11 Difference between Repair, Repurpose, Remake

As I delved deeper into the world of second-hand goods, I became increasingly fascinated by the creative potential of repair and repurpose. The images (Figure3.10, 3.11)I collected illustrate three key approaches to extending the life of clothing and other objects:

- Repair: This involves fixing a broken item to restore its original function. It is a practical and sustainable approach that can extend the lifespan of a product and preserve its history and craftsmanship.
- Repurpose: This involves finding a new use for an object that is no longer needed for its original purpose. It is a creative and resourceful approach that can reduce waste and give new life to old items.
- Remake: This involves transforming an object into something entirely new, often using its materials as a starting point. It is a highly creative and innovative approach that can lead to the creation of unique and one-of-a-kind pieces.

Through my research, I have gained a deeper understanding of the complex and interconnected world of repair and repurpose. By exploring the diverse ways in which people around the world approach these practices, I hope to contribute to a more sustainable and circular economy.

3.2.2 Kintsugi Transformation Workshop

This two-day workshop (Table 3.1) aimed to explore the public's perception of Kintsugi, a Japanese art form of repairing broken pottery with gold lacquer, in the context of digital fabrication, repair, and upcycling. The workshop participants, predominantly high school students from Singapore, were guided through a four-step process: ideation, modelling, 3D printing, and assembly.

Table 3.1 Workshop Schedule

Time	Day 1	Day 2
9:00	Introduction of KMD	Yesterday’ s Recap
9:30	-	Assembling and Testing
10:00	Kintsugi Introduction	-
10:30	Ideation	Discussion
11:00	3D modelling	Presentation Preparation
11:50	-	Sharing

Workshop Process

1. Ideation: Participants were introduced to the philosophy of Kintsugi, emphasizing the beauty of imperfection and the value of repair.

2. Modelling: Using digital design tools, participants created 3D models of broken objects, incorporating Kintsugi-inspired design elements.

3. 3D Printing: The 3D models were printed using filament materials, simulating the process of repairing broken pottery.

4. Assembly: Participants assembled the 3D-printed pieces with the broken pieces.

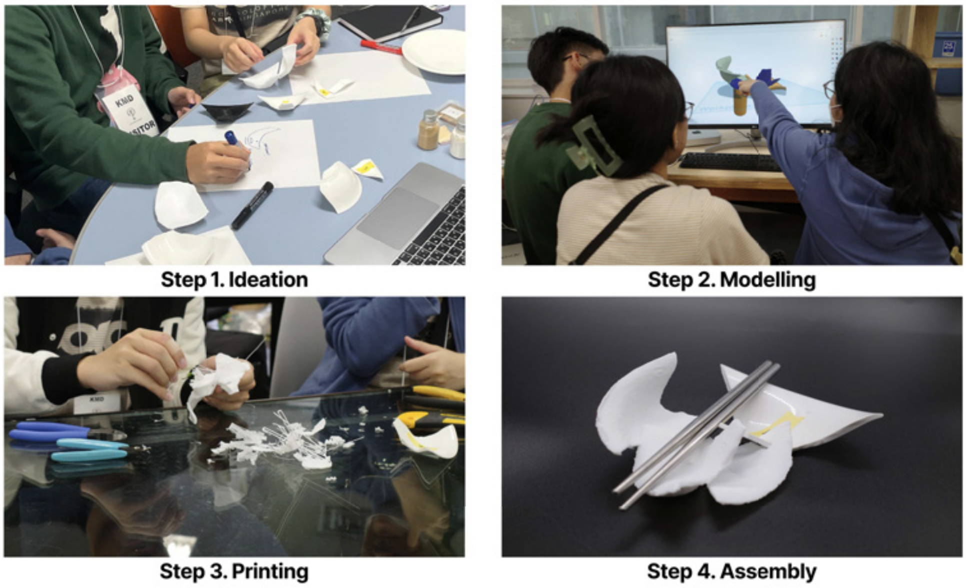


Figure 3.12 The process of the Kintsugi Transformation workshop

Interview Question

The following are the questions that had been asked in order to gain a general understanding of the relationship between the participants and the repair/ repurpose of broken ceramics:

- What do you think about the making process? How do you feel during the process?
- Would you like to utilise a broken dish next time? Why? And why not? What would you like to make?
- Have you ever tried to fix anything? What is it? Why? And how do you fix it?
- What are the differences among recycle, repair and upcycle?
- Any other comments?

Workshop Outcomes

The workshop yielded both tangible and intangible outcomes. Participants created a functional dim sum holder with a chopstick rest that embodied the principles of Kintsugi and digital fabrication. Additionally, a semi-structured group interview revealed valuable insights into participants' perceptions of repair and upcycling. Many participants expressed limited familiarity with digital fabrication tools, often relying on traditional methods like tape and glue for repairs. Broken objects were frequently discarded or repurposed as decorations, rather than being repaired. Furthermore, participants tended to view upcycling and repair as distinct concepts, with upcycling focused on adding value to waste materials and repair centred on restoring an object to its original state, often overlooking the emotional and historical significance of the object.

Conclusion

The Kintsugi transformation workshop provided a unique opportunity to bridge the traditional Japanese repair method with contemporary technology and clarify the definition of repair, recycle, upcycle and repurpose. By exploring the concept of repair and the beauty of imperfection, participants gained valuable insights into the potential of digital fabrication for sustainable design and creative expression. The workshop also highlighted the need for further education and awareness regarding the ethical and aesthetic implications of repairing and upcycling broken objects.

3.2.3 Ethnography: A Study of Community-Driven Electronics Repair

This ethnography explores the intersection of technology, community, and sustainability through the lens of a repair club hosted by Forest Fixers in London. As a member of the UK-originated repair community, the Restart Project [39], Forest Fixer shares the same purpose with other repair communities of helping people fix their beloved for free [33]. By examining the practices, motivations, and challenges faced by participants and volunteers, this study seeks to understand

Figure 3.13 The Location of the Repair Community

the role and their opinions of such initiatives in addressing the growing issue of electronic waste and promoting a more circular economy.

This research employed a mixed-methods approach, combining participant observation and unstructured interviews. The researcher attended a repair club session at The Mill in E17, London(Figure 3.13), actively participating in the repair process while observing the interactions between participants and volunteers. Additionally, in-depth interviews were conducted with key members of Forest Fixers to gain insights into their motivations, goals, and challenges.

The Role of Community

The repair club(Figure 3.14) served as a hub for individuals in the neighbourhoods who are passionate about technology and sustainability. Participants were drawn to the event for various reasons, including:

- Skill-sharing: Many participants were eager to learn different repair techniques and share their knowledge with others.
- Community building: The event provided an opportunity for like-minded individuals to connect and socialise, especially for the people who are concerned about the right to repair.
- Sustainability: Participants were motivated by a desire to reduce electronic waste and promote a more sustainable lifestyle.

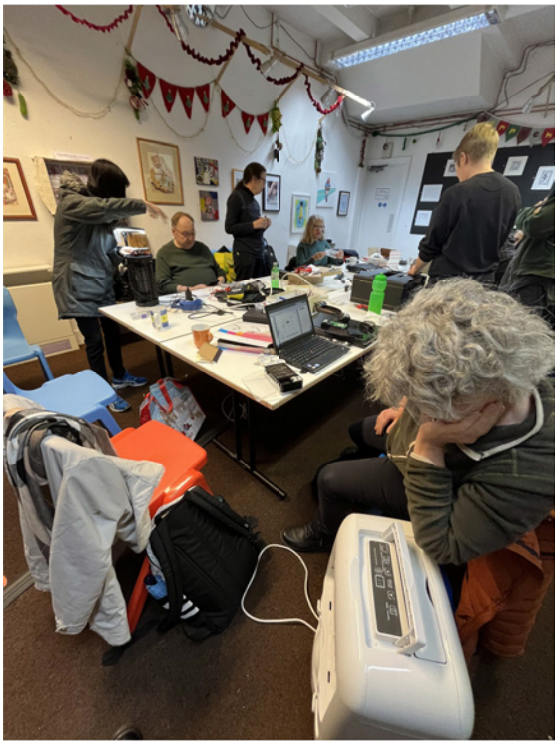


Figure 3.14 Participants engaging the repair community

Figure 3.15 Different screwdriver bits were used for repair

The Role of Volunteers

Volunteers played a crucial role in the success of the repair club. They worked as repairers and instructors with engineering backgrounds, providing valuable expertise and technical skills. They were often able to identify and address complex issues, sharing their knowledge with other participants. Also, they provided several comments on improving the repairability of the design to make a better product [2].

Challenges in Repairing Modern Devices

A significant challenge identified by both participants and volunteers was the increasing difficulty of repairing modern electronic devices. Several factors contribute to this(Figure3.15, 3.16, 3.17, 3.18):

- Planned obsolescence: Many devices are designed with a limited lifespan,

Figure 3.16 This amplifier speaker could not be fixed because of parts lacking

Figure 3.17 Finding the location of the screws is problematic

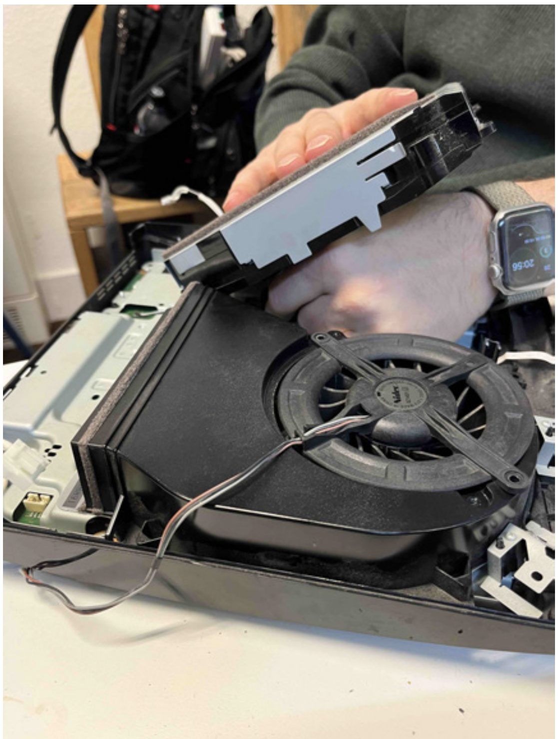


Figure 3.18 An example of things that are not designed for repair

such as using degraded material or increasing the barrier to accessing the repair service, making repairs impractical or impossible.

- Complex designs: Due to the development of technology and its increasing complexity, modern devices often feature intricate designs that require specialized tools and knowledge to disassemble and repair.
- Use of adhesives: Because of the requirement of compactly designed devices, the widespread use of adhesives in device assembly hinders disassembly and repair efforts.

The Impact of Repair Culture

By promoting repair and reuse, the repair communities can contribute to a more sustainable future. By reducing electronic waste and extending the lifespan of devices, these initiatives can help mitigate the environmental impact of the tech industry. Additionally, the repair communities can empower individuals to take control of their technology, fostering a sense of independence and self-reliance towards the consumer society.

Conclusion

The repair club at The Mill serves as a powerful example of community-driven innovation and sustainability. By bringing together individuals with diverse skills and passions, the club fosters a culture of repair and reuse. However, the challenges posed by modern device design highlight the need for systemic changes to promote repairability and durability. As technology continues to evolve, it is essential to prioritize sustainability and ensure that devices are designed with repair in mind.

3.2.4 Repair Survey

This section presents the results of the survey (Appendix A) conducted to investigate consumer attitudes and behaviours towards product repair. The survey aimed to explore factors influencing repair decisions, perceived repairability of different product categories, and the motivations behind repair attempts. The data

How confident are you in your making skills?
How confident are you in your repair skills?

Count of Repair Skills Responses (columns); Count of Making Skills Responses (rows)

Scale (0-5)	0	1	2	3	4	5	Total
0	3	2	0	0	0	0	5
1	2	6	2	0	0	0	10
2	1	3	6	0	1	0	11
3	1	3	2	8	1	0	15
4	0	1	4	11	8	1	25
5	0	0	0	0	6	1	7
Total	7	15	14	19	16	2	

Figure 3.19 The comparison of people's ability to make and repair

collected through a non-probability convenience sampling method was analysed using descriptive statistics and correlation analysis.

Demographic Information

Demographic information other than the level of confidence in making and repairing skills was not collected. The survey participants were primarily individuals with varying levels of making and repair skills. A significant correlation (Figure 3.19) was found between these two skills ($r \approx 0.773$), indicating that individuals who are confident in their making skills are also likely to be confident in their repair skills. However, a slight bias towards higher confidence in making skills was observed.

Perceived Repairability of Products

The survey assessed the perceived repairability of various product categories using a Likert scale ranging from "Very Unlikely" to "Very Likely."(Figure 3.20) The results revealed significant differences in perceived repairability across product

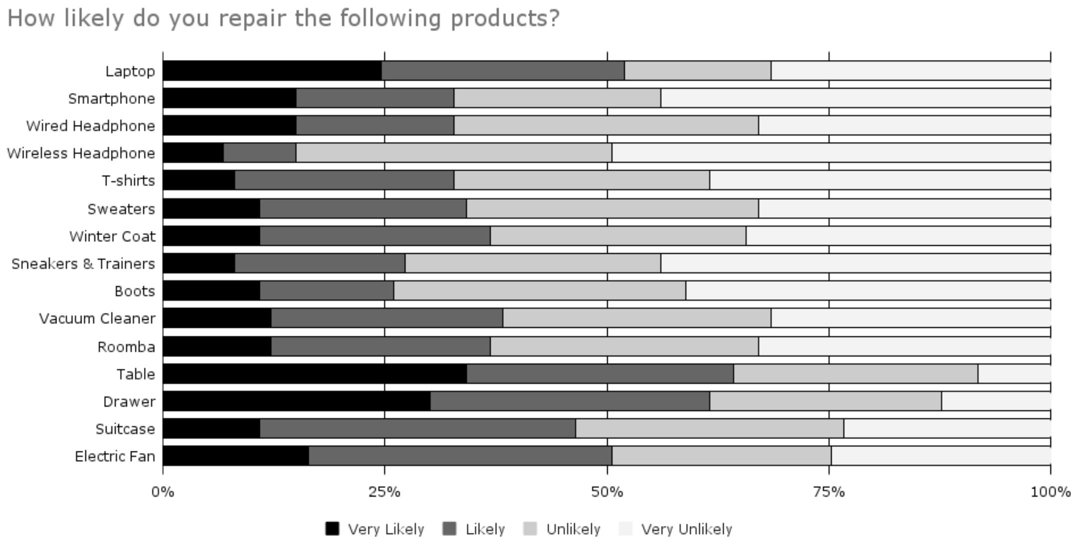


Figure 3.20 The perceived repairability of various product categories

categories:

- High Repairability: Clothing and footwear were perceived as highly repairable, with a large proportion of respondents indicating a willingness to repair these items.
- Moderate Repairability: Electronics and furniture were perceived as moderately repairable, with a mix of respondents expressing willingness and unwillingness to repair these items.
- Low Repairability: Complex electronics, such as laptops and smartphones, were perceived as the least repairable, with a majority of respondents indicating an unwillingness to repair them.

Motivations for Repair

The survey (Figure 3.21, 3.22, 3.23) identified several key motivations for repairing products by asking reasons why and why not people repair:

- Cost-Saving: A significant proportion of respondents were motivated to repair products primarily to save money.

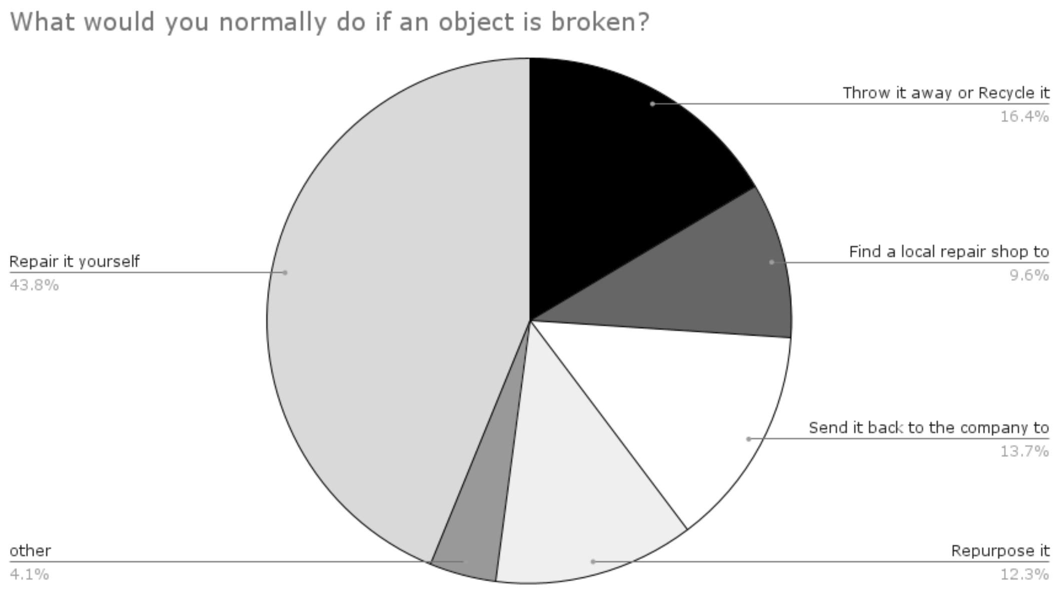


Figure 3.21 The pie chart of the decision-making result after product broken

- Emotional Attachment: People were more likely to repair items that they had an emotional connection to, such as sentimental objects or heirloom pieces.
- Sense of Accomplishment: The satisfaction derived from successfully repairing an item was a strong motivator.
- Environmental Concerns: A smaller but still significant group of respondents were motivated by environmental considerations, seeking to reduce waste and extend the lifespan of products.

Discussion

The findings of this study provide valuable insights into consumer attitudes and behaviours towards product repair. The perceived repairability of products is influenced by a variety of factors, including the complexity of the product, the availability of replacement parts, and the individual's skill level.

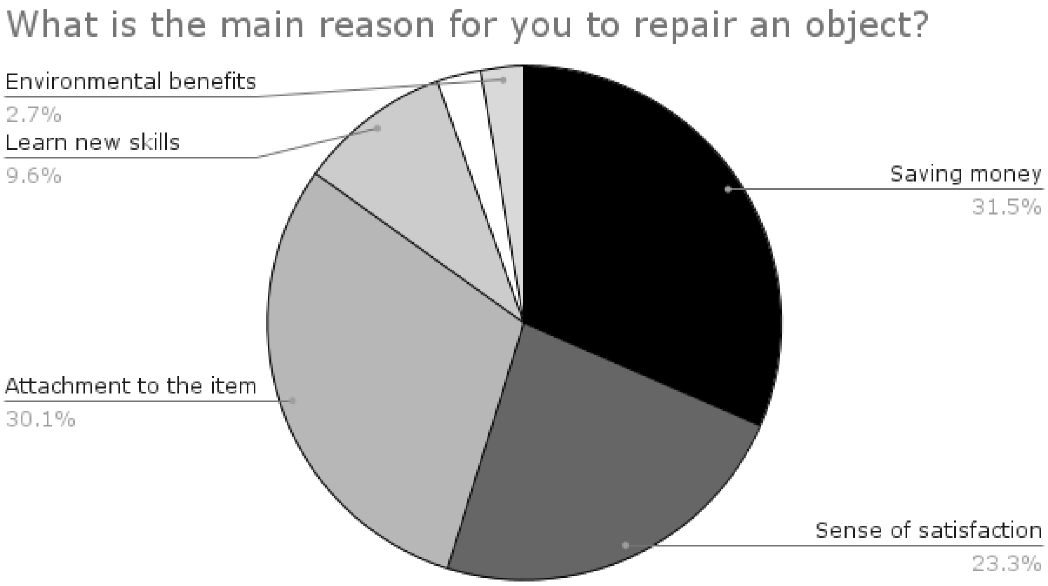


Figure 3.22 The pie chart of the reason for repair

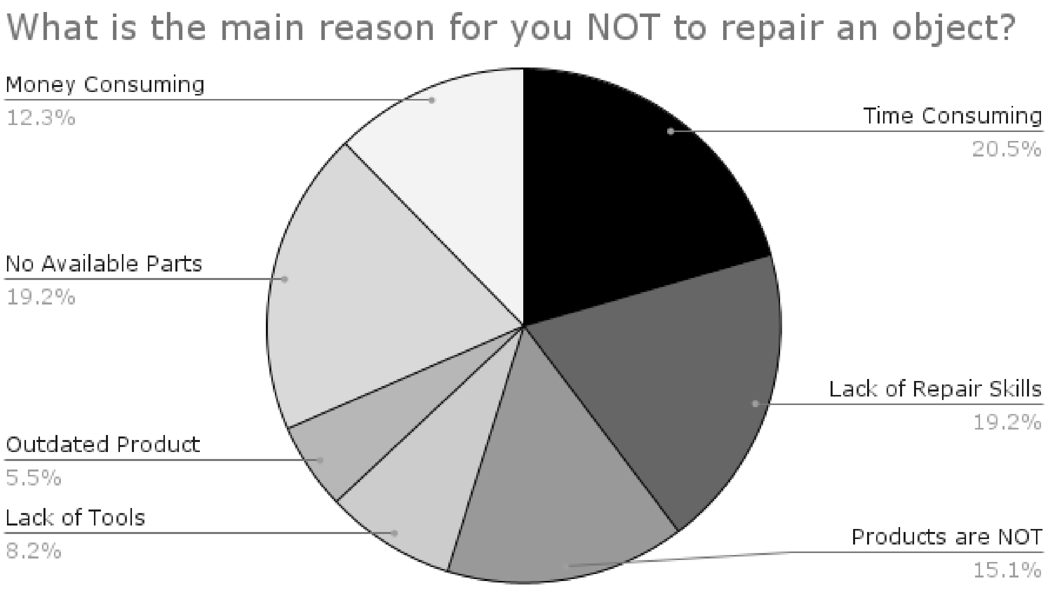


Figure 3.23 The pie chart of the reason for not repairing

The strong correlation between making and repair skills suggests that these skills are often intertwined and that individuals who are confident in one skill are likely to be confident in the other. However, the slight bias towards higher confidence in making skills may indicate a need for further education and training to empower individuals to undertake repairs.

The motivations for repair identified in this study highlight the importance of both economic and emotional factors. By understanding these motivations, manufacturers, policymakers, and repair professionals can develop strategies to encourage repair and reduce waste.

The limitations of this study include the use of a non-probability convenience sample, and do not specify the product category of the repair motivation, which may limit the generalizability of the findings. Future research could employ a larger and more diverse sample to strengthen the findings.

Additional research could explore the impact of cultural and societal factors on repair behaviours, as well as the role of education and training in promoting repair skills. Furthermore, investigating the potential for innovative repair models, such as community repair initiatives and repair cafes, could provide valuable insights for policymakers and industry professionals.

By addressing the limitations and exploring these areas of future research, we can gain a deeper understanding of consumer attitudes and behaviours towards product repair and develop strategies to promote a more sustainable and resilient future.

3.2.5 Summary

This chapter delved into the realm of repair through a multifaceted approach, combining auto-ethnography, ethnographic research, a workshop and a survey.

The auto-ethnographic exploration revealed that traditional repair methods like kintsugi, while aesthetically pleasing, may not always be practical due to time and cost constraints. On the other hand, the double dance of agency in repair is initiated by the broken artefact. The repair of everyday objects like rice cookers highlighted the potential travel of home appliances which causes the context differences and the importance of repairable design, accessible tools, and shared knowledge in repairing practices. The challenges faced in accessing professional bag repair services underscored the need for more accessible repair options. Finally, the analysis of the repair, repurpose, and second-hand market landscape provided a deeper understanding of the complex and interconnected world of repair and repurposing, revealing opportunities for circular economy models and sustainable consumption.

The Kintsugi transformation workshop offered a unique opportunity to bridge traditional and contemporary repair practices. By exploring the concept of repair and the beauty of imperfection, participants gained insights into the potential of digital fabrication for sustainable design. The workshop also revealed the differences between people's definitions of repair and the importance of education and awareness in promoting sustainable repair practices.

The ethnographic study of the community-driven electronics repair club at The Mill shed light on the potential of collective action in fostering a repair culture. However, it also revealed the challenges posed by modern device design, including planned obsolescence, complex designs, and the use of adhesives. These factors hinder repairability and contribute to electronic waste.

The findings of the survey shed light on the complex interplay of factors influencing consumer attitudes and behaviours towards product repair. Perceived repairability is shaped by a combination of product complexity, part availability, and individual skill levels. A strong correlation between making and repair skills suggests that these skills are often intertwined, although a slight bias towards making skills indicates a need for increased emphasis on repair education and training. Motivations for repair are multifaceted, encompassing both economic and emotional considerations. Understanding these motivations is crucial for developing strategies to encourage repair and reduce waste. While this study provides valuable insights, the non-probability convenience sample and lack of specific product category information limit the generalizability of the findings.

In conclusion, this chapter explores repair as a sustainable and empowering practice in different contexts. By understanding the motivations, challenges, and opportunities associated with repair, we can develop a possible proposal to foster a future where repair is valued, accessible, and integrated into the design and lifecycle of products. This requires a shift in mindset, collaborative efforts between designers, manufacturers, and consumers, and systemic changes to promote repairability and durability.

3.3. Proposal: Design for Better Repair Experience

By comparing the overall understanding of repair through literature review and the findings in the ideation and pretesting, a fact was revealed: the right to repair and Design for Repair was often considered from the perspective of product design rather than from a wholistic and systematic view such as repair experience design. Therefore, an updated version of the Design for Repair which is from the perspective of designing a better repair experience was proposed and a design based on the principles was also developed.

3.3.1 Developing Principles of Design for Repair

The Actor Map of Repair

To clarify the actors intertwined in the repair process, an actor map (Figure 3.24), which illustrates the various actors and the product flows involved in the repair of a product, was drawn based on the observation in Ideation and Pretesting stage. The designer and manufacturer are the initial creators of the product. When the product breaks, the user has several options: they can either throw it away, repurpose it, fix it themselves, send it back to the manufacturer for repair or replacement, or have it repaired by a professional repairer. The repairer has the necessary knowledge, skills, tools, and parts to carry out the repair. The dashed lines represent plausible product flows, indicating that the product might not always follow a linear path from creation to disposal but can be repurposed or repaired at various stages. On the other hand, mapping the actors with the product flows could also picture the product life cycle, which helps us focus more on the journey of the product and its repairability.

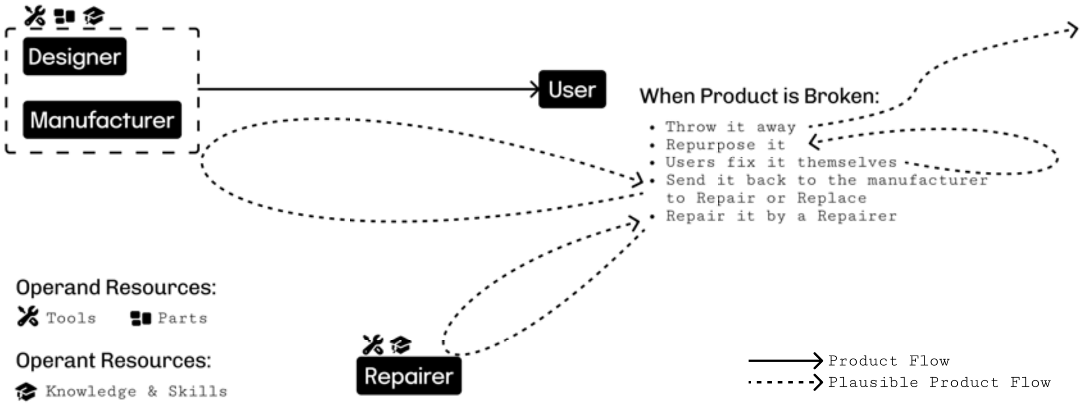


Figure 3.24 The actor map of repair

The Various Levels of Negotiation in Repair

The concept of "Artefact Ecology" [12,13] provides a framework for understanding the complex relationships between artefacts and the humans who interact with them. Also, the concepts of "negotiated endurance" [45] and "repairedness" [49] describe different negotiations in repair. If we combine the three mentioned concepts, Artefact Ecology, negotiate endurance and repairedness, with the actor map of repair from a human aspect, we would be able to redefine repair as "a series of negotiations" (Figure 3.25), since every stage of a repair process requires divergent negotiations with different factors involved and the repair experience is the result of the series of negotiation of repair. For instance, humans have to negotiate with every broken part, the context and resources of repairing the artefact, potential repair decisions, and eventually, the outcome of repair, which is also negotiable.

On the other hand, this diagram (Figure 3.26) visualizes the dynamic process of negotiation and repair within such an ecology from an artefacts' aspect. By examining the various layers of negotiation involved in the repair of a broken artefact, we can gain diverse insights into the resilience and adaptability of these systems.

At the heart of this concept is the notion of an artefact, a physical object or system composed of multiple parts. These parts, in turn, interact with each other and with external actors to form an intricate network. When a part of an artefact

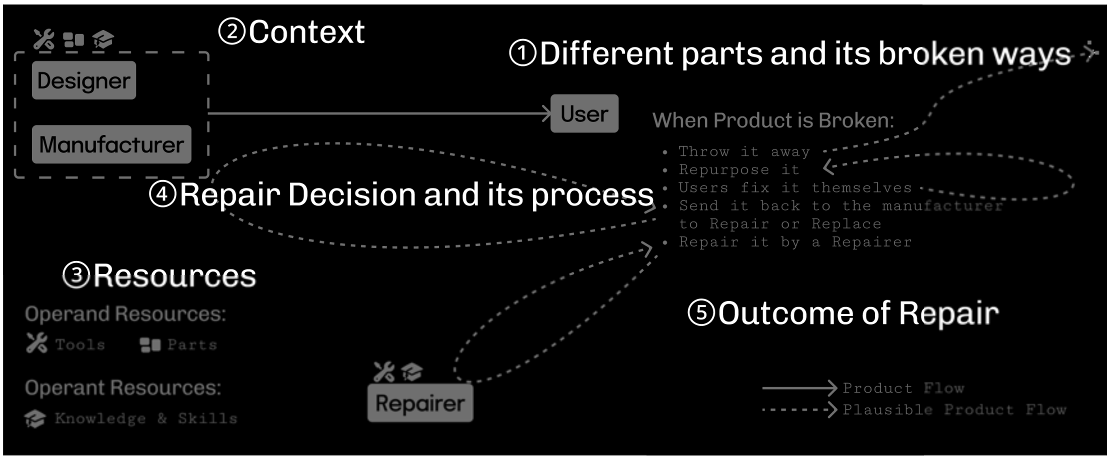


Figure 3.25 Repair: a series of negotiations

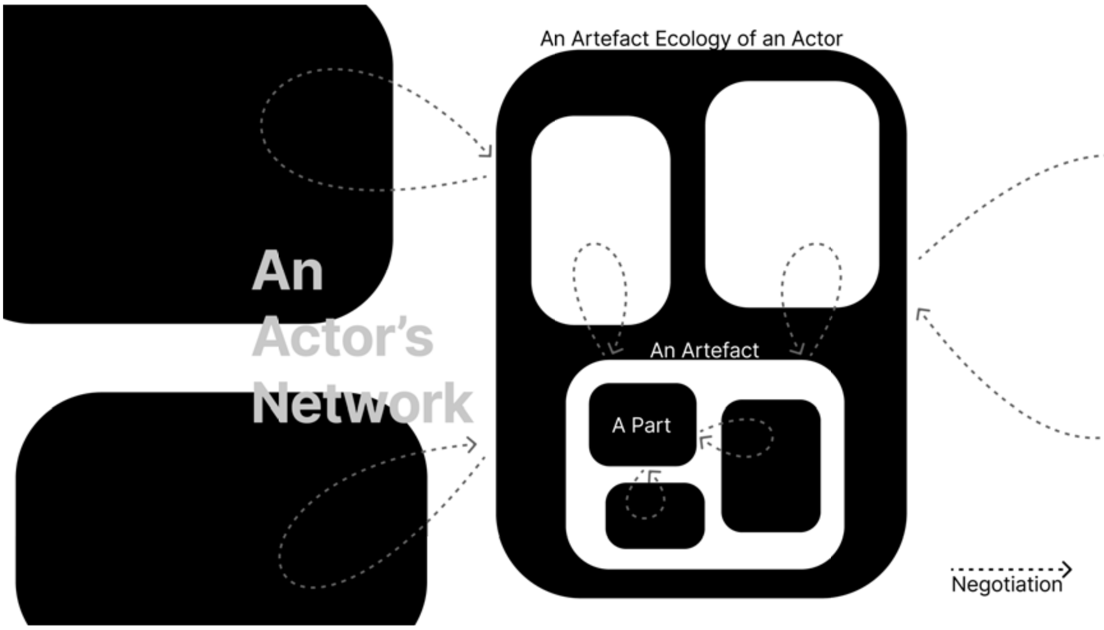


Figure 3.26 The different dynamics of negotiation in the process of repair from micro to macro scale

fails, a series of negotiations may ensue, involving various stakeholders, from the individual components themselves to the human actors who maintain and repair the artefact. The following are the key components:

- Part: Individual components that build up the artefact.
- Artefact: The physical object or system in question.
- Artefact Ecology of an Actor: The ecology includes artefacts and the human interacting with them.
- Actor's Network: This encompasses the various actors (humans, organizations, etc.) involved in the negotiation and repair processes.

The dotted lines in the diagram represent the various levels of negotiation that may occur when a part of the artefact fails:

- Part-to-Part Negotiation: Individual components may need to negotiate with each other which informs the human to find alternative solutions or workarounds, such as the different shapes of broken pieces in the traditional Kintsugi.
- Artefact-to-Artefact Negotiation: The artefact itself may need to negotiate with other artefacts in the ecology, particularly if the repair requires resources or information from external sources, for instance, the tools and parts used in the repair process of the rice cooker.
- Actor-to-Actor Negotiation: Human actors, such as engineers, technicians, and policymakers, may need to negotiate with each other to coordinate repair efforts, allocate resources, and make decisions about the future of the artefact. Take the bag repair service as an example, the repair decision was made after the negotiation between the user and the manufacturer. Also, in the example of the second-hand market, the repairers and the sellers would negotiate the outcome of repair and its selling price.

Through these negotiations, repair activities are initiated, aiming to restore the functionality of the broken part or the entire artefact. The ultimate goal is to achieve a “working version” [49] of the artefact, a state where it can continue to fulfil its intended purpose.

The diagram illustrates the intricate dance of negotiation and repair by humans and artefacts that occur within an artefact ecology. By understanding the various levels of negotiation and its dynamics with the diverse range of actors involved, we can appreciate the complexity and resilience of these systems. As technology continues to advance and artefacts become increasingly interconnected, the importance of effective negotiation and repair strategies will only grow.

The Updated Principles of Design of Repair

The concept of Design for Repair (DfR) has gained increasing significance in recent years as a response to growing concerns about sustainability and the circular economy. While traditional DfR principles often focus on product longevity and ease of repair, this research proposes an updated framework 3.27 that incorporates a broader perspective on the repair process and the diverse range of actors involved, so that a better repair experience could be designed.

The proposed framework is structured around the product life cycle, encompassing the stages of Production, Use, and End of Life. This structure is inspired by the actor map 3.24, which illustrates the various stakeholders involved in the repair process and their interactions with the product.

- Production Stage
  - Using appropriate materials: Prioritize the selection of durable and repairable materials that are suitable for the intended use and can be easily repaired or recycled.
  - Using common parts: Standardize components to facilitate repair and reduce the need for specialized tools or expertise.
  - Modularity and disassembly: Design products with modular components that can be easily disassembled and reassembled, avoiding the use of adhesives that can hinder repair.
- Use Stage

How to Design for Repair?

1. Repair is a process that makes a broken object work again, but the working version is negotiable.
2. Since the object after repair could only be as close as possible to its original status, every working version that is good enough for the user or owner should be acceptable.
3. Checklist of Design for Repair Principles:
   - Production:
     - Using appropriate materials
     - Using common parts
     - Concerning disassembly and reassembly (modularity, no adhesives)
   - Use:
     - Accessibility to repair service
     - Availability of spare parts
     - Clear instructions for maintenance and repair
   - End of Life:
     - Difficulty of disassembly
     - Materials and parts recycle
4. The following tips might be helpful for developing a repairable product:
   - Disassemble to learn.
   - Ask repairers for opinions.
   - Consider the whole system.
   - Embrace hacking if needed.

Figure 3.27 The first version of Design for Repair principles

  - Accessibility to repair services: Provide clear and accessible repair services, including information on authorized repair centres, independent repair options, and self-repair resources.
  - Availability of spare parts: Ensure that spare parts are readily available and affordable, enabling users to repair their products independently or through authorized repair services.
  - Clear instructions for maintenance and repair: Provide comprehensive user manuals and repair guides that are easy to understand and follow.

- End of Life Stage
  - Difficulty of disassembly: Design products that can be easily disassembled at the end of their useful life, facilitating the recovery and recycling of valuable materials.
  - Materials and parts recycling: Prioritize the use of recyclable materials and design for disassembly to maximize the potential for recycling and reuse.

The updated DfR framework also emphasizes the importance of negotiation and collaboration among various actors involved in the repair process 3.26. This includes manufacturers, repair service providers, consumers, and independent repair communities. By fostering open communication and cooperation, it is possible to create a more sustainable and equitable repair ecosystem.

The following tips are based on observations and insights gained from ideation and pretesting stages:

- Disassemble to learn: Take apart existing products to understand their design and identify potential improvements for repairability.
- Ask repairers for opinions: Consult with repair technicians and experts to gain valuable insights into the challenges and opportunities for repair.
- Consider the whole system: Evaluate the entire product lifecycle, from design and manufacturing to use and disposal, to identify potential areas for improvement in repairability.

- Embrace hacking if needed: Encourage a culture of innovation and experimentation, allowing users to modify and repair their products in creative ways.

By adopting the updated DfR principles and incorporating these tips, designers and manufacturers can create products that are more durable, repairable, and sustainable, ultimately contributing to a more circular economy.

3.3.2 From Principles to Concept: A Repairable Design

To bridge the gap between theoretical principles and practical application, we embarked on a redesign project focused on a common household appliance: the electric fan. Despite its relatively simple structure and circuit, the fan often ends up in landfills rather than being repaired. This section explores the potential for a more repairable design, addressing the following key points:

- Developing a repair experience that is both functional and engaging.
- Designing a fan that can be assembled and disassembled without tools or screws.
- Implementing design strategies to support self-repair and empower users to take control of their devices.
- Integrating the creative process of repair into the design to enhance the overall user experience.

A Deeper Dive into Fan Design: A Repairability Analysis

To initiate the redesign process, a comprehensive understanding of existing fan models was essential. Three distinct models (C1, C2, and C3, Figure 3.28) were procured to facilitate a detailed repairability analysis.

The disassembly process (Figure 3.29)revealed varying levels of complexity across the three models (Table 3.2). Model C1 presented the most significant challenge, with its hidden lock structure obstructing the initial disassembly step. Model C2, while offering a more accessible lock, posed difficulties in loosening the screws due to a diverse array of screw types. Model C3, despite its intricate

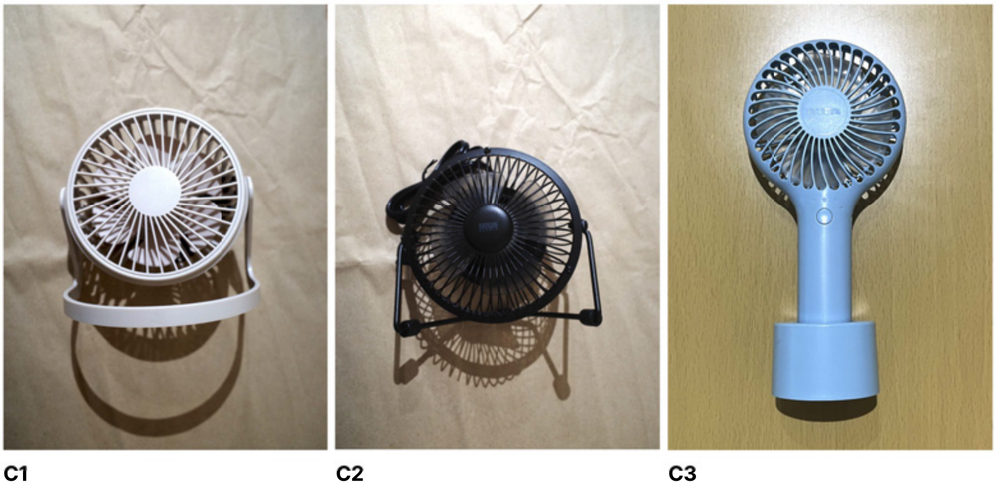


Figure 3.28 Case studies for applying the updated Design for Repair Principles

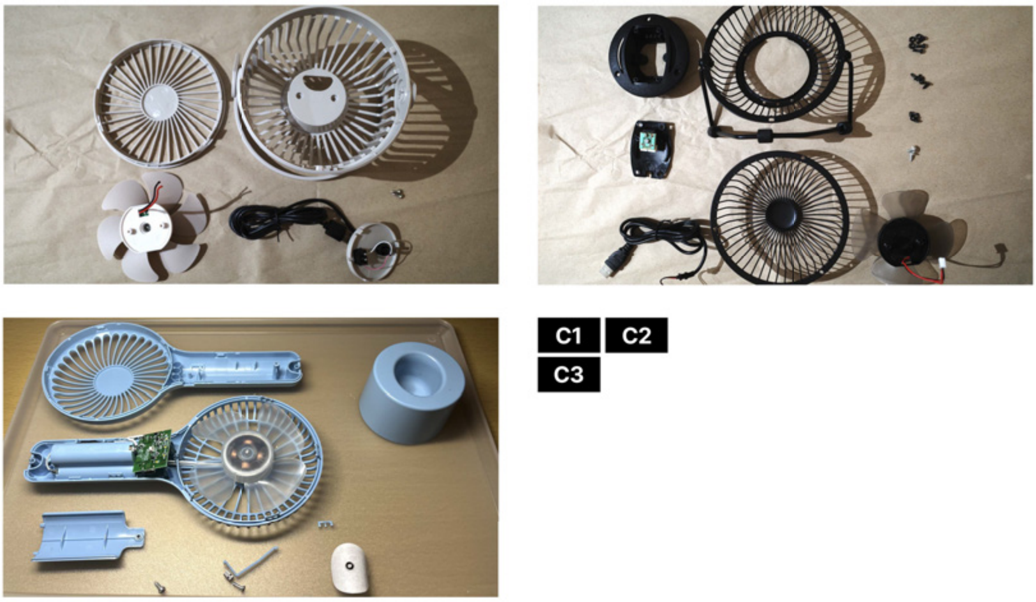


Figure 3.29 Disassembly of C1, C2, C3

Table 3.2 Overview of the analysis of C1, C2, C3

No.	Disassemble Time	Tools and Screws Counts	Note
C1	02;32;28	3 tools, 1 kind of screws	It's difficult to understand how to open since the lock structure is hiding inside.
C2	03;15;01	2 tools, 4 kinds of screws	The lock structure is easier to understand, but it might be tricky to loose the screws.
C3	17;15;11	3 tools, 2 kinds of screws	The structure is the most complicated to understand and disassemble, and it would be nearly impossible to assemble it again because there is some damage to it after disassembling.

design, was successfully disassembled. However, the disassembly process raised concerns about potential reassembly issues, as certain components were prone to damage.

These findings underscore the crucial role of design in influencing product repairability. Simpler disassembly processes can significantly enhance the ease of repair and overall sustainability.

Prototype Development: A Fusion of Tradition and Innovation

Inspired by the insights gleaned from the disassembly analysis, the initial phase of the redesign process involved generating a series of sketches (Figure 3.30). These sketches explored various assembly and disassembly techniques, aiming to create a fan that could be easily repaired and reconfigured.

A particularly intriguing source of inspiration emerged from the realm of traditional Japanese crafts. *Yosegi-zaiku*(寄木細工), a meticulous woodworking technique, employs interlocking pieces to construct intricate patterns without the use of nails. This ancient craft offers a compelling model for a screwless and tool-free assembly and disassembly process, which could potentially be applied to the fan design (Figure 3.31).

User Feedback and Design Iteration

The initial prototype (Figure 3.32) was showcased at Maker Faire (Figure 3.33), where valuable feedback was gathered from attendees. Key insights included:

- Ease of Maintenance: The design was generally praised for its ease of cleaning and maintenance.
- Clarity of Disassembly: Some participants suggested the need for clearer visual indicators to guide the disassembly process.
- Material Innovation: A few participants proposed incorporating recycled materials, such as repurposed Mintia boxes, into the design.

In response to this feedback, the updated prototype introduced the concept of Repair Indicators and further emphasized the potential for Creative Repair.

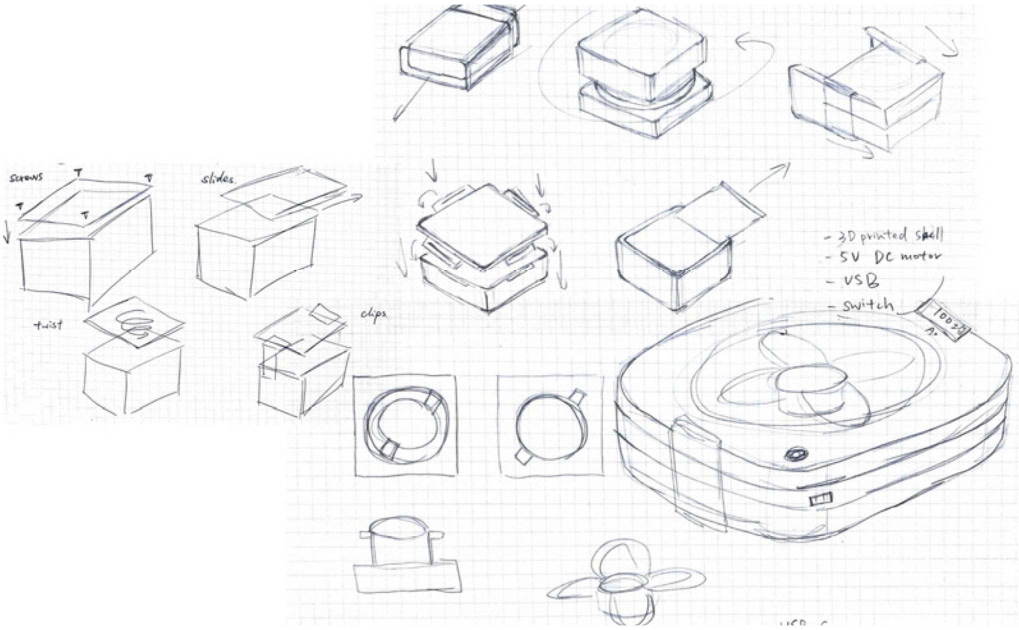


Figure 3.30 Study Sketches of How a fan could be disassembled

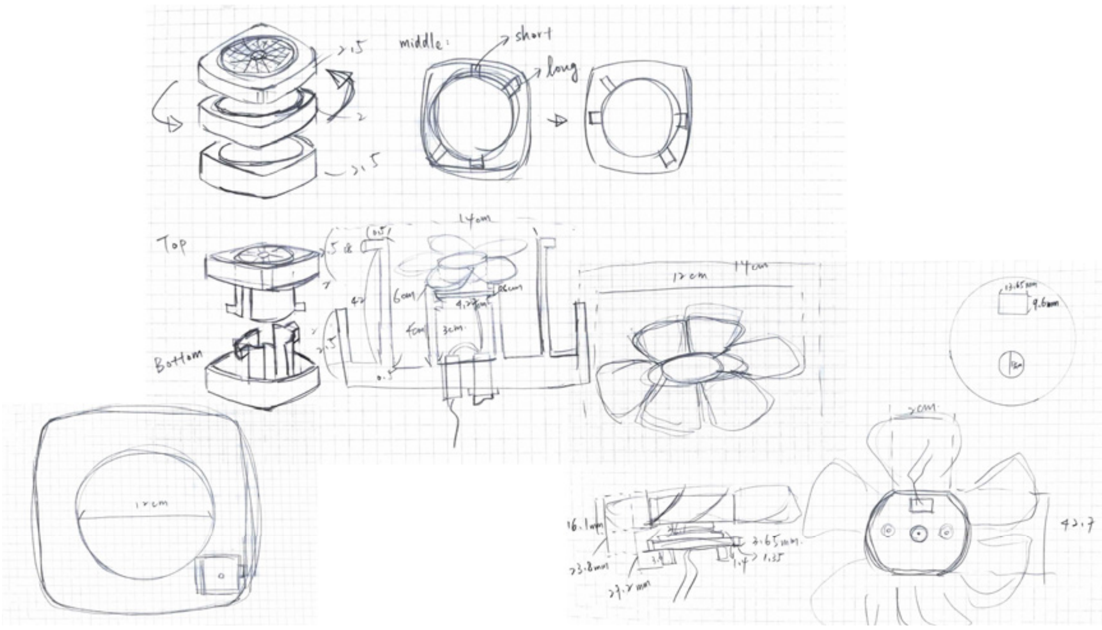


Figure 3.31 Overall concept of redesigning a fan

Figure 3.32 The initial prototype and its disassembly

Repair Indicators: A Navigational System for Devices

Inspired by the metaphor of navigating a space, the Repair Indicator system aims to simplify the disassembly process (Figure 3.34). By providing visual cues and symbols, the indicators reduce reliance on traditional manuals and empower users to independently explore the device's interior.

By adopting a universal design language, the Repair Indicators can be applied to a wide range of electronic devices, making them more accessible for repair and customization. This approach aligns with the principles of self-repair and encourages users to engage in creative problem-solving.

Creative Repair: A New Perspective on Product Design

The concept of Creative Repair (Figure 3.35) extends beyond simple disassembly and reassembly. It envisions a future where users can personalize and modify their devices using readily available materials and techniques. By incorporating design elements that facilitate creative expression, we can foster a community of makers who are empowered to extend the life of their products.

For instance, the fan's modular design could allow users to experiment with

Figure 3.33 Exhibiting in Maker Faire

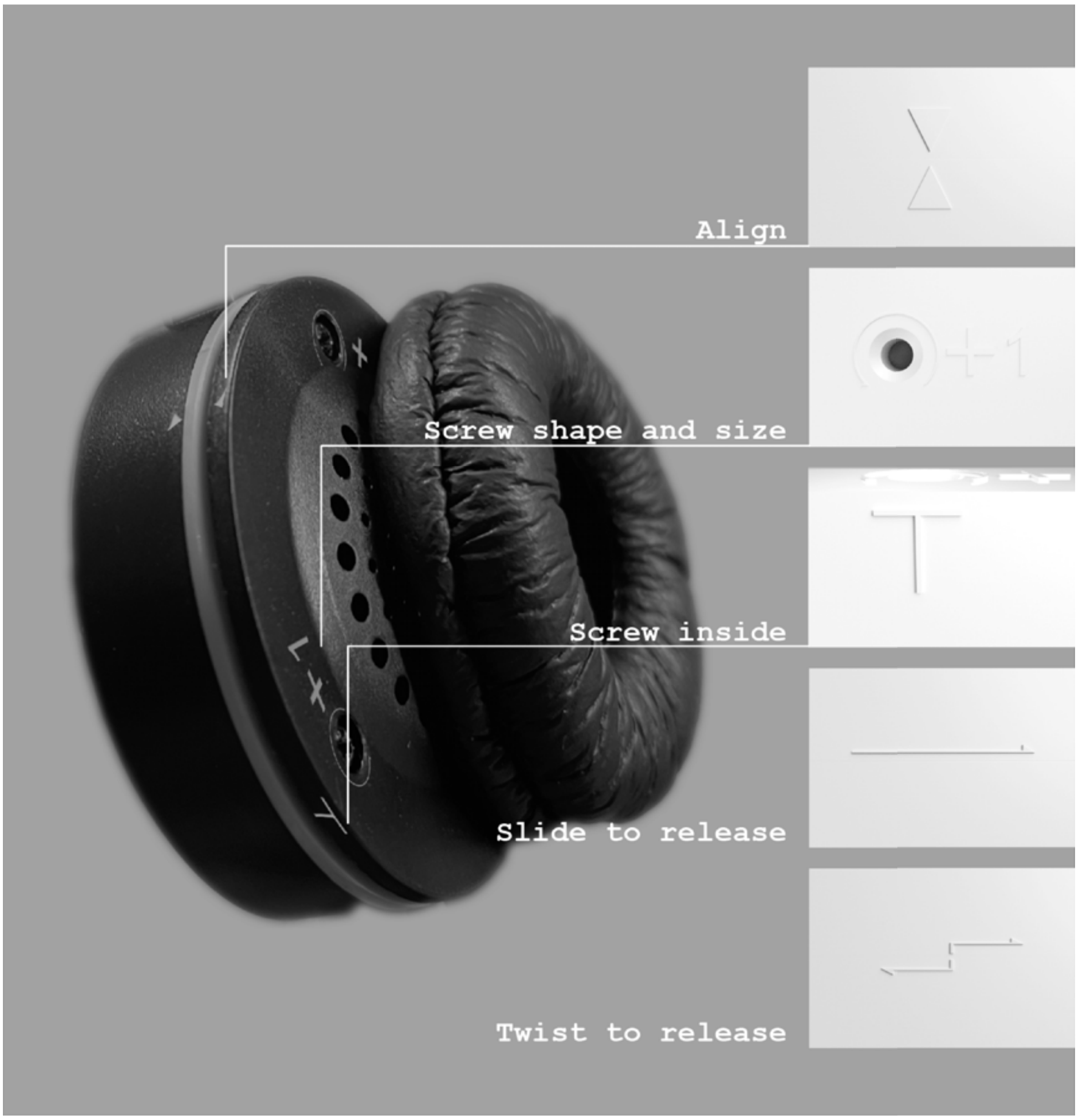


Figure 3.34 Concept of Repair Indicator

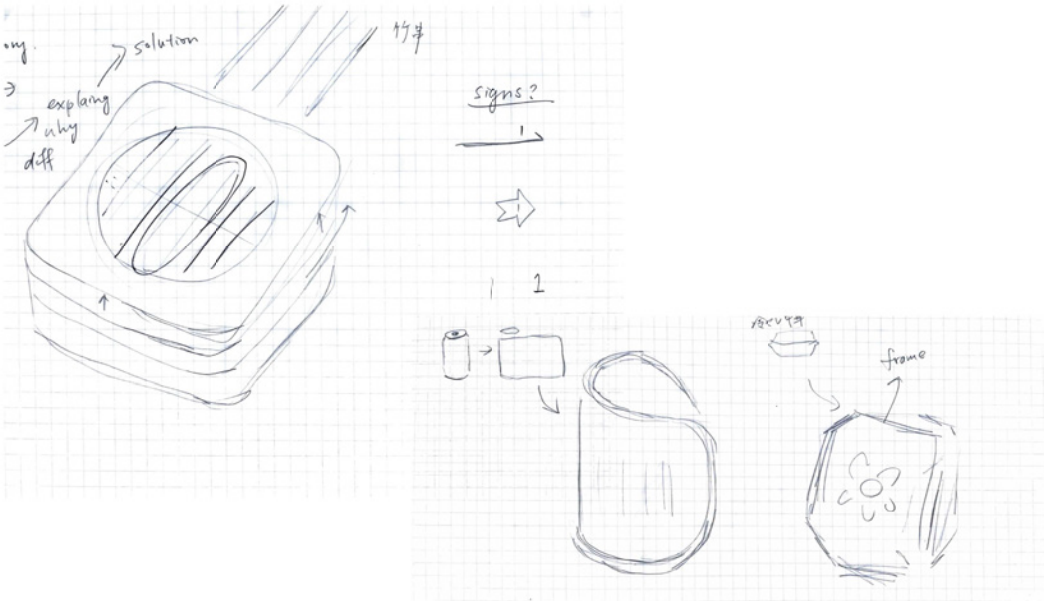


Figure 3.35 Ideas of implementing creative repair experience

different colour schemes, and materials, or even add custom features. By providing a platform for customization, we can encourage users to view their devices as works of art, rather than mere functional objects.

A Repairable Fan: The Final Prototype

The culmination of our research and design efforts led to the development of a Repairable Fan Prototype (Figure 3.36). This innovative design incorporates several key features to promote user-friendly repair and customization:

- Easy Assembly and Disassembly: The fan's modular structure allows for effortless disassembly and reassembly, eliminating the need for specialized tools.
- Repair Indicators: A comprehensive system of visual cues, including both disassembly and wiring indicators, guides users through the repair process, reducing the reliance on complex manuals.
- Creative Repair Potential: The design encourages creative expression by providing opportunities for customization and personalization. Users can

experiment with different materials, colours, and configurations to create a truly unique fan.

By prioritizing repairability and user empowerment, this prototype represents a significant step towards a more sustainable and user-centric future for electronic devices.

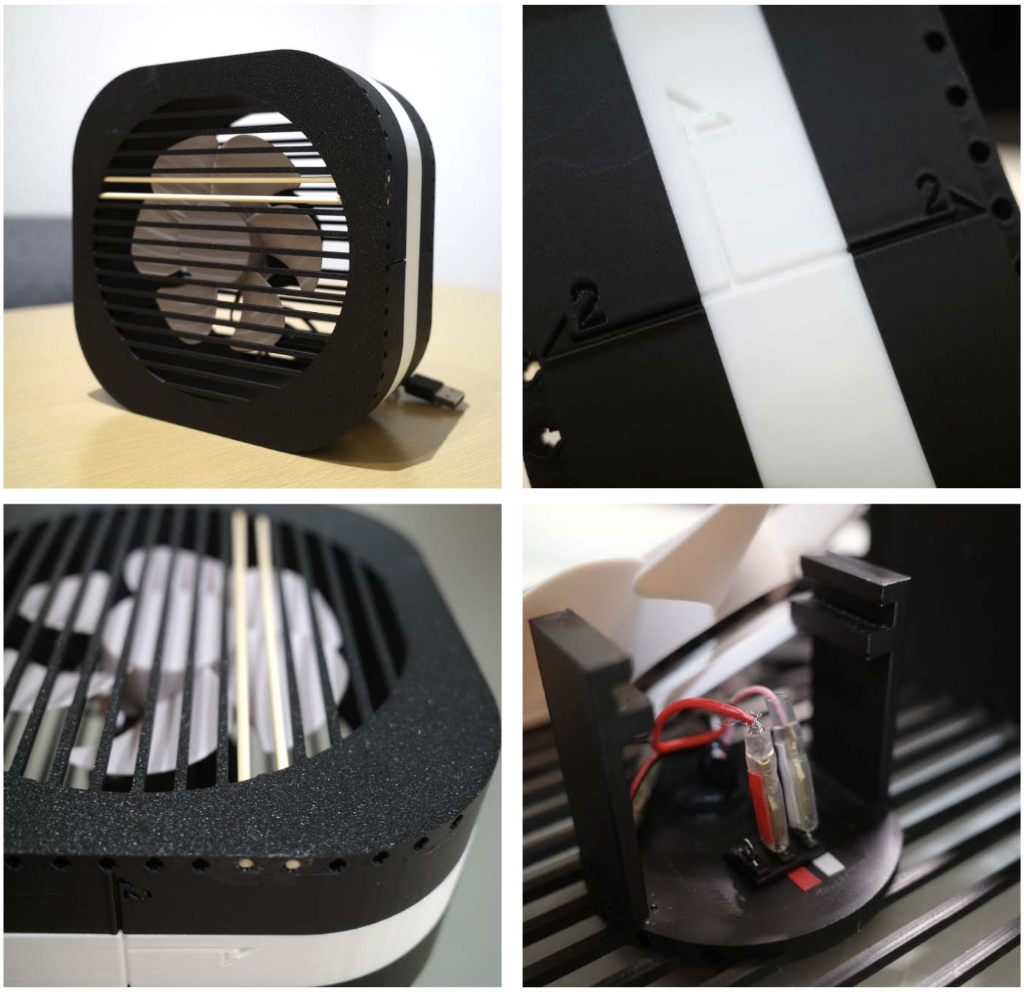


Figure 3.36 A Repairable Design Prototype

Chapter 4
Evaluation and Results

4.1. Proposal Evaluation

The evaluation of the Design for Better Repair Experience proposal was separated into two parts. First, a user experiment that examines the repair experience of the relevant prototype compared to the purchased product, and second, a designer interview which gathers the professionals' feedback on utilising the guideline to ideate concepts. In this section, the settings of the user experiment and designer interview will be demonstrated.

4.1.1 User Experiment

The goal of this study was to evaluate the effectiveness of a prototype designed with a focus on design for repair and repair as a creative process. By conducting user experiments, we aimed to understand people's perspectives toward repair and assess the prototype's repairability.

Five groups, six participants in total were recruited to participate in the experiment. The experiment took place at Keio University between October 29th and November 12th, 2025, with each participant session lasting approximately one hour and involving a two-scenario approach, which was repairing a purchased product and an updated prototype.

Table 4.1 details the diverse ability of making of the individuals involved in the study which might cause the differences in the experiment outcome, according to the correlation result of people's ability to make and repair in the pretest survey (Figure 3.19). Participant P1 possesses average-making abilities, primarily focused on cooking. P2 demonstrates proficiency in working with clay and textiles, but their technical expertise in these areas is limited. P3 is primarily a digital

Table 4.1 The participants of the user experiment and their ability of making

No.	Ability of Making	Repaired Outcome
P1	Average, mainly cooking	U1
P2	Good with clay and textile, but not too technical	U2
P3	Mostly working digitally	U3
P4-1	Good at crafting, but not the electronics	U4
P4-2	Making in a Wasteland Punk style	U4
P5	Good at crafting, but not the circuit-related	U5

Figure 4.1 The table layout of the user experiment

maker, with a strong preference for working with digital tools and software. P4-1 is skilled in crafting but lacks experience with electronics. P4-2 is a maker who specializes in creating objects in a Wasteland Punk style, which means some sort of patching and collaging. P5, similar to P4-1, excels at crafting but lacks experience with circuits. This table effectively highlights the varied backgrounds and interests of the participants, providing a foundation for understanding their potential contributions to the user experiment.

Before the experiment, necessary items were sourced, cameras were set up to record the process, and the purchased product and updated prototype were prepared similarly by removing internal connections and securing the cover shell. Common tools and resources which were possible to find in dollar shops, such as scissors, tapes, bamboo sticks, and wire, were provided on the table (Figure 4.1).

During the experiment, participants were first introduced to the experiment and its objectives. They were then presented with the first scenario, where they were asked to identify and repair the broken parts of a purchased product. Participants were free to either fix the broken part or give up. In the second scenario, participants were also asked to identify and repair a broken part of the prototype, focusing on redesigning and reassembling the broken component, but aiming to fix it in this scenario.

After completing both scenarios, participants were interviewed using a semi-structured questionnaire (Appendix B) to gather insights into their experiences, perceptions of the prototype's repairability, and their overall attitudes toward repair. The collected data was then analysed to draw conclusions about the prototype's effectiveness and identify potential areas for improvement.

4.1.2 Designer Interview

The goal of this study was to gather insights and feedback from experienced product and industrial designers on the efficacy and clarity of the updated Design for Repair Guideline, which focuses on designing a better repair experience. By understanding their perspectives, we aimed to identify areas of strength, weaknesses, and potential improvements in the guidelines, so that the updated Design for Repair Guideline would be possibly implemented in the industry. Four experienced product or industrial designers in different design categories were recruited to participate in the study, selected based on their relevant industry experience and expertise in product design.

Table 4.2 details the professional backgrounds of the individuals interviewed for this study. Designer D1 specializes in creating bags and tools and works as a freelancer, managing their own projects independently. D2 focuses on UI/UX design and digital product development within an in-house setting, working as part of a larger team. D3 has expertise in industrial product and furniture design, working within an agency environment. Lastly, D4 is an in-house designer specializing in laptop design. This table provides a snapshot of the diverse design expertise and professional experiences of the interviewed designers, which are valuable for understanding their perspectives on the design process and challenges faced in their respective fields.

Table 4.2 Interviewed designers and their profession

No.	Design Category	Working Style
D1	bags and tools	Freelance
D2	UI/UX, digital products	In-house
D3	Industrial Products, Furniture	Agency
D4	Laptop	In-house

The procedure involved a three-step process, conducted either online or in person. First, the information of the researcher and the purpose of this study were introduced to the participating designers, and the overall process of the interview and subsequent design exercise was explained in detail. Second, participants were provided with the updated Design for Repair Guideline (Appendix C) and an example prototype with its relevant experiment outcome to illustrate the concepts. They were then tasked with generating design ideas for a product category they were familiar with, applying the principles outlined in the guidelines. Participants were encouraged to create multiple design sketches, focusing on incorporating repair-friendly features and considerations. Photographs were taken of their sketches to document their design process and ideas. Finally, a semi-structured interview (Appendix D) was conducted to gather feedback on the guideline. The interview questions were designed to probe participants' thoughts on the clarity, relevance, and usability of the guideline.

4.2. User Experiment Result

4.2.1 Overall Observations

The user repair behaviour observed in this study aligns with Hiescher's three-phase model of home repair [35]: diagnosis, fixing, and integration. All participants initiated the repair process in both scenarios by diagnosing the issue through a simple power-on test (Figure 4.2).

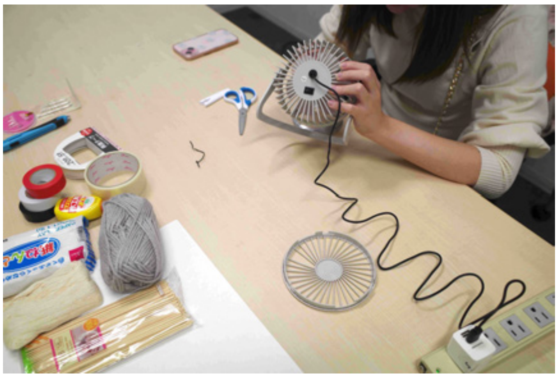


Figure 4.2 Participant diagnosing the problem by plug-in the power

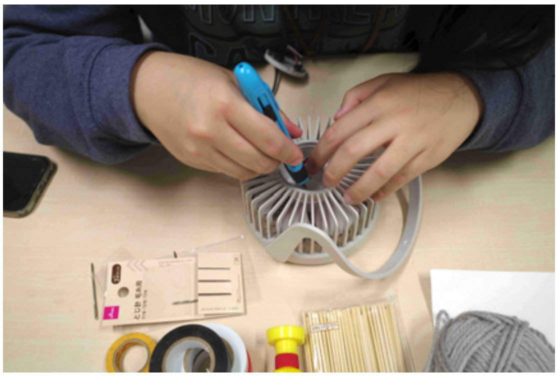


Figure 4.3 Participant using a cutter as the screwdriver to loosen the screws

Figure 4.4 Participant repaired the appearance by using the toothpick as the missing part

Figure 4.5 Participants disassembling the prototype without using tools

Figure 4.6 Participant wiring the power and motor following the repair indicator

Repair of Purchased Product

In the case of the purchased fan, a significant number of participants abandoned the repair attempt after the initial diagnosis. This suggests that the perceived complexity of the repair, coupled with the lack of readily available tools and materials, discouraged further efforts. Those who attempted the repair demonstrated creative problem-solving by utilizing everyday objects as makeshift tools and parts, for instance, using a cutter knife as a screwdriver (Figure 4.3) or a toothpick as the missing part (Figure 4.7). But ultimately, none of the participants were successfully restoring the fan's functionality, due to the lack of professional repair tools, such as soldering iron.

Figure 4.7 Participant weaved on the prototype as a way of creative repair

Repair of Updated Prototype Fan

In contrast, the repair of the prototype fan yielded more positive results. Nearly all participants were able to successfully disassemble, modify, and reassemble the device without the aid of specialized tools (Figure 4.5, 4.6). The repairs showcased a range of creative approaches, from simple fixes to more elaborate modifications (Figure 4.7). The five repaired prototypes, labelled as U1 to U5, presented in Figure 4.8 illustrate the spectrum of creativity observed, ranging from minor modifications, such as using black tape and bamboo sticks which are close to their original appearance, to radical re-imaginings of the original design, for example, weaving with yarns or modifying it into a little monster.

These findings highlight the influence of product design on repair behaviour. The simplicity and modularity of the prototype fan facilitated user intervention, while the complex internal structure of the purchased fan presented a more challenging repair task.

4.2.2 User Experience with a Purchased Product

Initial Reactions and Expectations

Participants generally approached the task with a mix of curiosity and apprehension. They were intrigued by the challenge of repairing a broken device but were also aware of the potential difficulties. As P1 expressed, “I really wanted to fix it, but at the beginning, I didn’t know how to do it or how to take it apart.”

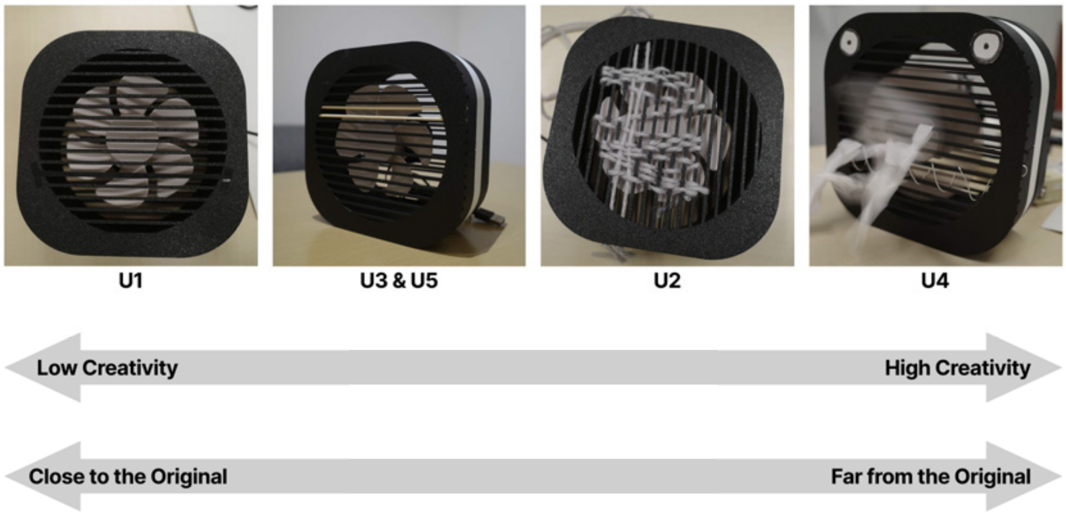


Figure 4.8 The result of the user experiment

This initial uncertainty highlights the importance of user-friendly design, which can reduce anxiety and encourage exploration.

Challenges Encountered

Several key challenges emerged during the repair process:

- Difficulty in Disassembly: Many participants struggled to open the device without damaging it. The lack of visible seams or release mechanisms made it difficult to identify the correct disassembly procedure. As P2 noted, "I couldn't open or it didn't allow me to open the fan and get inside."
- Limited Access to Internal Components: Once the device was opened, participants often found it challenging to access the specific components that needed repair. The complex internal structure and the use of small, delicate parts hindered the repair process.
- Lack of Clear Instructions: The absence of clear instructions or visual guides made it difficult for users to understand the repair steps. This led to trial-and-error approaches, which often resulted in frustration and wasted time.

- Tool Limitations: Participants were provided with a limited set of tools, which further restricted their ability to perform precise repairs. The lack of specialized tools, such as screwdrivers or pliers (Figure 4.3), made it difficult to manipulate small components.

Emotional Responses

The challenges encountered during the repair process had a significant impact on participants' emotional responses. Many expressed feelings of frustration, particularly when they were unable to identify the problem or when their attempts to repair the device failed. As P2 stated, "I gave up pretty quickly, but there was no way to get inside there."

However, some participants also experienced a sense of satisfaction and accomplishment when they were able to successfully repair some parts of the device, for instance, figured out the correct way of the wire connection through trial and error. This positive emotional response highlights the potential for repair to be a rewarding and empowering activity.

By understanding the challenges and emotional responses associated with repairing a purchased product, designers can develop products that are more repairable and user-friendly.

4.2.3 User Experience with an Updated Prototype

Initial Reactions and Engagement

Participants generally responded positively to the updated prototype, expressing feelings of curiosity and excitement. The visible repair points and the inclusion of additional materials encouraged exploration and experimentation. As P2 stated, "I think I was feeling a sense of play and curiosity." This initial engagement suggests that the updated prototype was more inviting and less intimidating than the purchased product.

Design Features and User Interaction

Several design features of the updated prototype facilitated a more positive user experience:

- Visible Repair Indicators: The clear and accessible repair indicators made it easy for users to identify the areas that needed attention. For instance, the participants can follow the indicators to open the shell of the fan (Figure 4.5) and connect the wire inside (Figure 4.6). This reduced the initial uncertainty and confusion experienced with the purchased product.

- Additional Materials and its Creative Repair Process: The provision of additional materials, such as yarn (Figure 4.7) and tape, expanded the possibilities for repair and customization. Participants were able to experiment with different techniques and create unique solutions (Figure 4.8).

- Clear Labelling and Instructions: While not explicitly mentioned in the quotes, it is likely that the updated prototype included clear labelling and instructions, which would have further aided the repair process.

Users were able to engage with the prototype in a variety of ways. Some focused on repairing the functional aspects of the device, while others explored creative possibilities for customization. As P2 noted, "It's like a combination of repair and upcycle." This flexibility allowed users to personalize the device and make it their own.

Comparison to the Purchased Product

In comparison to the purchased product, the updated prototype offered a significantly more positive user experience. The clear design cues, accessible components, and additional materials made the repair process more enjoyable and less frustrating. Participants were able to engage with the device on a deeper level, exploring both functional and aesthetic possibilities.

By incorporating Design for better repair experience principles, the updated prototype demonstrated the potential for products to be designed with repair in mind. This approach can lead to increased user satisfaction, reduced waste, and a more sustainable future.

4.3. Designer Interview Result

4.3.1 Analysing Sketches

The designers' sketches reveal a convergence of practical and innovative approaches to product repair experiences. D1 emphasizes the importance of modularity, proposing a simple yet effective solution for replacing damaged bag straps. This aligns with the concept of design concerning disassembly in the production stage which facilitates easy repairs (Figure 4.9). D2 highlights the need for systematic repair processes, particularly for digital devices, suggesting that a more efficient feedback system could enhance user experience (Figure 4.10). D3 introduces a creative and sustainable solution for repairing broken objects using readily available materials, demonstrating the diversity of possible working versions through the potential for low-cost, DIY creative repairs (Figure 4.11). D4 focuses on the preservation of digital data during hardware repairs, advocating for systems that enable seamless data transfer to temporary devices (Figure 4.12). Collectively, these sketches underscore the designers' understanding of the challenges and opportunities in product repair and its experience, highlighting the importance of modularity, user-centric design, and sustainability in creating a better repair experience.

4.3.2 Comments on Updated Design for Repair Principles

This section delves into the designers' perspectives on the updated Design for Repair guideline, examining their understanding of core principles, their interpretations of these principles, and their experiences with product repair. By analysing their insights, we gain valuable insights into the challenges and opportunities of designing for repair, as well as the potential for improving the repairability of products across various industries.

The interviews revealed a varying degree of understanding of core repairability principles among the designers. Modularity was a concept understood by several participants. D1, for example, recognized the importance of modular design in bags, highlighting the value of replaceable components. This understanding aligns with the principle of designing products with easily replaceable parts to extend

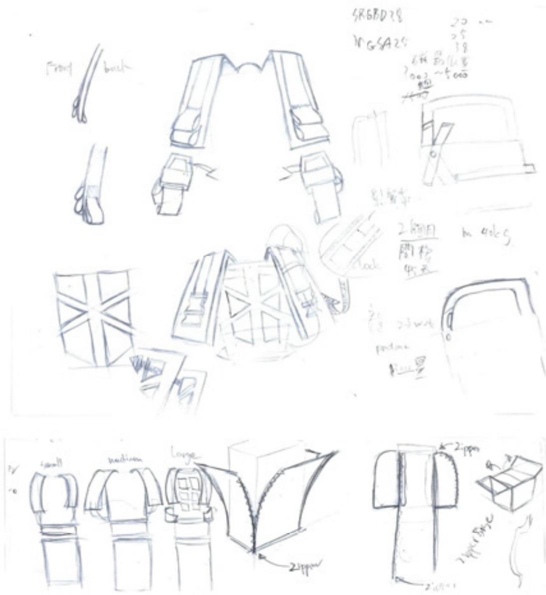


Figure 4.9 Outcome sketch of D1 (MING-CHIEH(Woody), CHANG)

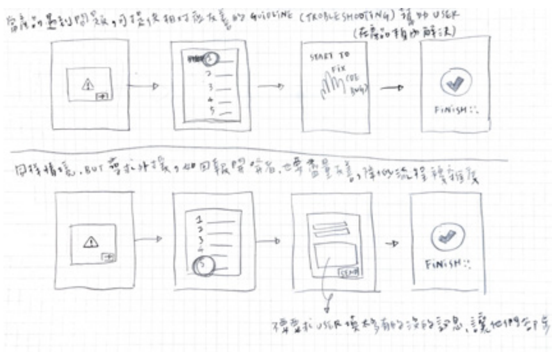


Figure 4.10 Outcome sketch of D2

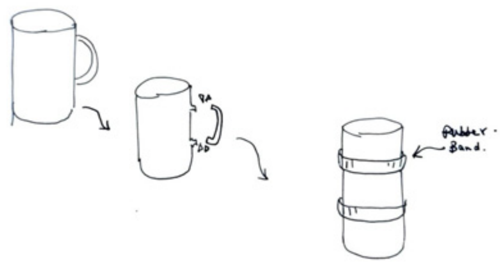


Figure 4.11 Outcome sketch of D3

Figure 4.12 Outcome sketch of D4

their lifespan. Accessibility was also recognized as a crucial aspect of repairability. D3 emphasized the need for clear instructions and readily available replacement parts. This highlights the importance of designing products that are easy to repair, even for users with limited technical expertise. While not explicitly stated by all designers, the importance of material choice was implicit in many discussions. The selection of durable and repairable materials is essential for extending a product's lifespan and reducing the environmental impact of its disposal.

The designers demonstrated varying levels of depth in their interpretation of repairability principles. The concept of a "working vision" was particularly nuanced. D3, for instance, recognized that different users may have different expectations for what constitutes a repaired product. This understanding is crucial for designing products that can be repaired in various ways to meet diverse user needs. A user-centric approach was consistently emphasized by the designers. However, there was some debate on whether this should always prioritize repairability. While most designers agreed on the importance of considering user needs, some, like D4, suggested that balancing aesthetics, functionality, and sustainability messaging could be a more effective approach. The tension between aesthetics and function was also acknowledged by the designers. While aesthetics are important for consumer appeal, they should not compromise the product's repairability. D4 suggested that focusing on branding and sustainability messaging could help balance these competing priorities.

The designers presented a spectrum of repair experience designs, each with its unique strengths and weaknesses. Though People frequently dispose of IKEA products once they are no longer functional, IKEA was highlighted as a prime example of user-friendly self-assembly, empowering consumers with clear, visual instructions. This approach, while effective for simple furniture, may not be suitable for complex electronic devices. Apple, on the other hand, offers a more streamlined repair process through its replacement program, prioritizing user satisfaction and sustainability. However, their aggressive marketing tactics often encourage consumers to upgrade to newer models, potentially undermining the longevity of their products. In contrast, companies like Balmuda, while producing high-quality products, have been criticized for their cumbersome repair processes, which can deter consumers from seeking repairs. These examples illustrate the trade-offs between user experience, sustainability, and business objectives in designing for repair. While IKEA excels at empowering users to assemble their own products, Apple prioritizes a seamless replacement experience, and Balmuda's repair process could be improved. Ultimately, the optimal repair experience design depends on factors such as the product's complexity, the target audience, and the company's sustainability goals.

The designers' insights offer a nuanced perspective on the potential applications of updated design for repair principles. While D2 highlights the challenges of applying these principles to biodegradable materials, they also emphasizes the inherent repairability of digital products due to their ongoing development and updates. D3's observation that daily utensils are easier to repair than complex household appliances underscores the need for design strategies that can be applied across a wide range of product categories. D4 raises a critical question regarding the ownership and control of products that are no longer supported or repairable, suggesting that the longevity of digital products is tied to ongoing support and updates.

The designers also identified several challenges in applying design for repair principles. Industry constraints, such as short product lifecycles and cost pressures, often impede the implementation of these principles. Additionally, the lack of clear and actionable guidelines can hinder designers' efforts to create repairable products. Furthermore, technical limitations, especially in electronics, can pose significant challenges in designing products that are both functional and repairable. Collectively, these perspectives indicate that the application of design for repair principles is both promising and complex, requiring tailored approaches for different product categories and addressing broader issues related to product ownership and sustainability.

The designers offered valuable insights into the challenges and opportunities of developing the design for repair. They highlighted the importance of defining what constitutes a "repair," noting the distinction between user-initiated modifications and professional-level restoration. The designers also emphasized the need to balance user freedom with adherence to industrial standards. While they appreciated the guidelines' systematic approach to sustainability, they suggested that more specific guidance is needed for complex products like laptops. The designers argued that guidelines should provide practical examples and case studies to illustrate how to apply sustainability principles to different product categories. Additionally, they emphasized the need to consider the trade-offs between repairability and other design factors, such as product size, cost, and performance.

The designers also provided positive feedback on the guidelines. D3 highlighted the guideline's effective categorization of the product life cycle, suggesting a structured approach to sustainable design. D4 praised the guideline's holistic perspective, aligning with their understanding of sustainability as a systematic approach. They also noted the guideline's potential to encourage more systemic thinking in product design.

The designers' diverse perspectives offer a nuanced understanding of the challenges and opportunities in designing for repair. While they recognize the importance of principles like modularity and accessibility, they also highlight the complexities of balancing user experience, sustainability, and business objectives. The case studies presented illustrate the various approaches to repair design, from user-friendly self-assembly to professional replacement services. To effectively implement design for repair, it is crucial to consider the specific needs of users, the capabilities of manufacturers, and the evolving landscape of technology and sustainability. By addressing these factors, we can create a future where products are designed to last, repaired easily, and ultimately contribute to a more sustainable society.

Chapter 5
Discussion and Conclusion

5.1. How might we design a better repair experience?

This research explored the shift in focus from designing for repair to designing the experience of repair, recognizing that repair is not solely a technical act but a complex interaction between humans and artefacts within a broader system. This perspective acknowledges that a positive repair experience is crucial for promoting product longevity and sustainability.

Negotiation and User Experience

This study answered the question, "How do humans and artefacts interact in the repair process?", by redefining repair as a series of negotiations in which the human and the artefact both have the agency, but the artefact initiates the interaction. Also, the repair experience can be understood as the outcome of a series of negotiations at various levels (part-to-part, artifact-to-artifact, actor-to-actor). A smoother, less frictional negotiation at each stage contributes to a more positive overall experience. User experiments with redesigned prototypes incorporating updated Design for Repair principles (tool-less disassembly/assembly, repair indicators, creative repair opportunities) demonstrated a reduction in user uncertainty and an increase in enjoyment. These findings suggest that designing for the repair experience can indeed encourage users to engage in repair activities, validating the hypothesis that user-centric design positively influences repair willingness.

Designer Perspectives and Industry Examples

From a designer's perspective, a systematic approach to repair design, as provided by the guidelines, was well-received. The analysis of various industry examples revealed a spectrum of repair experience design strategies. IKEA, for example, excels at empowering users through self-assembly with clear instructions, leveraging the "IKEA Effect" to enhance perceived value and engagement [77–79]. However, this approach is less applicable to complex electronics. Apple, conversely, prioritizes a streamlined experience through replacement programs and sleek design, achieving "dematerialization" [6]. Yet, their marketing strategies can inadvertently encourage replacement over repair [9], potentially undermining sustainability goals. This highlights the tension between user satisfaction, business models, and environmental responsibility.

Sustainability and Business Models

The discussion further explored the link between design for repair and sustainable business practices. Re-manufacturing was identified as a particularly promising strategy for retaining embodied energy and value [80]. Closing the price gap between repair and replacement is crucial [9], as current market trends often incentivize replacement through trade-in programs that foster brand loyalty but shorten product lifespans [52]. Research suggests that factors like accessible repair manuals, clear repair information, user-repair capabilities, and consideration of repairability at the point of purchase positively influence future purchase decisions and recommendations [81]. Interestingly, the cost spent on the repair itself was not found to be a significant factor in repurchase intent. However, other studies indicate that consumers who have spent less on repairs are less likely to recommend the repaired product [57]. This potentially suggests a correlation between perceived value and repair investment. Further research by Raihanian Mashhadi et al. [57] also highlighted the prevalence of impact and water damage as failure causes in consumer electronics, emphasizing the need for durable designs. They also identified disassembly difficulties and spare parts shortages as key barriers to consumer repairs.

This research demonstrates the importance of shifting the design focus from the product itself to the entire repair experience. By understanding the negotiation processes inherent in repair and incorporating user-centred design principles, it is possible to create more engaging and less frustrating repair experiences, thereby promoting product longevity and contributing to a more sustainable consumption model. However, aligning these design strategies with sustainable business models and addressing industry-specific challenges remains a crucial area for future research and implementation.

5.2. Limitation and Future Work

This research, while providing valuable insights into the application of design for repair principles from the perspective of designing a better repair experience, acknowledges several limitations that suggest avenues for future work:

- Guideline Specificity and Scope:

  A primary limitation lies in the generality of existing design for repair guidelines. This study highlighted the need for more detailed and specified guidance, tailored to different product categories and complexities. Future research should focus on developing concrete, actionable guidelines, potentially through case studies and practical applications within specific industries. This includes creating more specific guidance for complex products like laptops and addressing the unique challenges presented by IoT devices, which combine software, hardware, and data components, as noted by Boniface et al. [30]. This research also highlighted the importance of defining what constitutes a "repair," distinguishing between user-initiated modifications and professional-level restoration. Future work could explore this distinction further, developing taxonomies of repair actions and corresponding design strategies.

- Scenario and Product Category Breadth:

  This study focused on a limited set of scenarios and product categories. Future research should expand the scope to encompass a wider range of products, considering diverse use contexts and repair needs. This broader perspective would allow for the development of more robust and generalizable design principles. The research also identified the influence of industry constraints, such as short product lifecycles and cost pressures, on the implementation of design for repair. Future work could investigate strategies to overcome these barriers, exploring business models and policy interventions that incentivize repairable product design.

- Actor Perspective and Communication:

  This research primarily considered the perspectives of users and designers. Future studies should incorporate the viewpoints of other key actors in the product lifecycle, such as manufacturers, repair technicians, and policymakers. This broader stakeholder engagement would provide a more holistic understanding of the challenges and opportunities associated with design for repair. Furthermore, this research did not deeply investigate the optimal methods for delivering and communicating design for repair concepts to designers. Future work should explore effective communication strategies, including educational materials, design tools, and industry standards, to facilitate the practical application of these principles. This could include developing training programs, design checklists, and software tools that integrate design for repair considerations into the product development process.

5.3. Conclusion

This thesis has explored the critical shift in perspective from designing for repair to designing the experience of repair. Recognizing that repair is not merely a technical intervention but a complex interplay between humans, artefacts, and the surrounding system, this research has argued that a positive repair experience is paramount for promoting product longevity and fostering a more sustainable consumption model. This research adopted a two-stage design process (Figure 3.1) to investigate and address this complex issue.

The first stage, Ideation and Pretesting, focused on gathering rich insights into the multifaceted nature of repair experiences. This involved a combination of qualitative and quantitative research methods. Auto-ethnography provided personal reflections on diverse repair activities, from traditional Kintsugi to everyday appliance fixes, offering a grounded understanding of individual repair journeys.

Ethnographic studies of a London-based repair community provided valuable insights into collaborative repair practices and the social dimensions of repair. A hands-on Kintsugi Transformation Workshop further deepened the understanding of repair processes and their transformative potential. Complementing these qualitative approaches, a repair survey gathered quantitative data on people's repair experiences and attitudes, providing a broader statistical context.

The second stage, Proposal, is built upon the insights gained from the Literature Review and the Ideation and Pretesting stage. This stage focused on translating the research findings into practical design solutions for a better repair experience. A key component of this stage was the case study, "Redesigning a Fan," which served as a practical demonstration of how the principles and insights derived from the previous stages could be applied to create a more repairable and sustainable product. This case study provided concrete examples of how design interventions can improve the repair process and enhance the user experience.

By framing repair as a series of negotiations occurring at multiple levels, this study highlighted the importance of minimizing friction at each stage to create a seamless and enjoyable repair experience. User-centred design principles and accessible repair support, such as tool-less disassembly/assembly, clear repair indicators, and opportunities for creative problem-solving, were shown to significantly reduce user uncertainty and enhance engagement in repair activities. This underscores the direct correlation between a well-designed repair experience and increased user willingness to repair.

The analysis of diverse industry examples mentioned in the interview, from IKEA's user-friendly self-assembly model to Apple's streamlined replacement programs, revealed the spectrum of existing approaches to enhance repair experience and their respective strengths and weaknesses. While some strategies excel at empowering users, others prioritize efficiency or brand loyalty, sometimes at the expense of product longevity and environmental sustainability. This highlighted the complex interplay between user experience, business models, and the broader goals of sustainability.

Ultimately, this thesis demonstrates that designing for the repair experience is not just about making products easier to fix; it is about fostering a cultural shift towards valuing repair, extending product lifespans, and minimizing waste. By understanding the multifaceted nature of the repair process, through a rigorous design process encompassing both qualitative and quantitative research and practical application through a case study, and adopting a user-centric approach, we can create a future where repair is not a last resort but an integral and valued part of the product lifecycle. This requires a collaborative effort from designers, manufacturers, policymakers, and consumers to prioritize repairability, promote sustainable business models, and empower individuals to engage in meaningful acts of repair. Future research should focus on developing more specific design guidelines for diverse product categories, exploring innovative business models that incentivize repair, and further investigating the complex interplay between user behaviour, product design, and environmental sustainability.

References

[1] Right to repair: Making repair easier for consumers. URL: https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1794.

[2] Leanne Wiseman and Jay Sanderson. Design-Led Repair: Insights, Anecdotes and Reflections from Australian Repairers. In Eleni Kalantidou, Guy Keulemans, Abby Mellick Lopes, Niklavs Rubenis, and Alison Gill, editors, *Design/Repair: Place, Practice & Community*, pages 67–90. Springer Nature Switzerland, Cham, 2023. URL: https://doi.org/10.1007/978-3-031-46862-9_4, doi:10.1007/978-3-031-46862-9_4.

[3] プロジェクト Home Repairs | ZARA 日本. URL: https://www.zara.com/jp/ja/sustainability-home-repairs-mkt7998.html.

[4] RE.UNIQLO Studio - repair and recycle clothes | UNIQLO UK. URL: https://www.uniqlo.com/uk/en/special-feature/reuniqlo-repair-studio.

[5] Returns, Repairs & Exchanges - Patagonia. URL: https://www.patagonia.com/returns.html.

[6] Nathan Shedroff. *Design is the problem: the future of design must be sustainable.* Rosenfeld Media, Brooklyn, N.Y, 2009.

[7] Giles Slade. *Made to Break: Technology and Obsolescence in America.* Harvard University Press, 2006. URL: https://www.jstor.org/stable/j.ctvjhzqd7.

[8] Lara Houston, Steven J. Jackson, Daniela K. Rosner, Syed Ishtiaque Ahmed, Meg Young, and Laewoo Kang. Values in Repair. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, CHI '16,

pages 1403–1414, New York, NY, USA, 2016. Association for Computing Machinery. URL: https://dl.acm.org/doi/10.1145/2858036.2858470, doi:10.1145/2858036.2858470.

[9] Aaron Perzanowski. *The right to repair: reclaiming the things we own.* Cambridge University Press, Cambridge, United Kingdom ;, 2022.

[10] Pauline Munten and Joëlle Vanhamme. To reduce waste, have it repaired! The quality signaling effect of product repairability. *Journal of Business Research*, 156:113457, February 2023. URL: https://www.sciencedirect.com/science/article/pii/S0148296322009225, doi:10.1016/j.jbusres.2022.113457.

[11] repair, December 2024. URL: https://dictionary.cambridge.org/dictionary/english/repair.

[12] Susanne Bdker and Clemens Nylandsted Klokmose. The Human–Artifact Model: An Activity Theoretical Approach to Artifact Ecologies. *Human–Computer Interaction*, 26(4):315–371, December 2011. Publisher: Taylor & Francis _eprint: https://doi.org/10.1080/07370024.2011.626709. URL: https://doi.org/10.1080/07370024.2011.626709, doi:10.1080/07370024.2011.626709.

[13] Susanne Bødker and Clemens Nylandsted Klokmose. Dynamics in artifact ecologies. In *Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design*, NordiCHI '12, pages 448–457, New York, NY, USA, 2012. Association for Computing Machinery. URL: https://dl.acm.org/doi/10.1145/2399016.2399085, doi:10.1145/2399016.2399085.

[14] Robin Hanson. Adapt Or Start Over?, October 2024. URL: https://www.overcomingbias.com/p/adapt-or-start-overhtml.

[15] Jeremy Rose and Matthew Jones. The double dance of agency: a socio-theoretic account of how machines and humans interact. *Systems, Signs & Actions*, 1(1):19–37, 2005. Publisher: Linköping University.

[16] Peter-Paul Verbeek. *What things do: Philosophical reflections on technology, agency, and design.* The Pennsylvania State University Press, University Park, Pennsylvania, 2005. doi:10.1515/9780271033228.

[17] Bill Brown. Thing Theory. *Critical Inquiry*, 28(1,):1–22, 2001. URL: http://www.jstor.org/stable/1344258.

[18] Derrick Mead. *Design for Repair.* DesignFile, New York, 2015.

[19] Nataliia Roskladka, Gianmarco Bressanelli, Giovanni Miragliotta, and Nicola Saccani. A Review on Design for Repair Practices and Product Information Management. In *Advances in Production Management Systems. Production Management Systems for Responsible Manufacturing, Service, and Logistics Futures*, volume 692 of *IFIP Advances in Information and Communication Technology*, pages 319–334. Springer, Switzerland, 2023. ISSN: 1868-4238. doi:10.1007/978-3-031-43688-8_23.

[20] *Material culture and mass consumption.* Social archaeology. B. Blackwell, Oxford, OX, UK ; New York, NY, USA, 1987.

[21] Steven J. Jackson. Rethinking Repair. URL: https://direct.mit.edu/books/edited-volume/3021/chapter/82557/Rethinking-Repair.

[22] Douglas A. Harper. *Working knowledge: skill and community in a small shop.* University of Chicago Press, Chicago, 1987.

[23] Leah Maestri, View Profile, Ron Wakkary, and View Profile. Understanding repair as a creative process of everyday design. *Proceedings of the 8th ACM conference on Creativity and cognition*, pages 81–90, November 2011. URL: https://dl.acm.org/doi/abs/10.1145/2069618.2069633, doi:10.1145/2069618.2069633.

[24] Stephen Graham and Nigel Thrift. Out of Order: Understanding Repair and Maintenance. *Theory, Culture & Society*, 24(3):1–25, May 2007. URL: https://journals.sagepub.com/doi/10.1177/0263276407075954, doi:10.1177/0263276407075954.

[25] Kyungeun Sung and Tung Dao. Repair and Upcycling: How Do We Know Which Repair Is Considered as Upcycling? In Kyungeun Sung, Jagdeep Singh, and Ben Bridgens, editors, *State-of-the-Art Upcycling Research and Practice*, Lecture Notes in Production Engineering, pages 105–109, Cham, 2021. Springer International Publishing. doi:10.1007/978-3-030-72640-9_20.

[26] Tim Ingold. *Making: anthropology, archaeology, art and architecture*. Routledge, London, 2013. OCLC: 841914961.

[27] Jérôme Denis, Alessandro Mongili, and David Pontille. Maintenance & Repair in Science and Technology Studies. *Tecnoscienza – Italian Journal of Science & Technology Studies*, 6(2):5–15, 2015. Number: 2. URL: https://tecnoscienza.unibo.it/article/view/17251, doi:10.6092/issn.2038-3460/17251.

[28] Susan Freinkel. *Plastic: a toxic love story*. A Dodsworth Book. Houghton Mifflin Harcourt, Boston, 2011.

[29] 雄介橘. Acacia事件を通して見るEUにおけるスペアパーツと意匠権 —修理する権利論からの再評価の試み—. 福岡工業大学研究論集, 55(2):79–96, February 2023. Publisher: 福岡工業大学. URL: https://fit.repo.nii.ac.jp/records/799.

[30] Christopher Boniface, Lachlan Urquhart, and Melissa Terras. Towards a right to repair for the Internet of Things: A review of legal and policy aspects. *Computer Law & Security Review*, 52:105934, April 2024. URL: https://www.sciencedirect.com/science/article/pii/S0267364924000013, doi:10.1016/j.clsr.2024.105934.

[31] Damla Kilic and Neelima Sailaja. User-Centred Repair: From Current Practices to Future Design. In *Distributed, Ambient and Pervasive Interactions*, volume 14718 of *Lecture Notes in Computer Science*, pages 52–71. Springer, Switzerland, 2024. ISSN: 0302-9743. doi:10.1007/978-3-031-59988-0_4.

[32] Michael Saidani, Alicia Kim, and Madeline Kim. THE RIGHT-TO-REPAIR MOVEMENT AND SUSTAINABLE DESIGN IM-

PLICATIONS: A FOCUS ON THREE INDUSTRIAL SECTORS. *Proceedings of the Design Society*, 3:3463–3472, July 2023. URL: https://www.cambridge.org/core/journals/proceedings-of-the-design-society/article/righttorepair-movement-and-sustainable-design-implications-a-focus-on-three-industrial-sectors/F3CF568B07B270765770DDB8820BCFC7, doi:10.1017/pds.2023.347.

[33] John Wackman. *Repair Revolution: How Fixers Are Transforming Our Throwaway Culture.* New World Library, Novato, 2020.

[34] Repair Café - Fix Your Broken Items. URL: https://www.repaircafe.org/en/.

[35] Sabine Hielscher and Melanie Jaeger-Erben. From quick fixes to repair projects: Insights from a citizen science project. *Journal of Cleaner Production*, 278:123875, January 2021. URL: https://www.sciencedirect.com/science/article/pii/S0959652620339202, doi:10.1016/j.jclepro.2020.123875.

[36] The Repair Association. URL: https://www.repair.org.

[37] iFixit: The Free Repair Manual. URL: https://www.ifixit.com/.

[38] Self-Repair Manifesto. URL: https://www.ifixit.com/Manifesto.

[39] The Restart Project - The Right to Repair and Reuse Your Electronics. URL: https://therestartproject.org/.

[40] Lorraine Conway. Right to Repair Regulations. November 2024. URL: https://commonslibrary.parliament.uk/research-briefings/cbp-9302/.

[41] Halte à l'Obsolescence Programmée. The Franch Repairability Index. Technical report. URL: https://www.halteobsolescence.org/wp-content/uploads/2022/02/Rapport-indice-de-reparabilite.pdf.

[42] Mark Schaffer. Electronic Standards Are In Need of Repair. Technical report, 2017. URL: https://static1.squarespace.com/

static/53821f30e4b07bcdae103594/t/5982ea72e6f2e1930e9b4bb8/1501751930833/Report+-+Electronic+Standards+Are+In+Need+of+Repair.pdf.

[43] 嶋崎禅那 and 寺田麻佑. 欧州（EU）・米国における「修理する権利」と日本における「修理する権利」. 研究報告電子化知的財産・社会基盤（*EIP*）, 2022-EIP-96(26):1–7, June 2022. URL: https://ipsj.ixsq.nii.ac.jp/ej/index.php?active_action=repository_view_main_item_detail&page_id=13&block_id=8&item_id=218259&item_no=1.

[44] Melanie Jaeger-Erben, Vivian Frick, and Tamina Hipp. Why do users (not) repair their devices? A study of the predictors of repair practices. *Journal of Cleaner Production*, 286:125382, March 2021. URL: https://www.sciencedirect.com/science/article/pii/S0959652620354287, doi:10.1016/j.jclepro.2020.125382.

[45] Daniela K. Rosner and Morgan Ames. Designing for repair? *Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing*, pages 319–331, February 2014. URL: https://dl.acm.org/doi/10.1145/2531602.2531692, doi:10.1145/2531602.2531692.

[46] Marie Lefebvre. *To repair or not to repair: an investigation of the factors influencing prosumer repair propensity.* PhD thesis, 2019. Book Title: To repair or not to repair: an investigation of the factors influencing prosumer repair propensity. URL: https://figshare.com/articles/thesis/To_repair_or_not_to_repair_an_investigation_of_the_factors_influencing_prosumer_repair_propensity/11365325, doi:10.26174/thesis.lboro.11365325.v1.

[47] Piia Lundberg, Annukka Vainio, Noora Viholainen, and Angelina Korsunova. Consumers and self-repair: What do they repair, what skills do they have and what are they willing to learn? *Resources, Conservation and Recycling*, 206:107647, July 2024. URL: https://www.sciencedirect.com/science/article/pii/S0921344924002416, doi:10.1016/j.resconrec.2024.107647.

[48] Kristin A. Scott and S. Todd Weaver. To repair or not to repair: What is the motivation. *Journal of Research for Consumers*, 26(1):43–44, 2014. Publisher: Dr. Ekant Veer, Associate Professor, University of Canterbury.

[49] Ju Yeon Jung, Tom Steinberger, John L. King, and Mark S. Ackerman. Negotiating Repairedness: How Artifacts Under Repair Become Contingently Stabilized. *Proceedings of the ACM on Human-Computer Interaction*, 5(CSCW2):1–29, October 2021. Publisher: Association for Computing Machinery. URL: https://dl.acm.org/doi/abs/10.1145/3476069, doi:10.1145/3476069.

[50] Nataliia Roskladka, Anicia Jaegler, and Giovanni Miragliotta. From "right to repair" to "willingness to repair": Exploring consumer's perspective to product lifecycle extension. *Journal of Cleaner Production*, 432:139705, December 2023. URL: https://www.sciencedirect.com/science/article/pii/S0959652623038635, doi:10.1016/j.jclepro.2023.139705.

[51] María D. Bovea, Victoria Pérez-Belis, and Pilar Quemades-Beltrán. Attitude of the stakeholders involved in the repair and second-hand sale of small household electrical and electronic equipment: Case study in Spain. *Journal of Environmental Management*, 196:91–99, July 2017. URL: https://www.sciencedirect.com/science/article/pii/S0301479717301846, doi:10.1016/j.jenvman.2017.02.069.

[52] Mostafa Sabbaghi and Sara Behdad. Consumer decisions to repair mobile phones and manufacturer pricing policies: The concept of value leakage. *Resources, Conservation and Recycling*, 133:101–111, June 2018. URL: https://www.sciencedirect.com/science/article/pii/S0921344918300168, doi:10.1016/j.resconrec.2018.01.015.

[53] Ines Güsser-Fachbach, Gernot Lechner, and Marc Reimann. The impact of convenience attributes on the willingness-to-pay for repair services. *Resources, Conservation and Recycling*, 198:107163, November 2023. URL: https://www.sciencedirect.com/science/article/pii/S0921344923002987, doi:10.1016/j.resconrec.2023.107163.

[54] Eduardo Blanco-Espeleta, Victoria Pérez-Belis, and María D. Bovea. Repair index of energy-related products: Application to capsule coffee machines. *Sustainable Production and Consumption*, 46:146–160, May 2024. URL: `https://www.sciencedirect.com/science/article/pii/S2352550924000368`, `doi:10.1016/j.spc.2024.02.011`.

[55] Christian Wandji, Helmi Ben Rejeb, Andreas Riel, Peggy Zwolinski, and Cyrille Dalla Zuanna. Leveraging circularity through repair standards: A comparison of methods for assessing product reparability for extended use on mechanical products. *Procedia CIRP*, 120:273–278, January 2023. URL: `https://www.sciencedirect.com/science/article/pii/S2212827123007205`, `doi:10.1016/j.procir.2023.08.049`.

[56] EN. EN: 45554; General Methods for the Assessment of the Ability to Repair, Reuse and Upgrade Energy-Related Products, 2020.

[57] Ardeshir Raihanian Mashhadi, Behzad Esmaeilian, Willie Cade, Kyle Wiens, and Sara Behdad. Mining consumer experiences of repairing electronics: Product design insights and business lessons learned. *Journal of Cleaner Production*, 137:716–727, November 2016. URL: `https://www.sciencedirect.com/science/article/pii/S095965261631040X`, `doi:10.1016/j.jclepro.2016.07.144`.

[58] Julie Gobert, Romain Allais, and José-Frédéric Deroubaix. Repair and reuse: Misalignments between stakeholders and possible users. *Journal of Cleaner Production*, 317:128454, October 2021. URL: `https://www.sciencedirect.com/science/article/pii/S0959652621026664`, `doi:10.1016/j.jclepro.2021.128454`.

[59] Mostafa Sabbaghi and Sara Behdad. Design for Repair: A Game Between Manufacturer and Independent Repair Service Provider. In *Volume 2A: 43rd Design Automation Conference*, page V02AT03A037, Cleveland, Ohio, USA, August 2017. American Society of Mechanical Engineers. URL: `https://asmedigitalcollection.asme.org/IDETC-CIE/proceedings/IDETC-CIE2017/58127/Cleveland,%20Ohio,%20USA/258686`, `doi:10.1115/DETC2017-67986`.

[60] G. Q. Huang. *Design for x: concurrent engineering imperatives.* Springer, Dordrecht, the Netherlands, 1st ed. 1996. edition, 1996. doi:10.1007/978-94-011-3985-4.

[61] Stefano Filippi. *The design guidelines collaborative framework: a design for multi-X method for product development.* Springer, London, 2010. doi:10.1007/978-1-84882-772-1.

[62] Abla Chaouni Benabdellah, Imane Bouhaddou, Asmaa Benghabrit, and Oussama Benghabrit. A systematic review of design for X techniques from 1980 to 2018: concepts, applications, and perspectives. *The International Journal of Advanced Manufacturing Technology*, 102(9):3473–3502, June 2019. URL: https://doi.org/10.1007/s00170-019-03418-6, doi:10.1007/s00170-019-03418-6.

[63] Linköping University, Nazlı Özkan, and Renee Wever. Integrating repair into product design education: Insights on repair, design and sustainability. In *Insider Knowledge - Proceedings of the Design Research Society Learn X Design Conference, 2019.* Design Research Society, July 2019. URL: https://dl.designresearchsociety.org/learnxdesign/learnxdesign2019/researchpapers/40, doi:10.21606/learnxdesign.2019.16117.

[64] Design Council. How to: Design for repair, November 2023. URL: https://www.youtube.com/watch?v=T6wemyGBc-0.

[65] Design for easy Repair and Maintenance Sustainable | Product Design. URL: https://milani.ch/en/ueber-uns-en-us/blog/design-for-easy-repair-and-maintenance-a-sustainable-approach-in-product-design.

[66] Jida Huang, Behzad Esmaeilian, and Sara Behdad. Design for Ease-of-Repair: Insights From Consumers' Repair Experiences. In *Volume 4: 21st Design for Manufacturing and the Life Cycle Conference; 10th International Conference on Micro- and Nanosystems*, page V004T05A017, Charlotte, North Carolina, USA, August 2016. American Society of Mechanical Engineers. URL: https:

//asmedigitalcollection.asme.org/IDETC-CIE/proceedings/IDETC-CIE2016/50145/Charlotte,%20North%20Carolina,%20USA/258528, doi:10.1115/DETC2016-59685.

[67] Nazlı Terzioğlu. Repair motivation and barriers model: Investigating user perspectives related to product repair towards a circular economy. *Journal of Cleaner Production*, 289:125644, March 2021. URL: https://www.sciencedirect.com/science/article/pii/S0959652620356900, doi:10.1016/j.jclepro.2020.125644.

[68] Renske van den Berge, Lise Magnier, and Ruth Mugge. Sparking the Repair "Can-Do" Attitude: Enhancing Users' Willingness to Repair through Design Support in Fault Diagnostics. *International journal of design*, 17(3):25–, 2023. Place: Taipei Publisher: Chinese Institute of Design. doi:10.57698/v17i3.02.

[69] Serkan Bayraktaroğlu and Elif İdemen. Redefining Repair as a Value Co-Creation Process for Circular Economy: Facilitated Do-It-Yourself Repair. *International journal of design*, 18(1):1–, 2024. Place: Taipei Publisher: Chinese Institute of Design. doi:10.57698/v18i1.01.

[70] Elizabeth Chamberlain. How to Design a Product That Is Easy to Repair. *Wall Street Journal*, May 2022. URL: https://www.wsj.com/articles/design-repairable-products-consumers-11653506069.

[71] Beatriz Pozo Arcos, Conny Bakker, and Ruud Balkenende. How User Manuals Support the Diagnosis of Common Faults in Household Appliances: an Analysis of 150 Manuals. *Circular economy and sustainability (Online)*, 3(1):535–555, 2023. Place: Cham Publisher: Springer International Publishing. doi:10.1007/s43615-022-00195-5.

[72] Thomas Lee and Rachael Wakefield-Rann. Conspicuous and inconspicuous repair: A framework for situating repair in relation to consumer practices and design research. *Journal of Cleaner Production*, 294:126310, April 2021. URL: https://www.sciencedirect.com/science/article/pii/S0959652621005308, doi:10.1016/j.jclepro.2021.126310.

[73] The Agency of Design. URL: https://agencyofdesign.co.uk/design-out-waste/.

[74] Kibu. URL: https://kibu.family/.

[75] Fairphone. URL: https://www.fairphone.com/nl.

[76] Clara Amend, Ferdinand Revellio, Isabell Tenner, and Stefan Schaltegger. The potential of modular product design on repair behavior and user experience – Evidence from the smartphone industry. *Journal of Cleaner Production*, 367:132770, September 2022. URL: https://www.sciencedirect.com/science/article/pii/S095965262202368X, doi:10.1016/j.jclepro.2022.132770.

[77] Lauren E. Marsh, Patricia Kanngiesser, and Bruce Hood. When and how does labour lead to love? The ontogeny and mechanisms of the IKEA effect. *Cognition*, 170:245–253, January 2018. URL: https://www.sciencedirect.com/science/article/pii/S0010027717302743, doi:10.1016/j.cognition.2017.10.012.

[78] Michael I. Norton, Daniel Mochon, and Dan Ariely. The IKEA effect: When labor leads to love. *Journal of consumer psychology*, 22(3):453–460, 2012. Publisher: Elsevier.

[79] Chenoy Ceil. Ikea Effect to Measure the Effect of Labor on How People Value Things, December 2019. URL: https://papers.ssrn.com/abstract=3520598, doi:10.2139/ssrn.3520598.

[80] Andrew M. King, Stuart C. Burgess, Winnie Ijomah, and Chris A. McMahon. Reducing waste: repair, recondition, remanufacture or recycle? *Sustainable Development*, 14(4):257–267, 2006. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/sd.271. URL: https://onlinelibrary.wiley.com/doi/abs/10.1002/sd.271, doi:10.1002/sd.271.

[81] Mostafa Sabbaghi, Behzad Esmaeilian, Willie Cade, Kyle Wiens, and Sara Behdad. Business outcomes of product repairability: A survey-based study

of consumer repair experiences. *Resources, Conservation and Recycling*, 109:114–122, May 2016. URL: https://www.sciencedirect.com/science/article/pii/S0921344916300349, doi:10.1016/j.resconrec.2016.02.014.

Appendices

A. Repair Survey Questionnaire

Repair Survey

To all respondents:

Thank you for scanning the QR code.
This survey is aiming to understand more about repair.
Please help us fill out the form and share your opinion with us, and the information you share with us will be **ANONYMOUS** and confidential, which only be used in research and developing the project.
Your opinion is essential and valuable for us to make more repairable product, so that we could take a further step to have the right to repair, which would make the world more sustainable.

If you have any questions, please contact ihanhsieh@keio.jp, we would reach out to you soon.

Best,
I-Han Samantha Hsieh
Master Student
Future Crafts
Graduate School of Media Design, Keio University

* 表示必填問題

Do you repair?

In this section, we would like to ask you to think about repair.
Feel free to contact ihanhsieh@keio.jp if you have any question, we would be happy to support you.

1。 How confident are you in your making skills? *

This includes any kinds of making skills, such as sewing, sculpting, 3D printing, laser cutting, woodworking, metalworking etc. Please consider your skills in relation to a specific project or goal you have in mind.

單選。

	0	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	◯	Very Confident

2。 What would you normally do if an object is broken? *

單選。

- ◯ Repair it yourself
- ◯ Throw it away or Recycle it
- ◯ Repurpose it
- ◯ Find a local repair shop to repair it
- ◯ Send it back to the company to repair/ replace it
- ◯ 其他：________________

3。 How confident are you in your repair skills? *

單選。

	0	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	◯	Very Confident

4。 What is the main reason for you to repair an object? *

單選。

- ◯ Saving money
- ◯ Attachment to the item
- ◯ Environmental benefits
- ◯ Sense of satisfaction
- ◯ Learn new skills
- ◯ 其他：________________

5。 What is the main reason for you **NOT** to repair an object? *

單選。

- Time Consuming
- Lack of Repair Skills
- No Available Parts
- Money Consuming
- Lack of Tools
- Outdated Product
- Products are NOT Repairable
- 其他：

6。 How likely do you repair the following products? *

每列請僅選取一個答案。

	Very Unlikely	Unlikely	Likely	Very Likely
Laptop	⬭	⬭	⬭	⬭
Smartphone	⬭	⬭	⬭	⬭
Wired Headphone	⬭	⬭	⬭	⬭
Wireless Headphone	⬭	⬭	⬭	⬭
T-shirts	⬭	⬭	⬭	⬭
Sweaters	⬭	⬭	⬭	⬭
Winter Coat	⬭	⬭	⬭	⬭
Sneakers & Trainers	⬭	⬭	⬭	⬭
Boots	⬭	⬭	⬭	⬭
Vacuum Cleaner	⬭	⬭	⬭	⬭
Roomba	⬭	⬭	⬭	⬭
Table	⬭	⬭	⬭	⬭
Drawer	⬭	⬭	⬭	⬭
Suitcase	⬭	⬭	⬭	⬭
Electric Fan	⬭	⬭	⬭	⬭

7。 Any other opinions?

B. Interview Questions for Users

- How was your ability of making?
- How do you feel about the first product? What kind of difficulties have you discovered during the repair process?
- Comparing the first and second design, which one are you preferred? Why?
- Explain what you make, and why are you repairing the fan like this? What are you aiming to achieve during the process?
- What do you think about the second prototype and its repair process? How do you feel during the process? Is there anything to be improved?
- Other than the material offered, what kind of the material would you like to try on this model?
- Comparing to your daily experience of a broken product, what would you do normally? Do you repair? Why and why not? What are the differences between this model and your previous experience?
- How would you define as "Repair"?
- To what extent do you think creativity is needed in repairing an object?
- Any other comments?

C. Document Used in the Designer Interview

How to Design for Repair?

In this interview, we…

- explain the concept of Design for Repair
- utilise the concept in the product category that you are familiar with
- sketch a few ideas
- discuss the concepts

Before we start…

- Prepare pens and papers or any kinds of tools for idea sketching.
- Three Questions:
  - Please briefly introduce yourself
  - What kind of product do you normally design?
  - How would you define Repair?

Designer's Guideline

Repair is a process that makes a broken object work again, but the working version is negotiable.

Since the object after repair could only be as close as possible to its original status, any working version that satisfies the user or owner should be acceptable.

What would be a possible working version of a product?

Principles Checklist:

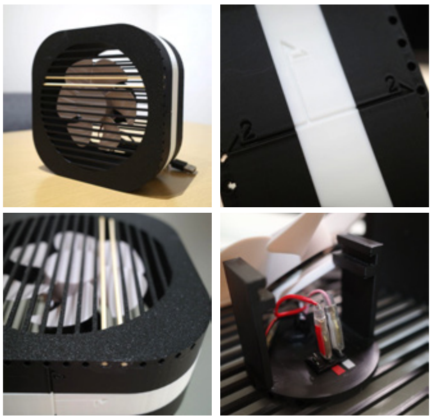
- Production:
  - ☑ Using appropriate materials
  - ☑ Using common parts
  - ☑ Concerning disassembly and reassembly (modularity, no adhesives, fewer tools)
- Use:
  - ☑ Accessibility to repair service
  - ☑ Availability of spare parts
  - ☑ Clear instructions for maintenance and repair
- End of Life:
  - ☑ Difficulty of disassembly
  - ☑ Materials and parts recycle

The following tips might be helpful for developing a repairable product:

- Disassemble to learn.
- Ask repairers for opinions.
- Consider the whole system.
- Embrace hacking if needed.

Example

1. Overall
2. Holes for Appearance Repair
3. Repair Indicator (Open)
4. Repair Indicator (Wire)



Different Working Version

Ideation Sketch

Base on the guideline offered, quickly sketch a few ideas that utilise the concept.

Interview

D. Interview Questions for Designers

Before Practising the Guideline:

- What kind of product do you normally design?
- How would you define Repair?

After Practising the Guideline:

- What do you think about the guideline and the point of view it offers? Which part is doing well? Which part needs to be improved? Is there anything that needs to be added?
- Which aspect of the guideline is the most essential in practice?
- How might this guideline influence your future design?
- What other kinds of products do you think the guideline is applicable? What kinds are NOT applicable?