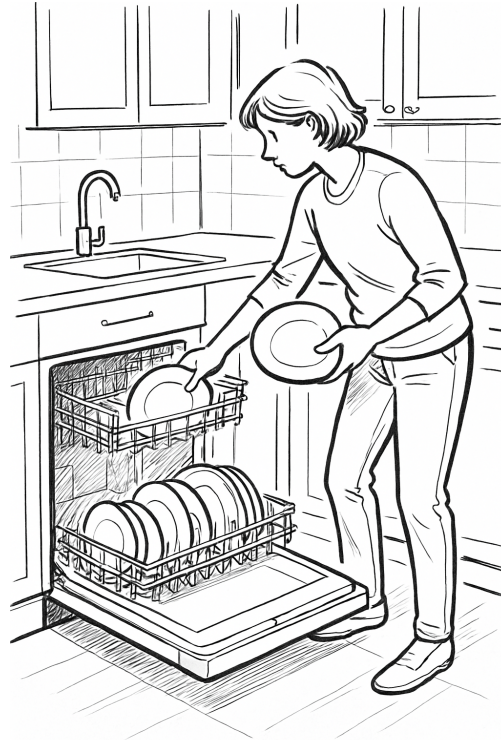




CHALMERS
UNIVERSITY OF TECHNOLOGY



Towards More Sustainable Dishwashing Behaviour

A User Research Study with Design Strategies to Modify
Unsustainable Practices

Master's thesis in Industrial Design Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY

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Abstract

Dishwashers have become part of the modern home and when used correctly can lead to significantly less water and energy consumption than the alternative of manual dishwashing. Manufacturers are constantly improving the efficiency of these appliances with better mechanical components, lower cycle temperatures and increases in capacity. However, an aspect which has received less attention is how the behaviours of users impact the efficiency.

This project investigated unsustainable behaviours in automatic dishwashing by studying previous research as well as conducting new research, through user studies in a lab environment complemented by a diary study in a home context. Six unsustainable behaviours were identified: (1) inefficient programme choice, where users choose to run a dishwashing programme which is either too intensive or too gentle, resulting in increased water and energy consumption or unclean dishes; (2) inefficient loading, not utilizing the full capacity of the dishwasher or overloading the dishwasher resulting in unclean dishes; (3) pretreatment of dishes, rinsing dishes under running water before placing them in the dishwasher; (4) inefficient detergent use, using more detergent than necessary for a good result; (5) manual dishwashing, households with dishwashers washing some dishes manually; and (6) poor maintenance, not doing the maintenance needed for effective cleaning and along lifespan of the appliance.

The study found that these behaviours depend on several factors among users, where the most critical ones were a lack of information, a lack of trust in the dishwasher and convenience. The next part of the project consisted of investigating how design could be used to address the unsustainable behaviours. Which resulted in the six design recommendations: sustainability sheet, programme costs, Auto Dose text, tips & tricks, scraping off tool and filter warning. These recommendations in addition to the insights from the research are aimed to serve as inspiration for dishwasher manufacturers on how they can improve the sustainability of their appliance by employing a user behaviour point of view.

Keywords: dishwasher, automatic dishwashing, sustainability, user studies, design for sustainable behaviour.

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Axel Ohlsson & David Rodríguez Altimira, Gothenburg, June 2025

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1

Introduction

Although dishwashers have become standard in modern households, there is a critical gap between their technological capabilities and user knowledge. Many users operate these appliances through intuition rather than through understanding, compromising washing efficiency and effectiveness. Therefore, influencing sustainability aspects such as energy consumption, water consumption and product lifespan.

Every year, household appliances require increasing amounts of energy and resources for their production and use (Hischier et al., 2020), representing a key area for sustainability efforts. This aligns with the United Nations' sustainable development goal "sustainable consumption and production" (UN, 2025).

This project is part of research studies conducted by Chalmers University of Technology, in collaboration with the kitchen appliances companies ASKO (Sweden) and ATAG (Netherlands). Both are part of the Hisense group, a global manufacturer of electronics and appliances. ASKO's R&D centre in Lidköping specializes in dishwasher innovation.

Dishwasher manufacturers constantly work to innovate and improve their products, this includes making their dishwashers more sustainable in relation to water and energy efficiency, an aspect which is of significant importance to customers. Although there are constant improvements in this aspect, there is a lack of research on how user behaviour affects dishwasher performance and in turn sustainability. Therefore, ASKO has initiated this project to further enhance environmental responsibility by analysing user behaviours and designing dishwashers with those in mind.

1.1 Aim

The aim of this project is to identify and gain a deeper understanding of unsustainable behaviours in dishwasher usage, by analysing previous research as well as conducting new research to fill in the gaps. The environmental impact of these behaviours is to be analysed, and design recommendations which promote more sustainable practices developed. Furthermore, these recommendations should be evaluated based on their environmental impact.

1.2 Research questions

The research questions which the project aims to answer are the following:

- What are the unsustainable behaviours carried out by users?
- What are the environmental impacts of these behaviours?
- How can design interventions encourage more sustainable behaviours?

1.3 Delimitations

To limit the scope of the project, the following demarcations have been made:

- Specific material choices of components are not part of the study.
- The chemical compositions of detergents are not to be studied.
- Only parts which the user interacts with are part of the study, the inner workings of the dishwasher are therefore outside of the scope.
- The project is on a pre-development level, therefore any design for manufacturing is outside of the scope.
- The project focuses on domestic dishwasher usage; professional usage is out of the scope.

1.4 Deliverables

A more theoretical outcome is expected in the first half of the project, which consists of a summary of the research results. After the planned activities are completed, the identified unsustainable behaviours will be clearly described and categorized. Additionally, their relative importance regarding the sustainability end goal will be outlined, considering other aspects as well, such as characteristics of the brand and its products, ease of further analysis and implementation, etc. The second outcome is more practical-oriented. Based on the gathered data, a set of design recommendations will be designed, developed and evaluated through an iterative and problem-solving approach.

2

Background

2.1 Client

Hisense markets dishwashers in Europe under several brands, including ASKO and ATAG. ASKO serves as the primary stakeholder in this project, with ATAG contributing on a smaller scale.

ASKO is a household appliances producer founded in Sweden. Inspired by nature and the Scandinavian design principles, the company focuses on a constant innovation to enhance the user experience and minimize the environmental impact. As a premium brand, it offers high-quality products with advanced functionalities and great attention to detail.

The dishwasher range exemplifies the brand's values through two aspects: a minimalistic approach on the exterior, featuring doors that integrate into kitchen aesthetics and discreet interfaces; and a well-equipped interior, with highly adaptable baskets and numerous customization possibilities. ASKO designs its dishwashers for a 20-year lifespan, implementing high quality materials, timeless aesthetics and flexibility in the use.

2.2 Manual vs Automatic Dishwashing

Households owning a dishwasher are currently more sustainable in their dishwashing practices, resulting in an average of 50% and 28% of water and energy savings respectively (Richter, 2011). However, manual dishwashing is still common in many European countries, with a mere 13% of households reporting to never wash dishes by hand (Richter, 2010). The use-phase greenhouse gas emissions could be reduced by 70% by switching from typical manual to recommended automatic dishwashing behaviours. Only following the best practices on manual dishwashing as described by Fuss et al. (2011) results in 18% less life cycle greenhouse gas emissions than automatic dishwashing (Porrás et al., 2020).

In general, dishwasher users do not perceive cleanliness level as a challenge to overcome if their automatic and manual dishwashing results are compared. The differentiation lies in variability, leading to more uniform cleanliness outcomes when using the dishwasher (Porrás et al., 2020). In terms of ergonomics and overall performance, automatic dishwashing is the preferred choice (Stamminger et al., 2007).

2.3 Regulations on Dishwasher Design

Regulations on programmes

The European ecodesign regulation states that household dishwashers must have a programme named “eco”, which is set as the default option on any dishwasher with a programme selector (Commission Regulation (EU) 2019/2022, 2019). There may not be any programmes named “normal”, “regular”, “standard” or “daily”. This is to promote the usage of the more energy and water efficient eco programme.

Regulations on energy Labelling

To aid consumers in making informed purchasing decisions, all dishwashers sold in the European Union must be supplied with an energy label (Commission Delegated Regulation (EU) 2019/2017, 2019). As can be seen in Figure 2.1, the energy label contains information on the energy consumption per 100 cycles, the water consumption per cycle, the rated capacity in place settings, the noise level, the programme duration, and the dishwasher’s energy efficiency class. All these data points are calculated on the eco programme. The energy efficiency class is rated on a scale from A to G, where A is the most efficient. The energy label previously used a scale from A+++ to D, which was changed to increase differentiation between products as most dishwasher sold in the EU were in the A++ or A+++ classes (Brunzell and Renström, 2020; Commission Delegated Regulation (EU) 2019/2017, 2019).

A good result on the energy label is a key factor for potential consumers choosing which model to purchase (Richter, 2010). Therefore, it is crucial for dishwasher manufacturers to get a competitive score on the label to market their dishwasher. For example, to get good scores on rated capacity manufacturers design their dishwashers based on the test procedure. However, since the test procedure does not perfectly mimic the conditions in actual household usage there is a gap between the use case the dishwasher is designed for and how it will be used. Especially when it comes to which dishes are used. As dishwasher capacity is measured in place settings and the user may use other configurations of dishes, the racks may not be designed for what dishes will be used.

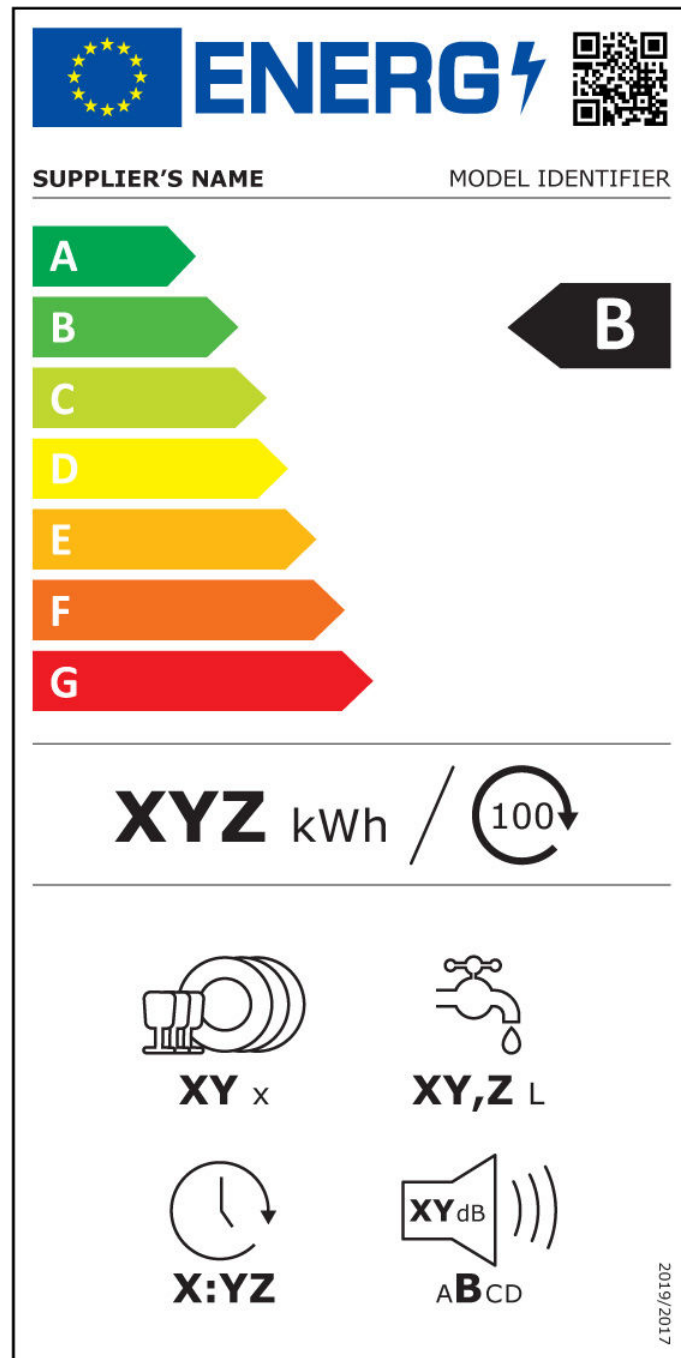


Figure 2.1: EU energy label.

2.4 Sinner's circle and the eco programme

To understand washing performance, experts often refer to the Sinner's circle theory. It consists of four factors that affect the effectiveness of automatic washing: time, temperature, chemical and mechanical action. They are interconnected, therefore decreasing one factor requires increasing one or more of the others (Stamminger and Bockmühl, 2025). It is often visualised as a circle as is illustrated in Figure 2.2, where the size of each quadrant depends on its effect in the cleaning process. Since the mechanical and chemical factors are fixed by measurement standards and by the hydraulic system of the dishwasher, eco programmes rely on increasing the time factor to compensate for the decrease in temperature, reducing the energy required to heat water (Stamminger and Bockmühl, 2025), which represents most of the energy involved in machine dishwashing (Porras et al., 2020). This translates into longer duration but more resource efficient programmes.

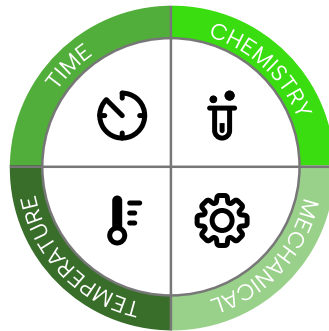


Figure 2.2: Sinner's circle.

As pointed out by Dekoninck and Elias (2011), environmental efficiency depends not only on those machine dependant variables derived from the Sinner's circle, such as increasing lifetime and reducing water, heating, or detergent usage, but also on consumer behaviour parameters. The authors highlight that very few studies focus on this group. Reducing water usage and heating energy is the direction towards a more sustainable appliance, since this represents 90% of the energy consumed (Dekoninck and Elias, 2011). Mechanically, dishwashers are optimized to a very high degree and, according to the dishwasher manufacturer client, the washing temperature is already the minimum required to kill bacteria, which has made it difficult to see notable improvements in efficiency in recent years. Hence, innovation requires a new direction: shifting from product-centred to user-centred approach, by studying user behaviours.

The Sinner's circle is not applied in this project as a tool for improvements in the chemical or mechanical areas, but to analyse the misconceptions users have about which dishwashing behaviours are truly sustainable. An example is the common belief that the longer eco cycle is less sustainable than a shorter quick programme.

2.5 Design for Sustainable Behaviour

Design for sustainable behaviour is a theoretical framework used to improve the sustainability of products where most of the environmental impact comes from the use or discard phase. This project adopted a behaviour-oriented approach, allowing for some flexibility. Analysing the brief, client requirements, and available resources naturally led to a design space facing towards this direction, aiming to facilitate more sustainable dishwasher interactions by targeting specific user behaviours. However, the inherent complexity of behaviour analysis required some adjustments to the project trajectory and the sequence of certain methodologies.

In a behaviour-oriented approach unsustainable behaviours are addressed through the application of one or several of five strategies shown in Figure 2.3 (Selvfors et al., 2023). The first strategy, enlighten, involves providing users with information to influence users towards certain behaviours. The second, spur, motivates users by offering rewards to those that adopt more sustainable behaviours. The third, steer, makes sustainable behaviours the obvious choice by making them easier to perform, more appealing or more prominent. The fourth strategy, force, removes the possibility of acting in any other way than in the intended sustainable manner. The fifth and final strategy, match, includes redesigning the product in such a way that the user does not have to change their behaviour; however, the result is still more sustainable.

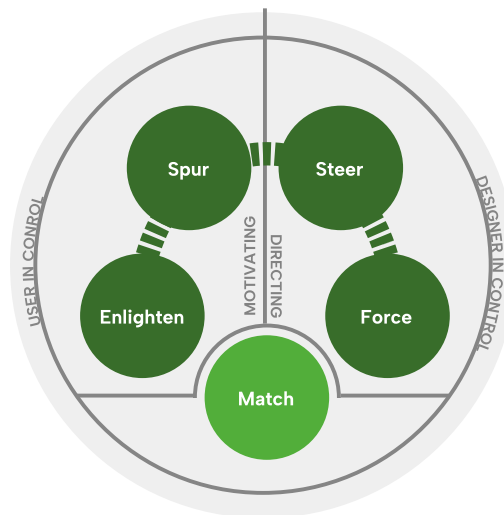


Figure 2.3: DfSB design strategies. Illustration adapted from Selvfors et al. (2023).

2. Background

3

Methods and process

As illustrated in Figure 3.1 the project was divided in two main phases: the research phase and the design phase. These phases culminated in the research synthesis and the design recommendations. The research phase is divided into three sections: literature study, market research, and user studies. The literature study covers two research questions: which dishwashing behaviours are unsustainable and what are their environmental effects. User studies were then conducted to identify any further unsustainable practices. Additionally, they addressed the literature gap on the connection between user behaviour and dishwasher design, contributing to the less explored field of user-centred innovation in dishwashers. To investigate how design interventions can promote sustainable behaviours market research was conducted, to understand customer needs and examine how other companies address the challenges. The ideation phase combined brainstorming based on user study outcomes, with support from market research insights. The evaluation and selection of potential concepts for further development was based on criteria determined by the project brief and the literature findings.

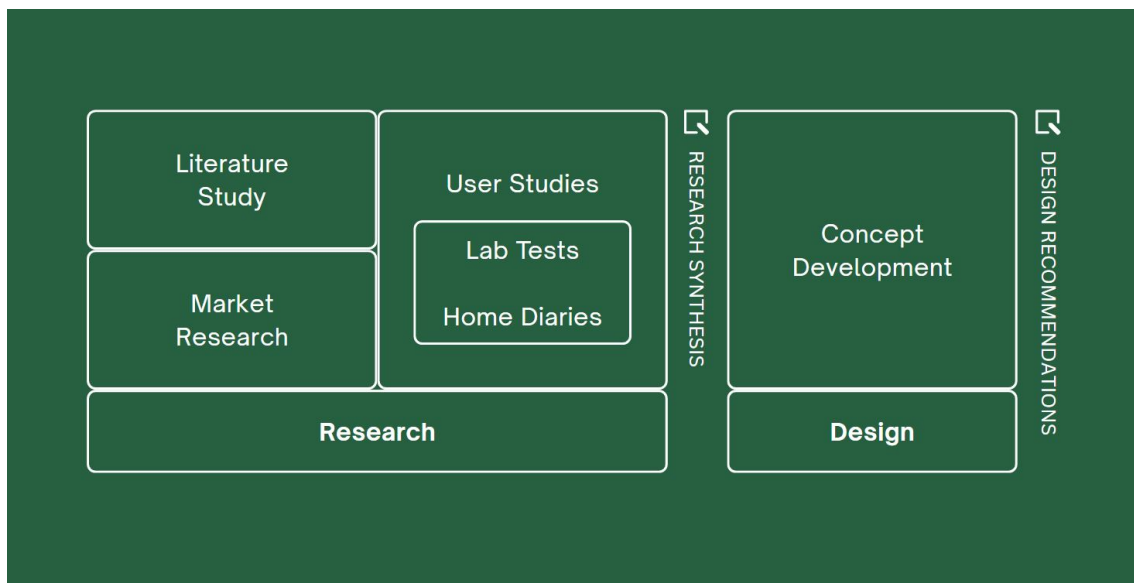


Figure 3.1: Visualisation of the project process.

3.1 Literature Study

A literature study was conducted to gain an understanding of previous research on unsustainable behaviours associated with dishwasher use. The study focused on several areas: factors at dishwasher purchase, differences between manual and automatic dishwashing, unsustainable behaviours in the use of dishwashers and their environmental impact, underlying reasons behind these behaviours and how often they occur.

To find relevant articles, online databases such as Google Scholar were used with the following search terms: “User behaviour dishwasher”, “Automatic dishwashing”, “Dishwashing behaviour resources”, “Dishwashing energy label”, “Dishwashing behaviour”. Articles were first screened based on their title. The abstract and conclusion of promising articles were then reviewed to confirm their relevance for the project. Using this process in addition to a snowballing method, to find articles through references in other articles, resulted in the collection of 36 articles. The content of the gathered articles was discussed with the supervisor from ASKO to get a second opinion on if it was relevant for the project and to get their opinion on the subject.

3.2 Market Research

To gain insight into the state of the art in automatic dishwashing, existing brands, models, features and their connection with potential customers were analysed. The market research was conducted in two phases: an online study and a visit to popular appliances stores in Sweden.

As part of a benchmarking approach, the online research studied a list of dishwasher manufacturers serving European markets such as Bosch, Miele and Electrolux. The focus was on examining the technical and aesthetic attributes of the dishwashers that were related to enhancing the user experience. This data was collected in the form of pictures and observations, selected for their relevance to sustainability, which is central to the study. In later stages, once the problems to address were clearly defined, the research expanded to include more manufacturers and dishwasher models from around the world, to explore potential solutions.

The site visit included two appliance retailers: Elgiganten and Elon. The customer journey was considered both when examining the displayed dishwasher models and during interviews with sales staff. These interviews studied what information stores give to customers, what information customers ask for and what impressions and opinions specialized employees have of the different dishwasher brands and models. Information was gathered regarding purchasing choice drivers and relevant attributes that influence customers’ model choice. Already implemented design for sustainable behaviour features were identified and classified.

Market research results were compared with the literature findings and served as the basis for choosing which dishwasher models would be included in the user studies conducted in the lab. Based on a human factors' perspective, a total of four types of dishwashers currently commercialised were identified. The market research results section presents these four categories in detail.

3.3 User Studies

The literature study identified a lack of user-centred research in the field of dishwasher innovation, specifically in how the appliance influenced user behaviour. To address this gap, user studies were planned and conducted, focusing on the unsustainable behaviours found in literature. These studies took place in both laboratory and home environments, as this dual approach was necessary to capture the complexity of user interactions. The end goal shaped the organization of these activities and was to discover effective ways to transform those unsustainable practices into sustainable ones.

3.3.1 Lab Studies

A user test was set up to get a better understanding of how the identified unsustainable behaviours happen and what the determinants behind them are. These tests took place in a controlled environment: a usability lab. The focus of the test was to see to which degree the design of the dishwasher influences the choices and behaviours of users. To plan this test, the following questions were answered:

- Which questions are to be answered with user testing?
- How should the test be set up to answer these questions?
- Which limitations are there with the way the testing is set up?

User test design

The user tests were planned to include all stages of the dishwashing practice where the appliance is involved. The method incorporated both observational practices and semi-structured interviews, especially for covering those additional stages of the practice taking place outside of the dishwasher. The sample consisted of ten participants, including different age groups. The material needed for emulating the process was dishes and dishwashers.

The number and types of dishes were selected based on common European eating habits, with the aim of encouraging scenarios where not all items would fit in a single dishwasher load. These are shown in Figure 3.2 and included: 12 large plates, 12 deep plates, 12 small plates, 12 small bowls, 12 water glasses, 12 wine glasses, 10 coffee cups, 12 sets of cutlery, an oven dish, a pot, a pan, a spatula, a pair of tongs, two knives (small and big), two cutting boards, a large bowl, two whisks, a sieve and two plastic lunch boxes.



Figure 3.2: Dishes used in the lab studies.

The market research identified four types of dishwashers based on human factors: high-end, "scroll through programme selection" mid-range, "individual programme selection buttons" mid-range and low-cost. However, since the project is in collaboration with ASKO, a premium brand, the low-cost category was excluded from further investigation. Instead, a mid-range model from Gorenje (also part of the Hisense group) was included to provide insights on appliances that are more similar to ASKO's, but with simpler interfaces and fewer basket customization options. Four dishwashers from different brands were tested, chosen to represent a variety of interface and interior designs. The interfaces differed in how programmes were selected, whereas the interior focus points were the cutlery options, the bottom rack design, filter design and solutions for specific items like wine glasses and knives. The four models were:

- ASKO - (high-end, screen based, "scroll through all the programmes to choose the desired programme") – DFI777UXXL



- Miele (mid-range, "Physical buttons with one button for scrolling through programmes.") – G 5233 SCU Excellence



- Bosch (mid-range. "individual programme selection buttons") - SM6ZDX49E



- Gorenje (Hisense mid-range, Screen based, "one button for each programme")- GS673C60W



Test procedure

In the test, participants were presented with a scenario of the aftermath of a dinner party where they had to take care of the dishes. Users were placed in front of the first dishwasher (all 4 dishwashers were tested, but only 2 of them per user) and a table with a variety of dishes that would have been used to prepare the food for the dinner party, as well as used for the table setting. The setup can be seen in Figure 3.3. The participant was then asked to do the dishes and think aloud throughout the test. As there were more dishes available than can fit in the dishwasher, participants had to prioritise which dishes to put in the dishwasher. The participant was asked what they would do with the rest of the dishes, if they would wash them manually or if they would wait and put them in the dishwasher for the next cycle.



Figure 3.3: Dishwasher setup for the user lab studies.

Participants were also asked to start the machine and in doing so they had to choose a washing programme. This procedure was then repeated for one more dishwasher model. Every user was introduced to the same scenario. After the test, around 20 reflection questions were asked. Data stored for further analysis included voice recordings and pictures of the loading layouts. Each test was planned to take 50 minutes. Participants did not know about the sustainability angle of the project as not to create any bias towards certain behaviours. The expected results from the testing were:

- Seeing what dishes users prioritise over others when they cannot fit all of them.
 - By having a larger number of dishes than can fit in the dishwasher it is possible to get an idea of which items users would not put in the dishwasher and why that is.
- Seeing how well users utilise the dishwashers full load capacity.
 - By letting participants load the dishwasher, to compare their fill level to an optimal level and see how many more dishes they could have fit.
- Placement of dishes within the dishwasher baskets.
 - By having participants place dishes freely within the dishwasher, the effect of the basket design on the users loading pattern becomes apparent. Do they follow the same pattern on all dishwashers, or do they change their habits based on the one they are currently loading?
- Seeing if users rearrange dishes to try to optimise space in the dishwasher.
 - As participants load the dishwasher, they realise all the dishes do not fit. Do they then rearrange items to try to fit more?
- Seeing if users choose different wash programmes in different dishwashers.
 - If participants choose different programmes depending on which dishwasher they are using, it might indicate that the design of the interface influenced their choice.

In addition to the testing of the dishwashers, the user study also contains an interview section with questions regarding aspects which were difficult to answer through physical testing, regarding maintenance, loading, programme choice, information availability, importance of sustainability and the user's own dishwasher. An overview of the ten participants who participated in the test can be seen in Table 3.1 and the test protocol in its entirety is presented in Appendix C.

Test nr	Occupation	Age	Nationality
1	Graduate student	20s	Swedish
2	Graduate student	20s	Swedish
3	Graduate student	20s	Swedish
4	Library employee	50s	British
5	Undergraduate student	20s	Swedish
6	Undergraduate student	20s	Swedish
7	Administration employee	50s	Swedish
8	Undergraduate student	20s	Japanese
9	Research intern	20s	Belgian
10	Graduate student	20s	Swedish

Table 3.1: Table of test participants

3.3.2 Home Studies

A diary study was conducted to fill in gaps from the lab study. This method was able to capture behaviour in its real context of user's homes, as well as with their own appliances and dishes, which was not possible in the lab tests. In the diary study, participants were asked to document five consecutive dishwasher cycles. Depending on the frequency of dishwasher use, these diaries were planned to be completed in 1-5 weeks. For each of the cycles, participants were prompted to document the date and time the cycle was started, take individual pictures of how they loaded each rack in the dishwasher as well as answer six groups of questions:

- How dirty are the dishes?
- How full is the dishwasher?
- Why did you decide to start the dishwasher at this specific moment?
- How did you experience loading the dishwasher? Why did you feel that way?
- How did you feel when navigating the interface? Why did you feel that way? Which programme did you choose? Why?
- How did you experience the end result?

All questions followed a single or multiple-choice format with predefined options except for those asking for reasons, which were completely open-ended with blank spaces for the user to write. In addition to this, participants provided information on their name, age, number of people in their household and the dishwasher brand and model. The diary was sent out to and filled out by three households. Given the long-term commitment involved in a diary study, participants were selected based only on their accessibility and age group. The first page of the diary is illustrated in Figure 3.4 while the whole diary is provided in Appendix A.

How to use the diary:

- 1. Starting the diary:**
Before starting the diary, follow these steps:
 - Fill out the information on the front page.
 - Take pictures of your dishwasher's interface as well as one of each rack without dishes (e.g., Top, Bottom, ...).

- 2. Document each wash cycle:**
For each wash cycle, follow these steps:
 - Take a separate picture of each dishwasher rack before starting the cycle. (e.g., Top, Bottom, ...)
 - Answer the questions on the corresponding page for that cycle.

- 3. How to take pictures of the dishwasher baskets:**



- 4. After 5 cycles:**
 - Take pictures of each page of the completed diary.
 - Email these pictures along with the pictures of the filled and empty dishwasher racks to the following email address:

My Dishwashing Diary

This booklet is part of a study aimed at understanding how dishwashers are used in everyday life. By taking part in this study you are helping us design more efficient dishwashers.

What to do:

- For your next 5 dishwashing cycles use this diary to record your dishwashing habits. **Please read the instructions on how to use the diary on the back of this booklet before starting.**



Name:

Age:

Number of people in household:

Dishwasher brand and model:
(Check the dishwasher door or user manual)

Figure 3.4: First and last page of the diary study.

3.4 Ideation

To develop design recommendations based on the results from the research phase, an ideation process, as illustrated by Figure 3.5 was implemented. First, four design directions were identified as the most relevant based on the insights generated through a KJ analysis of the research results. A list of design requirements was developed based on these directions and specific research findings, which was used as the basis for the ideation phase and as topics for brainstorming sessions. These requirements can be seen in Appendix A. The large number of generated ideas required to be narrowed down in several stages. Ideas with low sustainability impact, reduced functionality, or added complexity were removed first. A total of 70 ideas were grouped by topic, a second round reduced them to 16, which were assessed using a decision matrix.

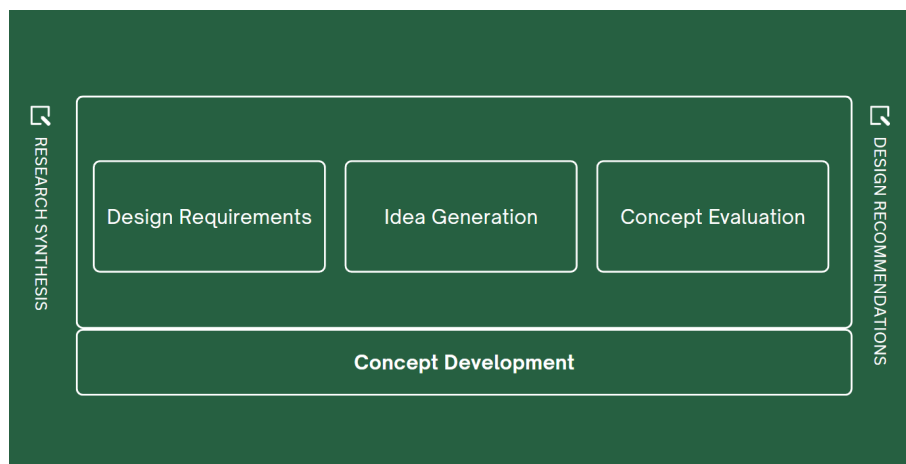


Figure 3.5: Ideation process.

The criteria for the matrix were weighed on a scale of one to five on how important they were to fulfil the goals of the project. The criteria were: sustainability impact, how big of an impact the idea could have on making the users' behaviours more sustainable; usability impact, how the idea affects the usability and the users experience either positively or negatively; implementability, how feasible it is to implement the idea in the near future; user acceptance, how well users will accept the idea and adapt their behaviours accordingly; marketability, how well the idea fits the client's business and improves their position in the market; and brand image, how well the idea fits ASKO's brand image, i.e. premium, high-end products.

Each of the 16 ideas was rated on a scale from zero to three on how well they fulfilled these criteria, where zero meant it did not fulfil the criteria at all, one meant it barely fulfilled the criteria, two meant it would probably fulfil the criteria and three that it would fulfil the criteria. Nine ideas were considered to have the best potential after being evaluated in the decision matrix. Finally, six ideas were chosen and developed as design recommendations.

4

Study of Literature

4.1 Consumer Needs at Purchase

The first decision consumers make that impacts sustainability is their choice of dishwasher. There are several factors which influence consumers purchasing behaviour. Based on the answers of a survey of 1209 participants across four European countries the most important ones are (Richter, 2010):

- 82,9% Low water and/or energy consumption
- 72,5% Cleaning performance
- 48,2% Low noise emission
- 37,1% Low purchase price
- 36,2% Good results on the energy label

In a more recent EU survey, 75% of consumers said the energy label rating had influenced their decision when purchasing a new appliance (European Commission: Directorate-General for Energy, 2024). These numbers indicate that the awareness about the label importance has considerably increased and most consumers show a strong will to be sustainable by prioritising low water and energy consumption. However, prioritising low consumption may also indicate that consumers want an appliance which is cheap to operate.

4.2 Unsustainable Behaviours in Literature

4.2.1 Inefficient Programme Choice

Inefficient programme choice is the behaviour when users do not use the most efficient programme for the types of dishes they aim to wash. This behaviour leads to a higher water and energy consumption than necessary and addressing it can therefore lead to significant savings in water and energy. In a survey with 4887 participants across six European countries, the eco programme was used in 19,6% of cycles (Alt et al., 2023b). Using the eco programme all the time instead of the current behaviour can lead to water savings of 24,6%, and energy savings of 16,7%, going from 3604 L to 2716 L and 282 kWh to 235 kWh per year based on the test standard of 280 cycles per year (Brunzell and Renström, 2020).

Even though around 80% of consumers value the water and energy efficiency of the

dishwasher when purchasing it (Richter, 2010), the use of the appliance does not always reflect this. Users often do not choose the most efficient programme for the types of dishes in the dishwasher. The eco programme has been specifically designed to be the most efficient programme for normally soiled dishes. However, for other types of soiling, there are programmes which might be more efficient. For example, for lightly soiled dishes the quick programme uses less water and energy (Tewes et al., 2024). Using the more efficient version of programmes for similar purposes e.g. eco instead of normal, quick instead of delicate as proposed by Alt et al. (2023b), can lead to up to 18% water savings and 22,5% energy savings.

Less efficient programmes are chosen for a variety of reasons. Alt et al. (2023a) found that there is a gap in knowledge when it comes to what soil level users think the eco programme can manage and its actual capabilities. Therefore, users will not choose the eco programme out of fear that the dishes will not become clean. Furthermore, 60% of users correlate a short cycle duration with a low energy and water consumption (Hook et al., 2018) even though the opposite is often the case. In connection with this there is a low acceptance rate for longer programmes even among those who believe that they are more efficient (Hook et al., 2018).

4.2.2 Pretreatment of Dishes

Pretreatments are the actions performed on dishes before placing them in the dishwasher to be washed. Dishwasher manufacturers recommend users scrape off large food residues in the rubbish before putting the dishes in the dishwasher, as to not clog up the filter. However, users do not always perform this pretreatment, or they perform other pretreatments instead. For example, a common pretreatment is rinsing dishes under running water before placing them in the dishwasher. This is not necessary for a good cleaning result and leads to an increase in water consumption and in the case of using hot water, an increase in energy use as well.

In Sweden 11% do not pre-treat their dishes in any way, 31% scrape of food scraps and 51% pre rinse each dish (Richter, 2010). Different dishes are also pre-treated differently where plates, bowls, pots, and pans are scraped off more frequently whereas cutlery, cups and glasses are not treated at all more frequently (Stamminger and Streichardt, 2009).

No prerinsing and just scraping off appropriately leads to no water or energy consumption whereas as a dishwasher prerinsing cycle uses about 4 L of water and 0 kWh (ASKO, n.d.). In comparison the water consumption manual prerinsing dishes before a cycle range between 0,3 L for a few dishes to 62 L for all dishes (Richter, 2011). In Sweden the average water consumption for pre-rinsing is 11 L per cycle (Richter, 2011).

Manual prerinsing with 5 litres of water heated to 40 °C, before a cycle adds up to 52 kWh extra annually (Brunzell and Renström, 2020). Whereas , prerinsing and soaking leads to 0,53 kWh extra per cycle (Porrás et al., 2020).

Dishes are pre-rinsed for a variety of reasons, Emmel et al. (2003) found that users say it depends on the food (20%), it is done out of habit (28%), from experience dishes will not get clean otherwise(28%), they do not think dishes will get clean otherwise (35%), or that the dishes will not be washed right away(39%).

4.2.3 Inefficient Loading

Not filling the dishwasher to its full capacity for each cycle is a behaviour which leads to increased energy and water consumption as the consumption stays the same regardless of how full the appliance is. In his studies of dishwasher behaviour across four European countries including Sweden, Richter (2011) found that less than 40% of all dishwasher loads are washed at full capacity. Furthermore, around 20% of baskets are only slightly used, and overfilling is more common with the upper rack than with the bottom rack. Every tenth dishwasher cycle could be saved if the dishwasher would be loaded to its full capacity (Richter, 2011). Based on the test procedure of 12x280 place settings per year with 90% load fill, 31 extra cycles are run per year. With the Miele eco program this would account to 301 L and 26 kWh. With “normal consumer behaviour” this would be 399 L and 31 kWh (Brunzell and Renström, 2020). Cultural differences when it comes to the dishes used can impact how well the capacity of the dishwasher racks can be used (Chen et al., 2023).

4.2.4 Inefficient Detergent Use

Using too much detergent leads to unnecessary chemical usage. The most common type of detergent are tablets, used by 76,2% of users, and 64,7% of those using multifunctional models (Stamminger and Streichardt, 2009). According to the dishwasher manufacturer client, tablets often contain more detergent than is needed in a modern dishwasher, as they are designed to work with a wide variety of models, some which require more detergent. Therefore, liquid or powdered detergents allow the user to use a more accurate dose, leading to less waste of resources.

Rinse-aid is a chemical which can be added to a wash cycle to improve drying time and prevent the formation of drying spots. A total of 60,7% of consumers use it, and even 49,7% of those use it in tandem with multifunctional tablets, which already have this functionality (Stamminger and Streichardt, 2009), making its use superfluous. As this chemical does not improve cleaning performance, it is not critical for the functionality of the dishwasher and its use can therefore be questioned from a sustainability point of view.

According to Stamminger and Streichardt (2009), less than 5% of consumers express dissatisfaction with their detergent choice performance, and using powder, tablets, or adding rinse-aid to multifunctional products does not significantly affect the outcome.

4.2.5 Manual Dishwashing

People who own dishwashers still do a chunk of their dishes manually. Approximately 15% of items are cleaned by hand even though there is a dishwasher available (Stamminger et al., 2019). Due to automatic dishwashing being more efficient than manual, this leads to additional water and energy consumption. Dishwasher owners are often also less efficient than people who only do manual dishwashing, which might be due to the increased efficiency acquired by washing larger loads of dishes (Stamminger and Streichardt, 2009).

Households with a dishwasher use on average 50% less water and 28% less energy per cleaned item and are more likely to use the running tap water when washing dishes by hand, probably because of the lower number of items to be washed (Stamminger and Streichardt, 2009). Among the several reasons stated by Stamminger et al. (2019) behind choosing to manually wash the dishes, the most common are: the need for some items immediately (56%), items that need too much space or are too bulky (52%) and items deemed as non-dishwasher-safe (51%).

4.2.6 Poor Maintenance

Most users do not do any maintenance on their dishwashers even though it is necessary for a well-functioning appliance. Maintenance can consist of cleaning the filter, running a machine cleaning cycle with machine cleaner, running a cycle with higher temperatures from time to time. As much as 78% of users have never had their dishwasher repaired and only 6% have done some repair on their own (Stratton et al., 2021). However, 36% of users indicated that they clean the filter (Belke et al., 2019). Poor maintenance can lead to breakdowns which lead to costly repairs (Stratton et al., 2021). A poorly maintained filter can affect the cleaning effectiveness of the dishwasher, leading users to either pre-rinse dishes or perform extra cleaning after the wash.

5

Market Research

When comparing ASKO to its competitors in the dishwashing sector, the most relevant attributes related to sustainability issues were identified.

On the interface, the eco programme is always the default option: it is a standard requirement. Most of the new models include a delay start (load shifting) option. Some AEG or Electrolux models integrate the QuickSelect touchscreen slider (ranging from the quick programme to the eco), together with the Ecometer (guiding the user to the most sustainable programme through visually green bars), as seen in Figure 5.1.



Figure 5.1: Ecometer and QuickSelect slider features (AEG, n.d.).

Regarding detergent dosage, ASKO has an auto dosing function for dishwashing liquid, storing up to 30 days of detergents. In the same way, Figure 5.2 shows Miele's auto dosing compartment for powder detergent, only for their PowerDisk detergent product, storing up to 30 days as well. It is common for the usual manual detergent compartment to have measurement lines, facilitating an appropriate dosage of powder detergent. All these features encourage the use of powder or liquid detergents, helping to prevent overdosing, which can result either from using tablets or incorrect user measurements.

In terms of how information is shared, manufacturers include in their user manuals an economical/sustainable dishwashing section where users can find practical tips. All companies communicate the recommended loading patterns through rack design, sometimes in very different ways. Likewise, the filter is designed to encourage and facilitate dishwasher maintenance using different approaches. Finally, it is popular among appliances manufacturers to provide an app to connect and control a range of appliances, including dishwashers. While some functionalities, such as remote monitoring, notifications and alerts, personalization, etc. may differ between companies, all these kinds of apps offer helpful information on types of programmes,

maintenance and tips for an optimal use of the machine. Unfortunately, since dishwashing is a relatively simple task, such apps are not widely adopted by dishwasher users, as they are perceived as unnecessary.



Figure 5.2: Miele’s auto dosing compartment for their powder detergent PowerDisk (Miele, n.d.).

Interviews with salespeople and field observation in stores provided valuable insights regarding purchasing choice drivers. According to this study, customers consider the energy label, for economic reasons related to energy efficiency rather than environmental concerns, and noise level when buying a dishwasher. Marketing deals can heavily impact the purchasing decision (e.g. through cashback, longer guarantees and sales). Customers often prefer to buy the least expensive option from a well-known brand, particularly when purchasing dishwashers just before selling their properties, where the brand name matters the most. Repair costs tend to be high, between 2000-3000 kr. It can cost 1500 kr just for the repairer to come and look at the machine, so users usually prefer to buy a new appliance instead of stretching its lifespan.

Looking more closely at specific attributes customers value, the sturdiness of the door is important for certain targeted groups, like families with kids. Some users prefer the classic cutlery basket because it is easier to take and bring to the specific kitchen drawer. In general, there is a tendency to avoid changes: running always the same programmes or buying new dishwashers with similar characteristics than the previous they owned (e.g. preferring the classical front control interface over the newer top interface designs).

Additionally, in the market there are regular machines and XL machines, where the difference is the height, meaning some kitchens can not accommodate the bigger XL machines. Some dishwashers have a plastic floor which might lead to bacteria, scuff marks, and worse drying performance, although these issues are often overlooked by customers. Some differences were spotted in how the filter was designed to promote interaction, with some brands utilizing colours and different shapes or handles for users to grab onto.

Regarding the interface design, compared to other appliances, screens in dishwashers are not as advanced. There are a lot of dishwasher models in stores without screens. Interfaces in dishwashers follow simplicity. To influence the programme choice by having eco as the default option, physical buttons interfaces do not steer the user as much as tactile screen interfaces. There is not as much variation between models and brands in the inside of the dishwasher than in the interfaces. Existing literature support most of the salespeople insights, usually through statistical data. Additional details regarding buying behaviours and current market trends in 2025 have been included, and these findings do not contradict earlier research either.

Four types of dishwashers were identified, analysed and described to be able to select which models were more appropriate to include in the user studies. These studies were planned to understand how design affects user behaviour. Although the main visible differences lie in the interface design, there are also less obvious differences in the level of baskets customisation and filter design. These were also considered in the choice. Finally, these are the four categories of dishwashers based on a human factors' perspective:

1. High-end model with different functionalities: top interface, advanced screen, tactile buttons (e.g. ASKO).
2. Mid-range model with "scroll through programme selection": front or top interface, basic screen, physical buttons (one for all programmes) (e.g. Cylinda, AEG, Bosch...).
3. Mid-range model with "individual programme selection buttons": front or top interface, basic screen, physical buttons (one for each programme) (e.g. Bosch).
4. Low-cost model with simple interface with few buttons: front or top interface, no screen, physical buttons, little to no information on programmes (e.g. Logik, Electrolux...).

6

User Research

6.1 Lab Studies

To analyse the test results, participants' comments were sorted into various categories such as pretreatment, user manual, and dishes not fitting, using a KJ analysis approach. Many of these categories were further divided into subgroups to better organize observations, especially when multiple participants shared similar perspectives on a topic. This section first provides a detailed explanation of the test results, and ends by highlighting the most significant insights, supported by direct quotes from the participants.

Tests results

Overall, age, gender, and profession did not show any significant impact on the results. Nationality also had little influence on automatic dishwashing habits, although manual dishwashing behaviours varied more. The only notable exception was a Japanese participant who experienced difficulties using the dishwashers in the test, as they were familiar with a different style of drawer dishwasher common in Asia.

Guidance on how to place items can reduce the need for aftertreatment, resulting in less water use and higher efficiency through optimal fill levels. The design of racks and supports should intuitively guide users. However, overly prescriptive guidance can make users feel limited or lead to inefficient use of space if the guiding features do not match their actual dishware.

Rearranging is a common user behaviour where users move items within the dishwasher after initially placing them, often to make room for additional items or to optimize the arrangement, which can lead to more efficient dishwashing by fitting more dishes per cycle. Motivations for this behaviour include the challenge and satisfaction of maximizing space, such as playing a game, as well as the desire to avoid manual dishwashing. However, the process requires extra effort.

Prerinsing is a very common unsustainable behaviour, resulting in unnecessary water and energy consumption, especially when hot water is used, and offering little benefit for most dishes; even alternatives such as wiping with a paper towel are unsustainable. Users often prerinse to prevent odours from dirty dishes left in the dishwasher for long periods, because it feels easier than scraping off food residues,

or simply due to the convenience of the sink being close to the dishwasher. Additionally, some users rinse dishes in the sink to avoid the unpleasant task of cleaning the dishwasher filter. Although many are aware of having a bad habit, it is unclear when scraping alone suffices.

Although keeping the dishwasher manual is common, reading it is rare, which means users often miss out on valuable information that could help them use the appliance more efficiently. Users may not fully understand the available features or how to select the most efficient programme, leading to suboptimal loading patterns and less effective use of the dishwasher's capabilities, sometimes overestimating or underestimating what the machine can handle. This knowledge gap can result in unnecessary water and energy consumption, as well as a lot of unused paper manuals in homes. Users tend to prefer online manuals, but many still prefer to learn through hands-on experience rather than reading instructions.

The interface should be intuitive and user-friendly while still offering enough information for users to make informed choices about which program to select, as insufficient guidance can lead to less appropriate program choices. If the information is unclear, users tend to stick with familiar options rather than the most efficient ones. Applying traditional usability principles, such as organizing controls from left to right, enhances ease of use. Users also appreciate knowing the remaining time on a cycle.

Organizing cutlery by type in the dishwasher's cutlery rack is a common and effective practice that improves both loading efficiency and cleaning performance, as similar utensils fit better together and are less likely to overlap, reducing the need for re-cleaning. Users are motivated to spend a bit more time organizing cutlery during loading because it saves time when unloading, allowing them to quickly sort and return items to the drawer in groups. They also believe that this arrangement leads to cleaner results.

In dishwashers equipped with both a cutlery rack and a basket, users frequently remove the basket to make room for more dishes, which results in unnecessary material use and production costs for a component that often goes unused. The cutlery rack, which cannot be removed, is typically preferred, since it is easier to space out utensils for a better cleaning, reducing the need for rewashing. Although some users prefer the basket for its portability and faster loading, it is easier to touch dirty or clean parts of the cutlery with the hands, since handles are usually placed downward. The cutlery rack is not versatile and often too large for the number of utensils.

Some dishes, such as knives, wine glasses, certain pans, and wooden items, are rarely placed in the dishwasher due to users' concerns about potential damage, which leads to more manual washing and increased water usage. Users worry that knives will become dull or rusty, wine glasses are seen as too fragile, and there is uncertainty about which pans, or wooden utensils are dishwasher-safe, with cast iron clearly avoided.

Users often choose to wash heavily soiled items by hand due to a lack of trust in the dishwasher's cleaning capabilities, which results in increased water usage. The act of washing one item by hand can prompt users to clean additional dishes the same way.

During the tests some users left extra space between small bowls in the dishwasher, explaining that they were unsure if they would get clean if placed closer together, while others packed the bowls tightly to maximize space while mentioning that they expect they might have to rinse them afterward. This uncertainty leads to sustainability issues: leaving too much space reduces the dishwasher's capacity and efficiency, while bowls placed too close together may require additional water for manual rinsing.

Users typically develop their dishwasher loading habits through trial and error, adjusting their approach based on whether dishes come out clean, which eventually leads to more automatic thinking. Loading workflows vary: some users load big items first to then fit smaller ones into the remaining gaps, others begin with cutlery since it is often on top of their pile of dishes, while others load from the bottom up to avoid water dripping on themselves. Although interaction colours on racks and supports are generally appreciated for guiding placement, they can be confusing if not used clearly.

The duration of a dishwasher cycle is less important to users when running the machine overnight or while away from home, but one participant mentioned avoiding unattended use due to concerns about potential electrical faults causing fires, water leaks, or disruptive noise at night, leading them to choose shorter, less sustainable programs instead.

The programme choice is often influenced by users' desire to save time rather than sustainability, with many opting for quicker cycles over the eco program, which, despite typically delivering satisfactory results, is perceived as too long, especially during the day. This leads to sustainability issues: selecting an inappropriate programme for the level of soil on the dishes can increase environmental impact, as using the eco program when higher temperatures are needed may result in poor cleaning and the need to re-run cycles, while not using eco when suitable wastes water and energy. Users' uncertainty about the actual benefits of the eco program, a preference for familiar or default options like "universal" or "normal," and a lack of clear information on the machine itself about each program's characteristics all contribute to suboptimal choices. Most users rarely adjust settings based on load conditions, relying instead on habit or previous experience.

Users admit starting the machine when it is as full as possible to maximize efficiency and minimize hand washing, though achieving this balance can be challenging, especially if users are tempted to run cycles on a fixed schedule rather than based on actual load.

Participants living in multi-people households reported that varying loading practices as something contributes to inefficient space use, increased cycle frequency, and even arguments. The process of rearranging to optimize space is often seen as too time consuming or not worth the effort.

The design of the dishwasher filter significantly influences how inviting and easy it is for users to perform maintenance, directly affecting the overall user experience. If the filter is difficult to access, has an unclear or uncomfortable shape, or does not visually indicate its function, users may be less inclined to clean it regularly. The user is more likely to search on the Internet than consult the manual if they do not see the process self-explanatory enough in the filter design. Failure to clean the filter leads to food stacking, which affects water circulation, reduces cleaning performance, and often results in users needing to re-run cycles, wasting water, energy, and potentially shortening the dishwasher's lifespan.

Reluctance to clean the filter can prompt users to pre-rinse dishes excessively, further increasing unnecessary water and energy consumption. Many users find filter cleaning unpleasant, are unaware of its importance, or simply do not know when it should be done, as dishwashers rarely provide this information beyond the manual.

There is a significant gap between what users believe is environmentally responsible and what actually is, leading to counterproductive behaviours, such as unnecessary prerinsing, frequent hand washing, or inappropriate program selection, all of which increase water and energy consumption. Many users do not understand why the eco programme is considered eco-friendly, mistakenly assuming that its longer duration means higher resource use. And while most recognize that filling the machine to maximum capacity is sustainable, there is confusion about what "maximum" actually means. There is also a lack of clear incentives or information: users feel the need of tangible data on electricity and cost savings to justify choosing the eco programme over faster cycles. Users generally believe dishwashers are more efficient than hand washing. Preferences for detergent types are based on habit rather than sustainability knowledge, and few users take advantage of features like delay start to run cycles during off-peak hours, as checking for cheaper electricity rates feels inconvenient.

Inadequate dish placement in the dishwasher undermines both space optimization and cleaning effectiveness, leading to sustainability issues such as running more cycles due to underfilled loads or inadequate cleaning, which increases water and energy consumption, and potentially damages mechanical parts if items move during washing, shortening the machine's lifespan. Common mistakes include not utilizing undefined middle spaces (ideal for flat items like plates and cutting boards), not grouping similar items for better fit and easier unloading, placing items so that they block water and detergent flow, and placing dishes where it is likely that they move around, which not only causes noise but also compromises cleanliness. Some users benefit from larger interior spaces and extra racks, as seen in certain dishwasher models, which encourages better loading and higher satisfaction. However, many

users are unaware of their dishwasher’s full potential and the best ways to arrange their dishes.

When users are faced with the decision to manually wash dishes that did not fit in the current dishwasher load or wait for the next cycle, their choices are often influenced by factors such as convenience, mood, the desire for a tidy kitchen, or the perceived ease of cleaning certain items, rather than sustainability. Manual washing, especially when done with running tap water, typically results in higher water and energy consumption compared to using the dishwasher, while waiting for the next cycle can lead to underfilled loads, which also wastes resources. Additionally, users may prefer to manually wash lightly soiled items that they see as easy to wash or very dirty items to avoid letting grime dry. Users prioritize immediate comfort and convenience over environmental impact when deciding whether to manually wash or wait for the current cycle to end.

When deciding which items to include in a dishwasher cycle, users often exclude certain dishes, such as large pots, pans, large bowls, utensils, food containers, wine glasses, or weird-shaped items, because these either take up too much space, are difficult to fit, or do not always come out clean. This leads them to believe that hand washing is faster or more efficient for these specific pieces. However, this is not usually the case. Hand washing typically results in higher water and energy consumption, while waiting for the next cycle with these items left out can lead to underfilled loads and reduced efficiency. The choices of users are in this aspect primarily driven by habits, perceptions of convenience and space optimization, rather than sustainability.

Users generally have limited knowledge about detergent choices and proper usage in dishwashing, often defaulting to the convenience of tablets without considering alternatives like powder or gel, that allow for dosage control. This lack of understanding can lead to underdosing, resulting in poor cleaning and the need to re-run cycles, which increases water and energy consumption, or overdosing, which wastes detergent and increases the environmental impact from its production and distribution. Additionally, many users are unsure about the specific roles of other chemical products, such as salt and rinse aid, and how to tailor their use to the dishwasher’s needs.

Summary of main insights

The awareness of good loading practices varies between users but is generally unclear, with several expressing uncertainty about the recommended space between dishes. For example, Participant 3 remarked, “I would put the small bowls without spacing because I want to fit as much as possible”. Another participant commented on how dish placement affected the effectiveness of the spray arms:

“This small plate is under a deep plate, that might be an issue, but if I saw it, I would not move it because I’m too lazy”

- Participant 1

Users prefer a level of guidance that strikes a balance, not being overly flexible or too constraining. There is a sense of doing something wrong when they place items in spaces not explicitly designed for them, "Sometimes if there is space on the edges, you can cheat a bit. It feels like cheating; I'd put for example cutting boards" (Participant 10). Guidance often feels confusing or misaligned with users' natural instincts for positioning items, leading to eventually placing them in a way that feels most convenient:

"With the cutlery I'd start like that (places them in an organised way) but maybe at some point I would just throw them in"

- Participant 3

Users generally prioritize automatic dishwashing over manual washing, aiming to fill the machine, "I like to put in as much as possible, so I don't have to hand wash" (Participant 7), though they often choose to do manual washing when only a few items remain or to avoid waiting for a full load. Large or weird-shaped items like pots, pans, food containers, and wine glasses are typically washed manually, "These kind of big things I do by hand because it's hard to fit into the dishwasher" (Participant 3), as well as items perceived as easy to clean, "The cutting boards are usually not that dirty, so I would just hand wash them" (Participant 6). There is a lack of confidence in the dishwasher's abilities, "Another reason why I wouldn't wait for the next cycle is because then I think it will dry in and then it's harder for the dishwasher to clean" (Participant 6), leading users to wash these items manually. Keeping an uncluttered kitchen countertop is important for many:

"I hate seeing dirty dishes piled up, it depresses me"

- Participant 4

Fragile or expensive items, as well as those made from less common materials, are typically washed manually, with users expressing specific preferences based on their perceptions of care and safety, "I think the dishwasher is gentler than my hand washing, for the ceramic items, but not for the tools. For the tools I know the torsion is bad" (Participant 6). There is widespread uncertainty about which pans are dishwasher-safe:

"It feels better to have frying pans and all this stuff done by hand"

- Participant 10

"The pan maybe you can put it in the dishwasher, but I wouldn't do it"

- Participant 1

Wine glasses, considered particularly fragile, bring mixed approaches, "I wouldn't put wine glasses in the dishwasher because I don't know how well they'd survive. But ironically, quite often they get broken when you're washing by hand" (Participant 4).

Options such as powder or gel for dosing control are rarely considered by users, largely due to a lack of awareness about the variety of dishwasher detergents available on the market:

“I only use pods ever, and I haven’t thought about using anything else”

- Participant 10

There is also a lack of knowledge about other chemical products for dishwasher care, “I would not touch that (rinse aid compartment) because I have no clue what it is” (Participant 10).

Generally, users do not feel influenced by the dishwasher interface when selecting a programme. They prioritize factors like time, “I’ll choose some programme which is not too long, of course” (Participant 7), over sustainability, due to practical reasons such as needing certain dishes quickly, avoiding noise or unsupervised cycles. While there is a preference for the eco programme among some users, “I’d choose the eco option, it takes a little bit more time but less water” (Participant 6), there remains uncertainty about its benefits:

“I don’t understand why is it more environmentally friendly to run a machine for 4 hours”

- Participant 4

Many users tend to choose the default option (usually eco) or the one seen as the “standard” washing programme, “I just put the first one that pops up because that’s like the regular washing programme” (Participant 5), rather than making decisions based on a detailed understanding of the available settings.

Older users clean dishwasher filters more than the younger. But they find the task unpleasant or even disgusting:

“One of my least favourite jobs is cleaning out the filter on the dishwasher”

- Participant 4

And they often feel they lack the necessary information to do it properly. The absence of clear indicators for when maintenance should be performed was highlighted by some of them, “I would just hope that there was one light in the panel that warns me” (Participant 6) or “I don’t think the dishwasher has any indication that the filter needs to be cleaned” (Participant 7). In addition, the filter design did not adequately explain the cleaning procedure in some cases, “When the machine was new, I didn’t put the filter back correctly and the dishes didn’t get clean”(Participant 7), leading to mistakes.

Identified design challenges based on user test insights

One of the challenges is to make loading or rearranging more enjoyable and rewarding for the user. To address this, the game-like satisfaction of fitting items efficiently could be explored using motivational cues or interactive elements. Another aspect is the perceived workload of scraping: it should be simplified to make the task feel easier and more appealing. The way information is shared should also be in the spotlight. The main challenge lies in delivering all necessary information within the limited space available, ensuring clarity without overwhelming the user. Clarifying what truly constitutes sustainable behaviour and helping users make the right choices is necessary.

To encourage more sustainable use, dishwashers should build trust with the user, giving them a solid understanding and confidence in the capabilities of the appliance. Increased confidence in the dishwasher's safety features and reliability could make users more comfortable with running longer eco programmes when they are not present, thereby promoting more sustainable usage.

The design must also strike a balance between freedom and constraint. The key questions are which dishes the dishwasher should guide users to place and how this guidance is communicated to ensure sustainable use. The types of dishes used regularly impact loading patterns, and it can be difficult to optimize space when dealing with bulkier items such as food containers, making it important for dishwasher design to accommodate this variability. Dishwashers currently provide little guidance on optimal loading, resulting in significant differences in loading patterns and usage among household members. Furthermore, users need to be confident that even delicate items can be safely washed and encourage optimal spacing between items. Preferably, the dishwasher should include either a rack or a basket and be designed so that users do not have to touch the dirty or clean ends of cutlery, promoting both hygiene and efficient use of space.

The filter, apart from being ergonomic, clearly identifiable and easy to reach, should communicate through its design and/or the interface when and how maintenance should be performed, facilitating the process even for experienced users and supporting more sustainable dishwasher use. Detergent overdosage could be addressed through improved communication and guidance through the design of detergent compartments and increased awareness of detergent alternatives.

6.2 Home Studies

Collected data for analysis included the diary responses to the questions and pictures of loading layouts. By comparing the answers with the pictures, correlations between reported behaviours and actual practices were examined. The findings from the three diaries are discussed below. The section ends with a summary of general insights and impressions.

The first diary was filled out by a three-person household, consisting of older adults aged between 55 and 64. This home uses a Bosch SMS40E28EU dishwasher that is over 10 years old and typically runs a cycle every three days, choosing the “normal 65°” programme each time regardless of how clean the dishes are. Users habitually pre-rinse dishes, often with soap, resulting in dishes that look extremely clean before the wash cycle. They feel confident when choosing a programme because they always choose the same one. When navigating through the interface, they feel relaxed, not in a hurry, and responsible, for completing pending tasks. When loading the machine, users feel positive emotions. They experienced the task as relaxing, not in a rush, amusing or satisfying, because they could fit everything). The bottom rack is neatly organized, while the top rack’s arrangement varies. Extra shelves and spaces between plates are used efficiently. However, large items like pots and pans are washed by hand. Every loading is full and perceived as full by the user. In addition, this is the reason for deciding to run a cycle. Users express satisfaction with the cleanliness achieved.

The second household consists of two people between the ages of 55 and 64 years old with a three-year-old Siemens SN65ZX48CE/25 dishwasher. They run a cycle approximately every three days, starting at different times throughout the day. The household often put pots in the dishwasher, but rarely pans. In the case where there are a lot of dirty plates, pots are washed by hand instead. The second drawer is often full of many smaller items, whereas the bottom drawer is filled with a few plates and some pots or oven dishes. Users do not prerinse and the types of dishes and their placement within the dishwasher varies significantly between cycles. Dishes washed in the dishwasher are dirty and the user perceives them to be dirty. When to run a cycle is based on when the machine is perceived to be full, which often happens right after a meal. The loading process generally evokes positive emotions, and the users find it satisfying and accomplishing, as they could fit all of their dishes with ease. For one cycle, the task was described as tiresome but still accomplishing, as it was a chore completed. When navigating through the interface to choose their usual programme users felt particularly confident but still felt the same when trying other programmes due to the simple unthreatening display. Programme choice is dependent on the user, where “Auto 45°-65°” is the one used most frequently, by habit. However, the “70° plates & pots” is chosen when washing dirty pots, adapting the programme to the soil level and types of dishes. Another user ran the “60°” programme because it was quick and hot enough to effectively clean the dishes quickly. Users are satisfied with the level of cleaning result, even though dishes are sometimes not dry at the end of the cycle.

Lastly, this one-person household, consisting of a young adult aged between 18 and 24 years old, uses an Electrolux CarePlus ESF6521 dishwasher that is over 10 years old. The user runs a cycle per week, washing mainly lunch boxes and avoiding pots, pans, or bulky items, which are hand washed instead. The dishes loaded are generally slightly dirty, as perceived by the user, and not prerinsed. The layout is consistent and organized across the five cycles. The loading could be optimized further, although the user perceives it as full. The decision to run a cycle is driven by the need for clean dishes before a weekly meal preparation, with the perception of a full load also influencing the choice. When loading the machine, the user feels both negative and positive emotions. They experienced the task as: stressful, with the need to think about what to handwash and which layout; frustrating, when afraid of breaking items and bad cleaning results when it seemed very full; and tiresome or disappointing, when admits that could have optimised better the layout. But overall, a feeling of satisfaction also repeats in most of the cycles. Confusion is sometimes experienced when selecting a programme due to uncertainty about the other options and additional steps that can show up. However, the user feels confident in general, familiar with the process and interface, and relieved, for completing a pending task. Every cycle is run with the “standard 65°” programme, chosen for its reliability and predictability, and because it feels like the default option. The user mentions not wanting to change it to avoid the risk of having to rerun a cycle due to bad results. After the cycle, they sometimes find that certain items, particularly plastics, are not fully clean or have collected dirty water, needing additional handwashing.

A comparison of the results from the three diary studies revealed several insights into the home usage of dishwashers. In single-person households, there is a higher level of consistency in both the loading pattern and the dishes used in each cycle. Prerinsing behaviour varied heavily between the three tests, ranging from extensive prerinsing, where the dishes are effectively cleaned prior to loading them in the dishwasher, to no prerinsing at all, as seen in Figure 6.1.



Figure 6.1: Differences in pretreatment of dishes between household 1 and 2.

Regarding the loading layout, Figure 6.2 shows that space is utilised much better when the main type of dishes included in a cycle are plates, not when they are pots, pans or lunch boxes. In all three households, despite loading the dishwasher very close to the maximum, there is empty space in the cutlery rack or basket.



Figure 6.2: Comparison between plates versus bulkier items in household 2.

The main reason for starting a wash cycle amongst the participants is when the dishwasher is perceived as full. While loading the dishwasher is sometimes described as tiresome, it is generally perceived as satisfying once completed. Users choose the same programme most of the time: the one that is considered to be the “standard”. However, they do not choose eco. Users are familiar with the interface and the entire programme selection process. They generally feel confident, relaxed, responsible and relieved, as it can be seen as the last part of the dishwashing process. Confusion is the most common negative emotion related to the interface interaction, occasionally identified in some cycles. In response to that, users state that they would like it as simple as possible.

7

Research Synthesis

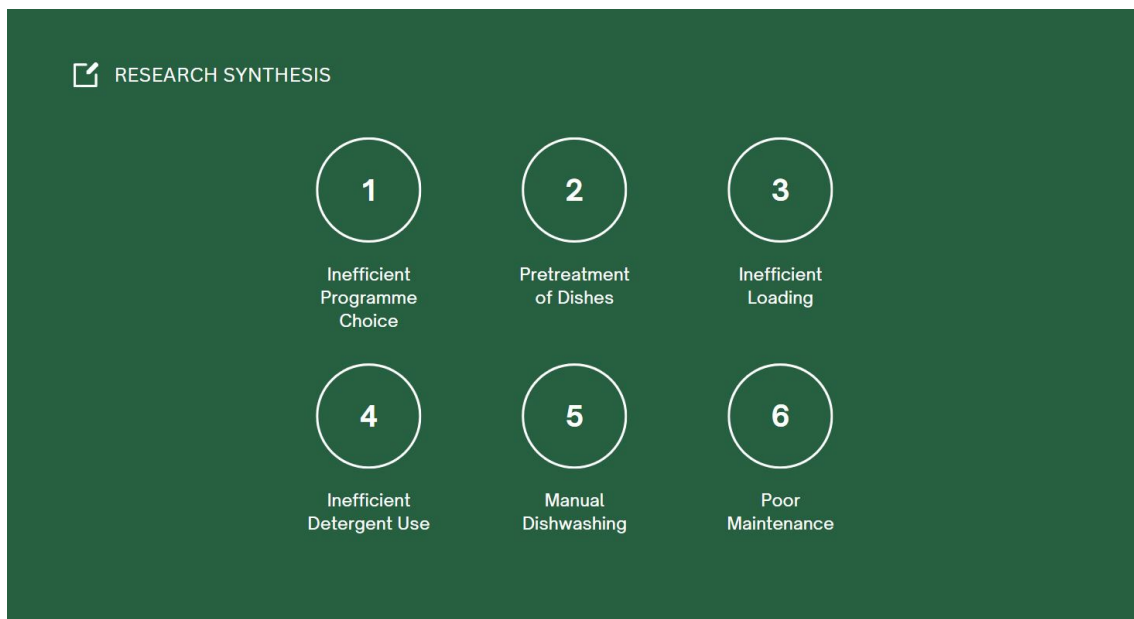


Figure 7.1: Six unsustainable behaviours.

Manual dishwashing in complement to dishwasher

Dishwasher users still do significant amounts of hand washing in addition to their automatic dishwashing. This was identified as a common behaviour both in the literature and in user studies. This behaviour leads to a significant increase in water and energy consumption as modern dishwashers are more efficient than manual dishwashing (Vivian et al., 2011). Participants in the user studies described a dislike of manual dishwashing and a preference for automatic dishwashing (Berkholz et al., 2010). However, they still partake in manual dishwashing.

There are several identified factors why users manually wash up some items. During the user studies it was identified that heavily soiled items which have burnt in soil, or which have been standing around for a while in the kitchen before being washed are more likely to be washed by hand. These items are often cookware such as pots and pans. The increased manual washing of these items was also identified by previous research (Stamminger and Streichardt, 2009). This is due to users not believing the dishes will get sufficiently clean from a dishwasher cycle, indicating a distrust in the

dishwasher's capabilities which may be based on previous experiences or not.

Dishes that are perceived as fragile are also more likely to be washed by hand as users fear they will get damaged in the dishwasher. Users were especially concerned about wine glasses, pans, and knives. This is consistent with previous studies on which items are more likely to be washed manually (Richter, 2010; Stamminger et al., 2019).

Users prefer to wash items that take up a lot of space in the dishwasher due to their size or shape manually (Richter, 2010). This aligns with the loading behaviours observed in both the lab tests and the home diary studies. Where users generally avoid putting in larger items such as oven dishes or pots and pans in favour of other items. Users feel like they are using the dishwasher in a more efficient manner through this behaviour as they can wash a larger number of items per cycle by not washing these large items. As many users want to fill the dishwasher as much as possible before initiating a cycle it may take several days before a cycle is started. Therefore, they feel like they need to wash some items manually instead of in the dishwasher as they are needed again before the next cycle can be completed. This is often the case for cookware used in preparation of food such as pots, pans, utensils and knives.

Another reason for manual dishwashing is in the case where some dishes do not fit into the dishwasher, and as the user does not want their kitchen to look cluttered, they wash these dishes manually instead of leaving them on the kitchen counter for the next cycle

Inefficient detergent use

User testing revealed that tablets are the preferred detergent type for most users. This finding aligns with existing literature; Stamminger and Streichardt (2009) report that in 2009, 76,2% of users used tablets. Generally, users are not well informed about the range of detergent options available, which means that they rarely consider dosage control alternatives that could help prevent overdosing and promote more sustainable practices using a more accurate dose. On the other side, a less common issue is underdosing, among users who rely on powder or gel detergent. This can translate into a bad performance of the machine and the need to hand wash or re-run a cycle. Both inappropriate dosing scenarios have an environmental impact: the first results in detergent waste, while the second leads to unnecessary water and energy use.

According to the literature, less than 5% of consumers report dissatisfaction with cleaning results, regardless of whether they use powder or tablets (Stamminger and Streichardt, 2009). This indicates that the widespread use of tablets is due to convenience or consumer unawareness of alternatives, rather than superior cleaning performance. The limited availability of powder or gel detergents in stores, along with insufficient communication from appliance retailers or dishwasher manufacturers about their benefits, contributes to this trend.

Test results also indicated that users are generally unsure about the exact function of rinse aid and how to adapt its use to their dishwasher's needs. According to Stamminger and Streichardt (2009), 60.7% of consumers use rinse aid in their dishwashers. However, this product does not improve cleaning performance and is not essential for the dishwasher's operation. Hence, its use is questionable from a sustainability perspective, especially when multifunctional products (i.e. all-in-one tablets) are combined with additional rinse-aid, since there is no significant difference in the cleaning results when comparing the use of a multifunctional product to a regular one with rinse aid (Stamminger and Streichardt, 2009). This excess of chemicals, as the authors report, is very common.

Inefficient loading

Most dishwasher cycles are run before the appliance is filled to its full capacity, with less than 40% of cycles run at full capacity (Richter, 2011). However, the cycles analysed in the user studies appear to be quite full, with minimal visible space available for more items. One of the identified reasons behind this discrepancy is that there are spaces within the dishwasher that are technically suitable for dishes but are not perceived by users as intended to be used. For example, the gaps between the rows of plates in the lower rack. Although this space is sometimes used for cutting boards or lids, it is seen as an improper placement.

Another reason why users perceive the dishwasher as being full when there is still space left is due to the placement of some dishes with more space between them than is needed to achieve a good cleaning result. Users partake in this behaviour as they are not confident that the dishes will get clean otherwise. The opposite is also true where some users place items closer to each other than the dishwasher can handle, even though they are aware that the dishes might not get clean, as they value fitting a lot of dishes more than the cleanliness of some items.

A significant difference in loading that was noticed between the home studies and the user testing was that the dishes were loaded in a more organised manner in the testing. During the tests all of the dishes were added in one go whereas dishes are added in waves after each meal in regular usage. Therefore, users cannot plan their loading layout beforehand as they do not know which dishes will be added at a later stage. To reach a high utilisation of the space users need to rearrange dishes as more are added to the dishwasher. This additional effort from users may result in them omitting this step, leading to dishes placed in a way which uses up more space than necessary. Therefore, reducing the efficiency of the space utilisation within the dishwasher.

Another factor behind the behaviour of starting dishwasher cycles before the machine is full is that there are some dishes within the dishwasher which the users need more urgently. As they need these items before the machine can be fully filled, they start the machine to get these items clean so that they can be used again. Fear

of odours developing within the dishwasher may also lead users to initiate a cycle before filling the dishwasher to its full capacity, as it may take several days.

Inefficient programme choice

Choosing which programme to use is an action where users can have a significant impact on the efficiency of their dishwasher through the push of a button. By choosing more efficient variations of their usual programmes, users can lower their water consumption by up to 22,5% and energy consumption by 18% (Alt et al., 2023b). However, there are two primary barriers for users to adopt this behaviour: a lack of information and the convenience of their usual habits.

Regarding the lack of information there are many users who think they act sustainably but, due to a lack of knowledge, might take part in unsustainable behaviours. There are also those who want to act more sustainably but do not know how. This is a factor behind many of the identified unsustainable behaviours. An example of this is in the usage of the eco programme, as many users relate longer programme durations with increased cleaning capabilities and higher water and energy consumption: 60% of people believe that water and energy can be saved by using short programmes, in comparison with the 25 which believed that longer programmes can be resource efficient (Hook et al., 2018). Both the user studies and previous research have shown users to have a strong preference for programmes with shorter durations (Hook et al., 2018). This preference is further reinforced by the fear of leaving the dishwasher running unattended due to a fear of fire from electrical failure or water damage, due to leakage.

Additionally, users generally have a low awareness of the differences between programmes. Programme selection is often based on the limited information available in the interface, which typically consists of a combination of programme name, symbols, temperature, and duration. This information varies between appliances, and users often do not have all information to make an informed choice of which programme is best for their scenario. As shown by Alt et al. (2023a), users exhibit a lack of trust in the eco programme's cleaning effectiveness, doubting its ability to clean the types of dirty dishes it was designed for. This distrust likely contributes to a lower utilisation of the programme.

While most of the information users need to make more sustainable decisions is available in the user manual, it is rare for them to read it unless there has been an issue with the appliance.

Poor maintenance

Inadequate maintenance can be the cause of breakdowns and expensive repairs (Stratton et al., 2021). The authors also note that 78% of users have never had a repair done, meaning that technical issues frequently lead to the purchase of a new machine. According to Dimara et al. (2024), under these circumstances, only

52% of dishwasher users successfully get the machine repaired. This early replacement reduces the appliance's expected lifespan and results in the environmental impact tied to manufacturing and distributing a new dishwasher.

The main maintenance task expected from users is cleaning the filter, yet in the lab user tests, only a few participants reported doing so. This aligns with literature findings, stating that only 36% of users clean the filter (Belke et al., 2019). The reason observed in the tests was a lack of information or guidance on when and how to perform the task, despite instructions being present in the manual, suggesting that the filter's design or user interface are not intuitive enough to explain the process themselves. Another recurring comment was that the task is unpleasant or disgusting, leading some users to prerinse more intensively to avoid having to clean the filter.

Apart from potentially shortening the dishwasher lifespan, not cleaning the filter leads to food stacking, which disrupts water flow, reduces cleaning performance, and often results in the need to handwash or re-run cycles, leading to increased water and energy consumption. Although these consequences can be listed, there is a gap in research: no studies have examined the environmental impact of an inappropriate dishwasher maintenance from a quantitative approach.

Pretreatment of dishes

Before placing dishes in the dishwasher, users are recommended to remove larger food residues by scraping them off. However, many of them rinse the dishes under running water in the sink instead. This practice leads to a significant additional water consumption and is not necessary in most cases. Prerinsing allows users to remove food residues more thoroughly than what is possible by scraping off any remaining food residues with a fork or knife. As observed in the home studies, some users prerinse to a degree so that the dishes are basically clean, using the dishwasher as a tool to verify the cleaning result. It is also a behaviour that takes place outside of the dishwasher, making it difficult to address through design. The main reason for prerinsing is either out of a distrust in the dishwashers cleaning effectiveness or due to being perceived as more convenient than scraping off. Users may have had a previous experience with a dish not getting clean without prerinsing, initiating the behaviour. Once users start to prerinse, it is often continued out of habit.

Users describe it as being more convenient to prerinse than scraping due to the proximity of the sink and that it allows them to avoid having to clean the filter, an activity which is described as disgusting. Another reason is that they want to avoid the emergence of odours within the dishwasher. This might mean that users want to behave sustainably by trying to fill the dishwasher efficiently. However, as this may take several days, they expect odours to form, so they prerinse to avoid it.

8

Concept Development

The most relevant design directions that drove the ideation phase were reducing manual dishwashing, promoting optimal usage of space, providing the right information and filter and pretreatment. The ideas that were developed during the initial brainstorming sessions were grouped into the following categories:

Rack design

One set of suggestions focused on enhancing the rack design. These included modifying the support structure to better secure particular items and increase user confidence. Additionally, it was proposed to add more icons to the racks, helping users load specific items more efficiently. To further build trust, especially when loading fragile items, there were also recommendations to incorporate more rubberised textures to the racks.

Interior changes

There were several ideas about implementing other physical changes within the dishwasher, such as increasing the premium feeling through the use of lights or smells or highlighting existing features within the dishwasher by making them more distinct, increasing user awareness.

Add-ons

Another approach was the implementation of add-on solutions, including the development of products that can be used together with the dishwasher to enhance its efficiency.

Interface

There were also suggestions for changes to the interface that included modifications in the available content, how users interact, and messages reminding them of certain tasks or providing them with tips and informative sustainability data, such as statistics of water and energy use.

Dishwashing unit

The dishwashing unit was a standalone concept, where the space next to the dish-

washer is used for storing soiled dishes which do not fit in the dishwasher. There is also space for a compost bag with a tool to scrape off food residues from plates.

Smart dishwasher

Finally, a large number of ideas suggested developing smart dishwashers by adding more sensors to make them more aware of how they are being used. One way to achieve this was to add visual cues within the dishwasher to guide users where to place certain items. Another direction was to help the user load the dishwasher by being aware of which dishes needed to fit and from this calculating the optimal layout for the dishes. There were also several ideas about how to present the user with information on how much of the available space they have used up within the dishwasher.

The following nine ideas were evaluated in a decision matrix. Five of them and the scraping tool from the dishwashing unit concept were developed and presented in the next section as design recommendations for the client.

Programme costs on screen

The programme costs on screen idea aims to increase the usage of the eco programme by adding information in the interface about water and energy consumption for each programme. As it is a common misconception among users that the eco programme uses more water and energy than other programmes due to its longer duration, displaying the numbers will make them aware of the actual water and energy consumption. The interface could also get the current electrical and water costs for the user and present the monetary cost of running each programme. Thus, making the benefits of choosing the eco programme clearer.

Auto Doser text

Some ASKO dishwashers are equipped with an auto dosing system, allowing for more accurate dosing of detergent, leading to less overdosing. However, this is only true if it is used as intended. From the user testing it was obvious that participants did not understand what the auto dosing unit was used for just by looking at it. Therefore, it is necessary to add explanatory text to increase user awareness of this feature.

Sustainability sheet

There is a lot of useful information in the user manual on how to use the dishwasher more sustainably. However, most users do not utilise information as they do not read the manual. Therefore, making the information available on a one-page sustainability sheet in a more easily digestible format with graphs and illustrations is

one way to get the users to engage with the information.

Tips & tricks

Presenting the most relevant user manual information on the interface, in smaller chunks, through tips & tricks. These tips inform the user on how to develop more sustainable dishwashing habits. The tips are displayed at moments when the user is looking at the screen, for example, when turning on the dishwasher.

Dishwashing unit

A dishwashing unit located next to the dishwasher. The unit consists of extra drawers where the user can store dirty dishes that are left over after the dishwasher is filled. The user can also store dishes which have been used and are deemed too dirty to put back with the clean kitchenware, but which are still deemed clean enough to use again. There is also space for a compost bag as well as a specialised scraping tool to facilitate scraping off food residues from soiled dishes.

Filter warning

Current ASKO dishwasher show a warning to users when it is time for them to maintain the filter. This warning shows up after a certain number of cycles and then does not show up again until the number has been reached again. It is therefore easily dismissible by the user. A more persistent warning which does not go away until the user maintains the filter may therefore be more effective at making sure the filter works as intended. A sensor within the filter compartment senses when the filter is removed and then put back into its place. The warning in the interface is complemented by a blinking warning lamp in the filter compartment, drawing the user's attention to the filter.

Better knife holders

The knife holders in the ASKO dishwashers are difficult to distinguish due to their colour, and placement. Furthermore, knives placed in them are in the way of other dishes. Moving these holders where users are more likely to notice and use them, and where they are not in the way of other dishes could encourage users to wash knives in the dishwasher more often, reducing the need for manual cleaning.

Dirty dish scanner

A system of sensors that detect which dishes are placed on the kitchen countertop and, based on these data, develop a plan for where they should be placed in the dishwasher to maximise space efficiency. The placement plan is shown inside the dishwasher using projections and lights. A similar idea was presented by Imai and Maeda (2017), who developed an algorithm that develops an optimal loading layout based on a photograph.

Fill percentage

Through sensors in the dishwasher, how much of the available space is being used is calculated. The user is then shown a percentage of how much space is used and is encouraged to get as close to 100% as possible.

Dealing with the unsustainable behaviour of not filling the dishwasher to its maximum capacity. Showing the actual fill percentage to the user makes the user aware of the available space and reflect on that they could fit more items. Gamifying the process could also be an incitement to fill the machine more thoroughly as it becomes more of a challenge.

When implementing this change, any negative effects that may arise due to overloading need to be taken into account. As users may load too much due to this added feature.

Four of these ideas were not pursued. Firstly, the dirty dish scanner concept was not developed further due to the amount of technology needed to be developed and implemented, in relation to its expected impact on sustainability. uncertain amount of improvement in sustainability as users still need to follow the guidance to make any difference. Next, the fill percentage idea was part of the smart dishwasher features requiring advanced technology. It could help manage load capacity and reduce manual dishwashing, but it does not address the underlying reason people run a cycle or wash by hand: the immediate need for clean dishes. Outside of the smart dishwasher group, the knife holder concept was not developed further as it was considered only to solve a small part of a small problem. Although making the knife holders more visually distinct might lead to more usage, it does not solve the issues with detergents wearing out the knives. Finally, the dishwashing unit concept was not developed further because, although it aimed to solve manual dishwashing issues by providing a drawer for soiled dishes to wait until the next cycle, its primary focus was actually reducing kitchen clutter, a concern not directly related to sustainability.

9

Design Recommendations

The concept development yielded six design recommendations addressing different unsustainable behaviours in different ways, as shown in Figure 9.1. All the recommendations provide information and feedback to the user regarding various behaviours at different times throughout the interaction. By providing information at the right time, users will be nudged to act sustainably and gain more trust in the dishwasher's capabilities.

All design recommendations could be implemented on their own, but they could also be implemented together to increase the potential for change and have a greater impact on several unsustainable behaviours.

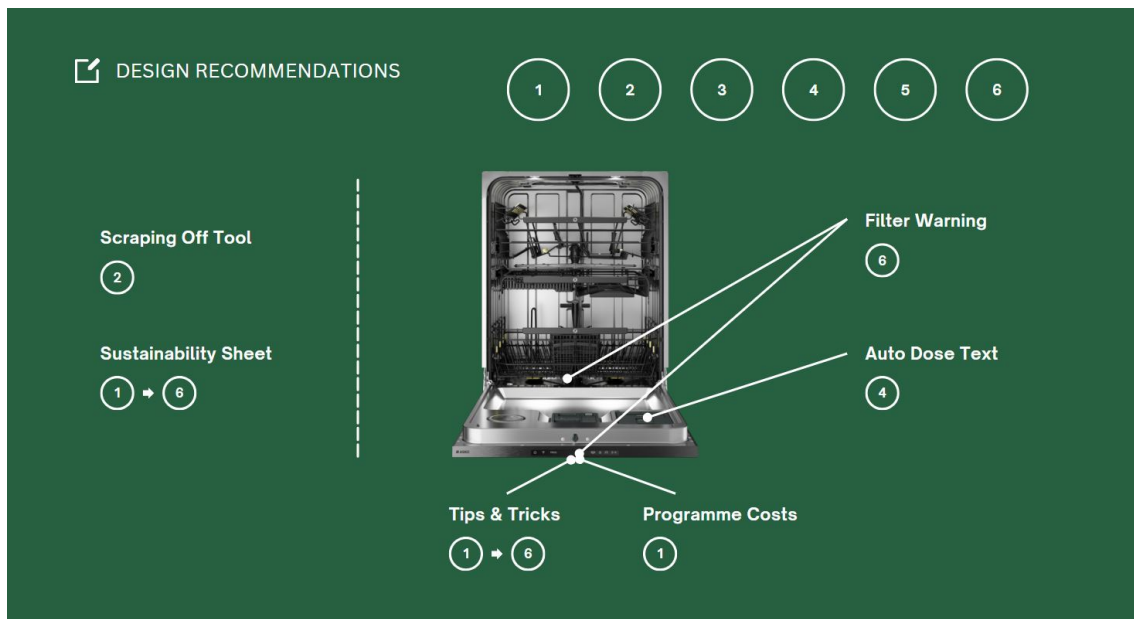


Figure 9.1: Design recommendations pointing to the dishwasher part where they are implemented and the unsustainable behaviours they address.

Sustainability sheet

The sustainability sheet is a one-page informational infographic designed to promote more sustainable dishwasher usage. It aims to enlighten users by providing information on best practices, which may influence their beliefs and attitudes towards certain behaviours. Additionally, it aims to clear up common misconceptions and motivate users to change their practices. See a format and design proposal in Figure 9.2.

The sheet is included with the rest of the informational material provided with the purchase of a new dishwasher. Printed on sturdy paper for durability and easier reading, the sheet uses bold headlines and colourful graphics to entice users to read it. It contains information on several aspects of dishwasher use, such as how to prepare dishes for the dishwasher, how to load it effectively, the benefits of powder/gel vs tablets, the difference between programmes and the importance of performing maintenance. By addressing all of the identified unsustainable behaviours, this design recommendation acts as an easily accessible source of information that users may read to gain an understanding of how usage affects the efficiency of the dishwasher.

Together towards sustainable dishwashing

Recommended practices for a more sustainable use of your ASKO dishwasher



ConnectLife
Connect your smart appliances and service from anywhere




Save time, skip rinsing

Pre rinsing is not necessary for a good result. Instead, scrape off food residues in the compost bag

Choose the eco programme

Use the least amount of energy and water to clean normally soiled dishes

Please read the user manual for more information



- ✓ Group similar items together
- ✓ Consider the water flow from the spray arms



- ✓ Check distance between dishes
- ✓ Use the middle spaces for flat plates, cutting boards or lids

Load your dishwasher efficiently

Load it to the full capacity and make sure all dishes can get cleaned



Avoid detergent overdosing

Auto dosing or options that allow for dosage control result in less waste of resources



Wash all types of dishes

Include dishwasher-safe labeled pots, pans, wine glasses, lunch boxes... Avoid hand washing them



Clean your filter regularly

An unmaintained filter may lead to poor cleaning results and a shorter appliance lifespan

Visit ASKO.SE  Follow us on social media

Figure 9.2: Sustainability sheet.

Tips & tricks

Tips & tricks provides information on how to act sustainably in a short format that fits in the dishwasher's display. The tips show up when the dishwasher is turned on, as well as after choosing a programme, times when users are looking at the display and where it does not interfere with user interaction.

They address a variety of topics, such as recommending the use of the eco programme, reminders to clean the filter, the benefits of powder/gel detergents, efficient loading advice, promoting washing of pots and pans or, as in Figure 9.3, discouraging pre-rinsing.

The length of the text determines the time of exposure, the time the user needs to read the message. The current screen size can display two rows of text of approximately 35 characters each using the font size shown in Figure 9.3. For longer tips, the text scrolls horizontally to show the whole tip. Each tip should be shown long enough to ensure readability while avoiding frustration which may vary depending on the length of the tip.

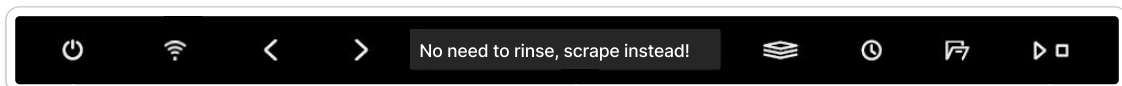


Figure 9.3: Example of a tip in the interface.

Programme costs on screen

By showing the water and energy consumption for each programme in the interface, users are made aware of what separates programmes in terms of efficiency. Therefore, increasing the usage of efficient programmes such as the eco programme. Currently, many users are unaware of how programmes differ in consumption and are unlikely to look it up. Data on the water and energy consumption of programmes is available in the manual, but bringing the data closer to the interaction has the potential to further motivate users. The data available to the user when choosing a programme will be a name, an icon, the duration, the energy consumption in kWh, and the water consumption in litres.

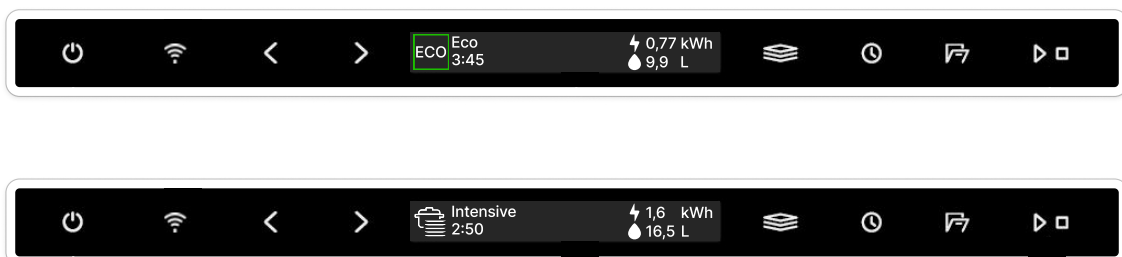


Figure 9.4: Example of the programme costs for two programmes.

Auto Dose text

Adding the words “AUTO DOSE” on the auto dose compartment, available in some ASKO dishwasher models, addresses the unsustainable behaviour of inefficient detergent use, often represented by the overdosing issue. The surface of the compartment has two interaction points with the following text groups: “RELEASE” and “GEL ONLY”. The last one including a drop symbol as well. To ensure that users are not confused about how these interactions should be carried out, the word “AUTO DOSE” is located on the top of the compartment, avoiding these two parts. The font and size of this additional text are the same as the other existing text groups, following the same aesthetics. The new design of the Auto Dose compartment compared to the old one is shown in Figure 9.5.

This design recommendation is purely informational. It enlightens the user about the existence of this feature in an explicit way. It has an important effect usability-wise, yet its environmental impact is not easy to estimate. The expected outcome is to spark curiosity about this feature, make users explore it and potentially start using it. The targeted users are not those who already know about the feature because they have read the manual, seen it on the company’s website or been told about it by salespeople. Therefore, its value is reserved for very specific scenarios, such as co-living households or those using second-hand machines.

By specifying that the compartment is meant for auto dosing, it becomes clear that it is not a compartment for manual dosing of gel detergent. Hence, highlighting the sustainability aspect of the feature with this clarification.



Figure 9.5: Before and after adding the Auto Dose text.

Filter cleaning warning

This concept addresses the behaviour of not performing the necessary maintenance in the dishwasher. At the same time, it deals with other unsustainable practices that can be derived from poor maintenance, such as prerinsing or manual dishwashing. These are the result of the reduced cleaning effectiveness caused by a dirty filter. The concept consists of three parts combined in a way users are steered to clean the filter when the dishwasher demands it: a sensor, a light, and a message on the interface, which can be seen in Figure 9.6.

To make the dishwasher aware of when the filter has been taken out to be cleaned, a hall effect sensor is installed in the filter compartment, in the bottom of the dishwasher. This space already houses the turbidity sensor, facilitating the installation of the warning lamp, as there is ready access to electricity. Installing the hall effect sensor includes putting a small magnet inside the filter as well. When the filter is removed, the change in the magnetic field is picked up by the hall effect sensor.

While the sensor keeps track of the completion of the task, the lamp warns with a blinking light about the need for the interaction while highlighting its specific location. Therefore, the reminders about the needed action are not only provided on the screen, when the user turns it on, but also during the dishes loading task, expanding the time users are exposed to these reminders and placing them closer to where the action takes place.

The light should be bright enough to be visible despite the regular dishwasher interior lighting and the kitchen lighting conditions.

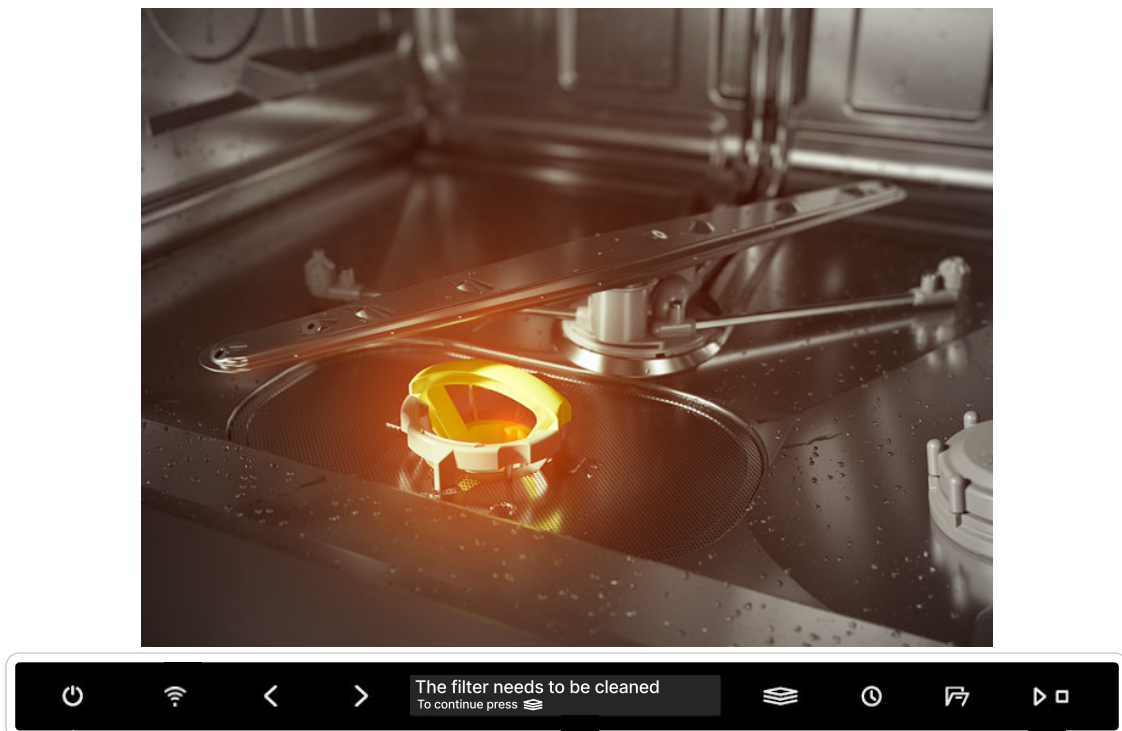


Figure 9.6: Visualisations of the warning light and message.

In addition to the blinking light located in the filter, a warning appears on the screen and informs the user that the filter needs to be cleaned. The only option to continue with selecting a programme is to press a specific button. The warning does not stop the user from running cycles if the filter is not cleaned. Instead, it just keeps popping up every time the screen is turned on until the user removes the filter to clean it. The reminder on the screen complements the light warning by describing the expected user interaction using words, describing in a simple and specific way what to do and when to do it.

Current solutions warn the user to clean the filter using only on-screen warnings, based on a cycles counter. If the user keeps ignoring the warnings, which are only triggered after several wash cycles, the filter can remain dirty for long periods of time. Although the addition of this sensor means more control over the user actions, the solution also needs to prevent the user from circumventing the cleaning of the filter by quickly removing the filter and putting it back.

Scraping off tool

Scraping food residues off the dishes is the first step in the dishwashing process. While some users skip this and opt to prerinse, others combine both methods by scraping and then rinsing. One way to communicate that scraping alone is sufficient is by creating the optimal preconditions to perform the task. Currently, scraping is done with improvised items such as cutlery or kitchen paper, which are not intended for the purpose. Hence, the addition of a new tool specifically designed for the task, see Figure 9.7, makes it easier, more efficient and appealing to scrape off, while highlighting its importance in the whole dishwashing process. The new tool steers users to adopt the sustainable behaviour of scraping, without prerinsing, by making it more obvious that it is the standard behaviour.

The scraping tool features a silicone head and a plastic handle, and it is dishwasher safe. Its handle is ergonomically designed with a minimal aesthetic. The colours used are yellow, ASKO's accent colour, and dark grey, to match the dishwasher racks. The shape of the head is like a spatula but longer, and with both a square and rounded corner to adapt to various types of dishes. When the tool is not used it has a designated spot in either the cutlery basket or cutlery rack, depending on availability in the specific dishwasher. See the tool proportions in Figure 9.8 and a detailed view in Figure 9.9. The general measurements are approximately 25 cm in length and 5 cm in width.

This tool is built for a specific task and provides a higher level of cleanliness compared to commonly used alternatives. Having cleaner dishes can help users understand that prerinsing is not necessary. Additional communication strategies, such as placing a removable label with more explicit information on the tool handle or implementing in parallel other design recommendations described in this section, might be useful to strengthen this message.

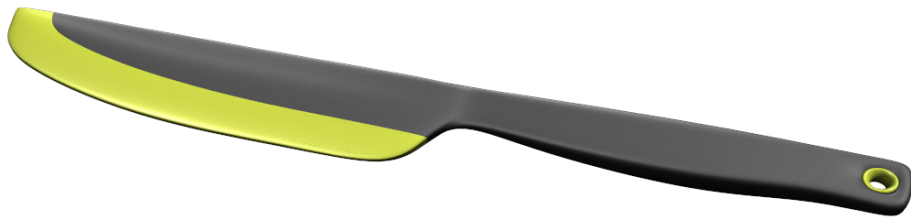


Figure 9.7: Scraping off tool.



Figure 9.8: Profile view of the scraping off tool.

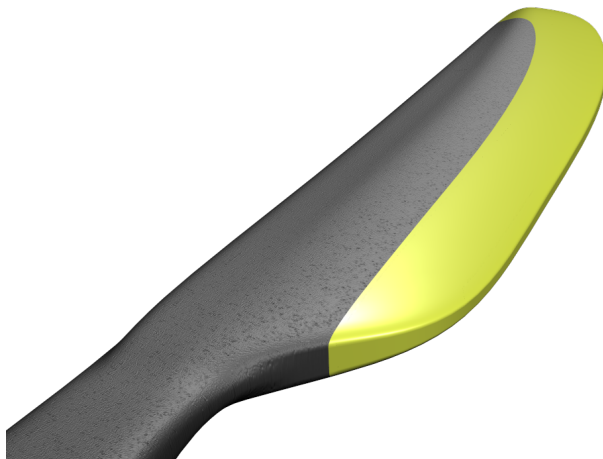


Figure 9.9: Detailed view of the scraping off tool head.

10

Discussion

10.1 Research Result

The user studies conducted in the project showed comparable results to previous research but also managed to fill in some of the gaps on why some of the behaviours occur, as well as how design aspects affect behaviour, especially regarding interface and rack design. However, this connection was not as obvious as expected and finding it was more difficult than anticipated. This may be due to the fact that the design of current dishwashers does not have a significant impact on behaviour or due to the tests being poorly designed to catch the connection. The testing still contributes with insights that can be used to develop dishwashers which are better designed to address the attitude and habits of users.

The project brief established a design space that focused on how the dishwasher itself could address unsustainable user behaviors, excluding external parts such as the role of salespeople or modifications to the associated app, which is not popular among dishwasher users. Close collaboration with the client further shaped the direction of the project, emphasizing physical solutions that enhance user interaction with the machine rather than targeting behaviors outside of it, such as prerinsing or manual dishwashing. For example, with the scraping tool, although the behavior occurs outside the dishwasher, the solution integrates with the appliance as an add-on.

10.2 Design recommendations

Reflecting on the design for sustainable behaviour framework, strategies that kept the user in control, particularly the enlightening approach, were prioritized. This was because the main challenge was to inform users and build trust in the appliance. More forcing approaches were considered but dismissed because of the risk of adverse effects and to preserve a user-friendly brand image. For instance, forcing auto dosing with liquid detergent could drive customers toward competitors that offer a tablet compartment. It was important to strike a balance between sustainability benefits and user acceptance.

When it comes to reducing environmental impact, addressing inefficient programme choice and those behaviours that occur outside the dishwasher, such as prerinsing and manual dishwashing, would likely have a similarly significant effect. However, the true impact of poor maintenance, inefficient loading, and inefficient detergent

use is still uncertain and needs further exploration.

For dishwasher manufacturers, the most straightforward behaviours to address are those that occur within the appliance itself. Changing habits like prerinsing and, specifically, manual dishwashing is especially challenging, as it would require a fundamental cultural shift in how people perceive the relation between kitchenware and the dishwashing activity, which also affects how dishes are loaded. Considering both where behaviours occur and their dependence on culturally accepted dish types and quantities linked to aesthetics and meal preparation routines, the easiest behaviours for manufacturers to target are inefficient programme choice, detergent use and poor maintenance. Among these, programme choice stands out as both the most accessible and potentially impactful, given the current lack of data on the environmental effects of the other two.

So far, sustainability development has focused on creating more efficient programmes to cater to the growing percentage of consumers who value purchasing appliances with a good energy label grade. However, guiding users to choose these more efficient programmes through design has not been prioritised. The previous work from manufacturers has been valuable for this project as it has created the preconditions for sustainable behaviour, at least in the programme choice area. Allowing this project and further work to focus on how to get users to choose these programmes and not on their development.

The six design recommendations can be further developed and evaluated by manufacturers to see how they can be implemented in their products and that this can lead to increased resource efficiency. However, even greater impact may be achieved if appliance manufacturers also use the work conducted in this thesis as inspiration for how to use design to further influence behaviour. Looking at sustainability challenges from a user-oriented perspective and applying these strategies in all aspects of the development process and not as an afterthought may lead to greater change. In addition, it may be applied to other appliances other than dishwashers that probably face similar sustainability challenges.

10.2.1 Sustainability sheet

The sustainability sheet employs the enlighten design strategy (Figure 2.3) to provide users with the necessary information to adopt more sustainable behaviour patterns. Since many unsustainable behaviours stem from user beliefs or attitudes that are based on insufficient information, the strategy is well suited to address these misconceptions effectively.

However, since it is grouped with the manual, guarantee, etc., it might be easy to overlook and put in a drawer without reading it. For similar informational and marketing material this is often the case. To address this, the sheet must capture users' attention through its design or by being separate from the other material. For example, placing it on the front of the dishwasher or within the dishwasher to be removed before use.

As users are likely to read the information on the sheet once or twice, it is uncertain whether the knowledge will lead to long-term behaviour changes. If users adjust their behaviour accordingly, the environmental benefits may be great.

The sheet is a low-cost, low-risk strategy to promote sustainable dishwashing use, as it does not require any change to current products. The material cost of printing the sheet will be outweighed by the water and energy savings of more resource-efficient habits.

10.2.2 Tips and tricks

The potential impact of the tips and tricks reaches across all the unsustainable behaviours as it also employs the enlighten strategy (Figure 2.3) to address the lack of information among users. However, further evaluation is necessary to see if the short format and brief exposure to the user is enough to make an impact on the user. Whether users look at the screen for long enough to read the tips also needs to be researched.

As the tips occur close to the interaction both in time and space, the potential for reflection and change of behaviour is greater. It is crucial that the messages are not perceived as annoying and cause frustration among users: a potential scenario if the messages appear for too long or at inappropriate times.

What the best way to show messages is could be further investigated, where the options are: short static text, text scrolling horizontally, text scrolling vertically, text fading out to be replaced by more text or smaller text in two rows.

10.2.3 Programme costs on screen

Displaying the water and energy consumption for each programme during programme selection uses the the steer design strategy (Figure 2.3); promoting the more sustainable option by highlighting their efficiency. Representing the water and energy consumption with the actual numbers in litres and kilowatt-hours might be the most accurate way, but there might be other ways to do it. For example, using symbols, colours or graphics to visualise which programmes are more efficient. However, showing the actual numbers makes it clear in what way the eco programme is more efficient than other programmes, something that many users find unclear.

A further addition could be to add the financial cost of each programme in the interface. As users have mentioned, they would be more likely to act more sustainably if they were informed of any cost savings that could be made. To add this feature, the dishwasher would need to be connected to the user's energy and water provider to get the current prices for these resources. This type of connection could also pair well with the delay start function, to facilitate running washing cycles when electricity is in low demand and is the cheapest. Financial costs were not added

to the current iteration of the design recommendation as it may cause the interface to get cluttered, as well as the comparatively small financial savings might not be enough to convince users to choose eco programmes.

Further evaluation needs to be carried out to see if these changes would lead to increased usage of more efficient programs. The potential savings must outweigh the extra time cost. Users should, however, not be compelled to always pick the programme which uses the least amount of energy and water, as more intense programmes are sometimes necessary to get an effective cleaning.

10.2.4 Auto dose text

Highlighting the auto dosing feature draws on the enlighten design strategy (Figure 2.3), motivating users by making them aware of their available choices. Including the auto dosing feature's name specifically targets only one unsustainable behaviour: inefficient detergent use. However, the environmental impact of this issue is harder to measure than others and is tied to a separate industry, adding another layer of complexity. Additionally, the widespread use and convenience of detergent tablets make it challenging for users to embrace this feature. Taking a forcing approach by removing the manual dosing compartment from the dishwasher was considered. This was not pursued because some users prefer not to use gel detergents, and correctly using powder detergent remains a sustainable choice. Additionally, the limited availability of alternative detergent options in stores would have created significant inconvenience for some ASKO customers.

Although auto dosing offers the convenience of not worrying about detergent for up to 30 days, this benefit is not as widely recognized as the convenience of tablets, which simply eliminate the need to measure detergent but still require attention for every wash. Adding "AUTO DOSE" to the compartment is the first step in communicate that auto dosing offers greater convenience than both tablets and manual powder dosing. This labelling also helps users quickly understand the feature without the need to read the manual. Still, other informational design recommendations, marketing strategies and improved market presence of liquid detergents might be necessary to increase user acceptance.

10.2.5 Filter warning

Failure to clean the filter is a common problem that could not be solved through filter redesign. Lab tests feedback revealed users preferred certain shapes or colours in the design of the filter, but these preferences did not translate into greater motivation to perform maintenance. Therefore, the communication strategy around the need was addressed. An approach based on the steer design strategy (Figure 2.3), utilising visual cues and a tracking system, is proposed to ensure users perform the task by making what they need to do more obvious.

The use of a hall effect sensor makes it easy to trick the system by simply removing

and putting back the filter without cleaning. However, since the system only steers rather than forcing cleaning, users can still run wash cycles, reducing the incentive to cheat. Forcing filter cleaning to be able to continue operating the machine could potentially lead to adverse effects, as users in a hurry might be more likely to find ways to circumvent the requirement. It can also negatively affect user satisfaction with the dishwasher model and the manufacturer.

The role of the warning light and the on-screen message is leading the user through the desired interaction by altering the regular user experience, making it less comfortable. These reminders are visible by the user throughout the entire interaction with the dishwasher. What the dishwasher wants from the user is very easily understood.

A filter cleaning warning supports dishwashers in reaching their intended lifespan, helping to preserve the resources involved in the manufacturing and distribution of new machines. It also minimizes the need for manual washing or repeated cycles caused by poor cleaning performance from food blockages, thereby reducing water and energy consumption. The sensor and indicator light are minor components that require little investment and have minimal environmental impact. Interface updates are software changes.

To further prevent users from bypassing the filter cleaning process, various strategies can be evaluated. Testing different warning messages, light colours, and blinking patterns is also important in future stages. By assessing which combinations are most effective, it is possible to increase user acceptance.

10.2.6 Scraping tool

When examining common scraping habits, particularly with flat plates, users typically transport dirty dishes from the dining table to the counter, often with cutlery on them. This naturally leads to the use of cutlery to scrape food waste into the compost bag. However, this method has its sensory drawbacks: the sound of metal against ceramic, the uncomfortable tactile feedback, and the sometimes unsatisfactory visual results might detract from the user experience. Although kitchen paper seems a more pleasant alternative, it is not sustainable. Introducing a new tool employing the steer design strategy (Figure 2.3), to remind users to scrape instead of rinse while making scraping more effective, could address these issues. However, encouraging users to adopt this change, more specific design requirements for the tool and assessing whether the habit with these new conditions persists over time requires further study.

Prerinsing stands out for its high environmental impact. This practice occurs outside the dishwasher itself, yet dishwasher manufacturers can address this unsustainable behaviour by promoting the scraping activity through design. The environmental cost of manufacturing and including the scraping tool as a new part of the dishwasher is relatively low, and if users do not wish to use it for scraping, it can still

function as a regular kitchen spatula.

Alternative strategies to discourage prerinsing were explored, such as relocating the dishwasher far from the sink, in another part of the kitchen or even a separate room. This would require a radical change in kitchen design that might confuse many users and was outside the scope of this project brief, which prioritised marketable solutions for the near future. A less disruptive but related idea involved developing a dishwashing unit combining the dishwasher, a waiting drawer, a trash bin, and a scraping tool. This led to the idea for the scraping tool itself. Although this integrated unit was appealing from a marketing standpoint, especially since the client has a similar laundry unit concept, it was set aside because the waiting drawer, a key component of the concept, addressed kitchen clutter more than the problem of manual washing, which was not relevant as the brief is focused on improving sustainability.

Nevertheless, the scraping tool was retained, and in line with its intended use, it is advisable to inform users that the food waste bin should be placed near both the dishwasher and the scraping tool. This arrangement enhances ergonomics and time efficiency, thereby promoting greater user acceptance.

10.3 Lack of user evaluation

The project's aims state that the design recommendations should be evaluated on their environmental impact and how well user will accept them. Evaluation was planned to be carried out together with potential users of the design recommendations. However, due to time constraints at the end of the project, this was not the case. Instead, they were evaluated by the project team with input from supervisors. This compromise might have led to a less accurate evaluation of environmental impact, as it is dependent on user acceptance of the new designs and how effective they are at changing behaviour.

10.4 Testing

Challenges with programme choice testing:

One of the aims of the test was to see how the design of the interface affects programme choice. As all participants had previous experience with dishwashers, they already had developed habits and, based on those, they chose the same programme for all machines. However, these habits are formed during the user's initial interactions with the dishwasher. Therefore, it is important to promote efficient programmes, if not to change unsustainable habits, to form sustainable habits for new users instead.

The decision to use clean dishes during the tests might have influenced the programme choice, as the level of soiling is a factor known to affect that. However,

using soiled dishes would have presented many challenges during the testing, either with an increased amount of work to continuously soil and wash dishes throughout the weeks of testing or with odours and sanitary problems.

Challenges with loading testing:

Two parameters were tested in regard to users loading practices, perceived max capacity and placement of dishes. When discussing how these would be studied in the best way, some variations of test setups were developed.

The first one included presenting a wide variety of dishes and letting participants load the machine with the dishes they would usually wash in the dishwasher. This would allow each of the tests to be similar to the real scenario. However, it would make analysing the result more complicated as there is an increased amount of variability in the results. There is also a risk that participants will try to fit as much as possible, moving away from their regular behaviour.

Another approach would have been to present a standardised set of dishes that can be used to fill the dishwasher to full capacity to see if participants manage to use all the space efficiently. This approach would make comparing results between tests easier but there would have to be a different number of dishes for each dishwasher, as they have different capacities. There is also less opportunity for behavioural insights as the dishes chosen are not based on regular user behaviour.

The chosen setup present users with a scenario of a dinner party, with dishes that would have been used both for serving and cooking the food, to see how users would prioritise different dishes. Allowing participants to adapt the test after their regular behaviour, enabling for a test closer to reality. Additionally, it provided insights on how users prioritise dishes and how the basket design can affect which dishes are chosen. The drawback with this setup was that an optimal load level will be more difficult to assess due to the different dishes used, an aspect that also led to challenges in comparing results between users.

Challenges with testing maintenance:

There are a few things that a user can do to maintain their dishwasher: empty the filter, run the machine in a higher temperature programme from time to time, and running a machine cleaning cycle. These offer quite limited test opportunities, especially when it comes to trying to understand how the design of the dishwasher can promote these behaviours.

There was an idea to test how the design of the filter can promote its cleaning, but testing this would be challenging. Asking participants in a test to do something with the filter would direct their attention to the filter, negating any of the designs ability to catch their attention.

It might be useful to test other ways to make users aware that maintaining the dishwasher can lead to better cleaning results and a longer life span. For example, different informational prompts to the user through the interface, auditive or in the app. Additional information could also be gathered about the habits of the users through questions such as: How often do you perform maintenance at home (filter cleaning, cleaning programme)? What prompts you to do maintenance?

Testing pre-rinsing:

There was no possibility to analyse this behaviour based on observation as a result of the lack of a sink in the lab. The level of soil influences the disposition to pre-rinse as well as the programme choice. However, using soiled dishes would have complicated the testing preparation to a degree that did not seem worthwhile.

Manual dishwashing:

Users value the freedom to own different types of dishes in terms of shape, material and overall aesthetics to adapt to their eating habits and express their identity. This translates into the necessity of manual dishwashing, even when owning a dishwasher, because of items that are not suitable for automatic dishwashing due to their size or material.

Inefficient detergent use:

There was limited testing users' detergent use in this study, which was a result of the difficulty in testing this aspect with the test setup. What could have been investigated further was why users choose to purchase certain detergents they do and how this choice affects sustainability. However, since detergent development and marketing are outside of the scope of the project, no such study was conducted.

11

Conclusion

The aim of this project was to identify and understand unsustainable behaviours in automatic dishwashing and address them through design. By combining new studies on user behaviour with a review of previous research, the most critical unsustainable behaviours were identified: pre-rinsing of dishes, inefficient programme choices, inefficient loading of the dishwasher, manual dishwashing in complement to automatic, inefficient detergent use and poor maintenance. These behaviours depend on a variety of determinants; where some reoccurring ones are a low level of trust in the cleaning effectiveness of the dishwasher, perceived convenience of business as usual and a lack of knowledge about which practices are truly sustainable.

The six design recommendations developed based on the gathered insights provide opportunities for dishwasher manufacturers to address sustainability. All the recommendations could be implemented by themselves or together in the same product. The sustainability sheet and tips and tricks cover all identified unsustainable behaviours; the addition of auto dose text deals with inefficient detergent use; the filter warning solution addresses the poor maintenance issue; including programme costs on the interface addresses inefficient programme choice; and the scraping tool, the prerinsing behaviour. Moreover, other behaviours are also indirectly addressed.

The informational recommendations, such as the sustainability sheet or tips and tricks, could work alone and lead to more sustainable behaviours without the need to implement other design recommendations. However, based on the ability of other purely informational resources to change behaviour, such as the manual, other interventions are likely to be needed as well.

The sustainability sheet, tips and tricks and programme costs solutions are easier to implement than the filter warning, scraping tool, and auto dose text, since they do not require significant changes in the manufacturing or assembling processes. Due to limitations in the evaluation stage, all recommendations require further development before they can be introduced on the market. However, the insights on unsustainable behaviours can support ongoing studies and projects related to innovation and development of dishwashers.

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A

Diary Study Template

CYCLE 1

Date*: / / 2025
Time*: :
*of cycle start

 **Before starting the machine take pictures of...**

- The upper basket The lower basket Other baskets (if applicable)

1. How dirty are the dishes?
The majority of them are...
Clean, I pre-rinsed Slightly dirty Dirty Very Dirty

2. How full is the machine?
Just before starting the cycle I think the dishwasher is...
Empty 1/3 full Half full 2/3 full Full

3. Why did you decide to start the machine at this specific moment?
.....
.....

4. How did you experience loading the dishwasher?
Choose all that apply
Frustrating Relaxing Satisfying Annoying
Accomplishment Happy Amusing Tiresome
Stressful Gross Pride Other:

Why did you feel that way?

.....
.....
.....

5. How did you feel when navigating the interface?
Choose all that apply

- Confused Frustrated Curious Indecisive
Anxious Confident Relaxed Relieved Proud
Stressed Responsible Other:

Why did you feel that way?

.....
.....
.....

Which programme did you choose? Why?

.....
.....
.....

6. How did you experience the end result?

.....
.....

Cycle 5 finished! Please see back cover for final instructions

How to use the diary:

1.

Starting the diary:

Before starting the diary, follow these steps:

- Fill out the information on the front page.
- Take pictures of your dishwasher's interface as well as one of each rack without dishes (e.g., Top, Bottom, ...).

2.

Document each wash cycle:

For each wash cycle, follow these steps:

- Take a separate picture of each dishwasher rack before starting the cycle. (e.g., Top, Bottom, ...)
- Answer the questions on the corresponding page for that cycle.

3.

How to take pictures of the dishwasher baskets:



4.

After 5 cycles:

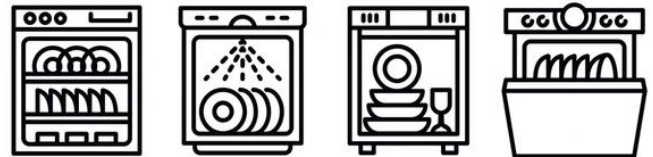
- Take pictures of each page of the completed diary.
- Email these pictures along with the pictures of the filled and empty dishwasher racks to the following email address:

My Dishwashing Diary

This booklet is part of a study aimed at understanding how dishwashers are used in everyday life. By taking part in this study you are helping us design more efficient dishwashers.

What to do:

- For your next 5 dishwashing cycles use this diary to record your dishwashing habits. **Please read the instructions on how to use the diary on the back of this booklet before starting.**



Name:

Age:

Number of people in household:

Dishwasher brand and model:

(Check the dishwasher door or user manual)

CYCLE 2

Date*: / / 2025
Time*: :
*of cycle start

 Before starting the machine take pictures of...

- The upper basket The lower basket Other baskets (if applicable)

1. How dirty are the dishes?
The majority of them are...
Clean, I pre-rinsed Slightly dirty Dirty Very Dirty

2. How full is the machine?
Just before starting the cycle I think the dishwasher is...
Empty 1/3 full Half full 2/3 full Full

3. Why did you decide to start the machine at this specific moment?
.....
.....

4. How did you experience loading the dishwasher?
Choose all that apply
Frustrating Relaxing Satisfying Annoying
Accomplishment Happy Amusing Tiresome
Stressful Gross Pride Other:

Why did you feel that way?

.....
.....
.....

5. How did you feel when navigating the interface?
Choose all that apply

- Confused Frustrated Curious Indecisive
Anxious Confident Relaxed Relieved Proud
Stressed Responsible Other:

Why did you feel that way?

.....
.....
.....

Which programme did you choose? Why?

.....
.....
.....

6. How did you experience the end result?

.....
.....

Cycle 4 finished!

CYCLE 5

Date*: / / 2025
Time*: :
*of cycle start

 Before starting the machine take pictures of...

- The upper basket
- The lower basket
- Other baskets (if applicable)

1. How dirty are the dishes?
The majority of them are...

Clean, I pre-rinsed Slightly dirty Dirty Very Dirty

2. How full is the machine?
Just before starting the cycle I think the dishwasher is...

Empty 1/3 full Half full 2/3 full Full

3. Why did you decide to start the machine at this specific moment?

.....

.....

4. How did you experience loading the dishwasher?
Choose all that apply

Frustrating Relaxing Satisfying Annoying

Accomplishment Happy Amusing Tiresome

Stressful Gross Pride Other:

Why did you feel that way?

.....

.....

.....

5. How did you feel when navigating the interface?
Choose all that apply

- Confused Frustrated Curious Indecisive
- Anxious Confident Relaxed Relieved Proud
- Stressed Responsible Other:

Why did you feel that way?

.....

.....

.....

Which programme did you choose? Why?

.....

.....

.....

6. How did you experience the end result?

.....

.....

Cycle 1 finished!

CYCLE 3

Date*: / / 2025
Time*: :
*of cycle start

 Before starting the machine take pictures of...

- The upper basket
- The lower basket
- Other baskets (if applicable)

1. How dirty are the dishes?
The majority of them are...

Clean, I pre-rinsed Slightly dirty Dirty Very Dirty

2. How full is the machine?
Just before starting the cycle I think the dishwasher is...

Empty 1/3 full Half full 2/3 full Full

3. Why did you decide to start the machine at this specific moment?

.....

.....

4. How did you experience loading the dishwasher?
Choose all that apply

Frustrating Relaxing Satisfying Annoying

Accomplishment Happy Amusing Tiresome

Stressful Gross Pride Other:

Why did you feel that way?

.....

.....

.....

5. How did you feel when navigating the interface?
Choose all that apply

- Confused Frustrated Curious Indecisive
- Anxious Confident Relaxed Relieved Proud
- Stressed Responsible Other:

Why did you feel that way?

.....

.....

.....

Which programme did you choose? Why?

.....

.....

.....

6. How did you experience the end result?

.....

.....

Cycle 3 finished!

CYCLE 4

Date*: / / 2025
 Time*: :
*of cycle start

 **Before starting the machine take pictures of...**

- The upper basket The lower basket Other baskets (if applicable)

1. How dirty are the dishes?
 The majority of them are...
 Clean, I pre-rinsed Slightly dirty Dirty Very Dirty

2. How full is the machine?
 Just before starting the cycle I think the dishwasher is...
 Empty 1/3 full Half full 2/3 full Full

3. Why did you decide to start the machine at this specific moment?

4. How did you experience loading the dishwasher?
 Choose all that apply
 Frustrating Relaxing Satisfying Annoying
 Accomplishment Happy Amusing Tiresome
 Stressful Gross Pride Other:

Why did you feel that way?

.....

5. How did you feel when navigating the interface?
 Choose all that apply

- Confused Frustrated Curious Indecisive
 Anxious Confident Relaxed Relieved Proud
 Stressed Responsible Other:

Why did you feel that way?

.....

Which programme did you choose? Why?

.....

6. How did you experience the end result?

.....

Cycle 2 finished!

B

Design Requirements

Design requirements

Rack design

1. Users should feel encouraged to place the cutlery in an organised way.
2. The dishwasher should encourage putting bulky items in the dishwasher
3. The dishwasher should be able to accommodate bulky items
4. The dishwasher should encourage loading to max capacity
5. The dishwasher should communicate how to be loaded in the most optimal way, so the loading patterns of the different individuals in a co-living situation don't differ a lot.
6. Dishes should be secure and not be able to move around excessively
- ~~7. Dishes placed according to the guidelines should be cleaned properly~~
8. The dishwasher should make users comfortable with loading fragile dishes
9. The racks should be inclusive with all different types of dishes
10. The dishwasher should be designed to make it more fun or inviting to load/unload/rearrange dishes.
11. Users should have patterns in mind when loading the dishes and feel confident about them, avoiding doubts and trial and error.
- ~~12. User guidance should rely on the use of accent colours and similar techniques, since they have a high user acceptance.~~
13. Users should feel invited to fit dishes even in those places where there are no pins, crucial for space optimisation.
14. The dishwasher should encourage users to place similar items together, on secure places and avoiding bad loading practices, such as items covering other items.
15. The dishwasher should make it clearer for users to understand the basic functioning principles of the machine, regarding spray arms and the distance between dishes aspect.
- ~~16. The dishwasher shouldn't include both a cutlery rack and a cutlery basket~~

Information

1. Users should be made aware of which programme is the most optimal for their dishes / The interface should communicate information about the programmes in a clearer way so it can be understood without reading the manual.
2. The benefits of choosing ECO programmes should be clear / ECO programme should be promoted
- ~~3. The dishwasher should provide feedback about the maximum loading layout, so users understand what is considered overloading and underloading.~~
4. The information included in the user manual should be shared with the user in a more interactive, fun and sustainable way (less paper). Getting to know the machine should be something users look forward to, not something they try to do as fast as possible just testing some buttons.
5. Users should understand actual sustainable dishwashing practices and be guided and encouraged to perform them, even without a reward. It should be attractive to dish wash in a sustainable way.
- ~~6. Users should be comfortable with running their dishwasher unattended.~~
- ~~7. Users should have a better understanding of the dishwashers' capabilities and trust them to handle dirty dishes.~~
- ~~8. Users should know when running a cycle is more sustainable than hand washing based on the number of items and types of dishes.~~

Detergent use

1. The dishwasher should encourage the correct dosage of detergent

Filter

1. Users should know when the filter needs cleaning
- ~~2. Users should know how to clean the filter~~
- ~~3. The filter should be easily accessible~~
4. The filter should be easily distinguishable

Pretreatment

- ~~1. The dishwasher should counteract odours~~
2. The perceived workload of sustainable pretreatment should be low

C

Test Protocol

Test number:		
Date:		
Name:		
Living situation:		
Email:		
DW order:		
Notes:	Dishwasher 1	
	Dishwasher 2	
	Reflection	

0. Introduction

Thank you for being here today! You are going to test out some different models of dishwashers. During these tests, we'll ask you to use the dishwashers in different ways and observe how you carry out these tasks. There are no right or wrong ways. If you have any questions at any point, feel free to ask but know that we might not answer if it would interfere with the results of the test.

First, we'd like to know which of these 4 dishwashers is more similar to the one that you have at home, or you have used before? Does your machine have a cutlery basket or shelf? We have a Miele, a Bosch, an ASKO and a Gorenje, please feel free to look at the interior, the interface...

1	Miele	Bosch
2	ASKO	Bosch
3	Gorenje	Bosch
4	Miele	ASKO
5	Gorenje	ASKO
6	Gorenje	Miele

Focus points	Miele	Bosch	ASKO	Gorenje
Cutlery	Top rack + big basket	Standard basket	Top rack + middle rack	Top rack
Wine glass	Rubber	Rubber	Rubber	Very simple (no rubber)
Bottom rack	Weird-shaped	Half of them can be flat	Can be flat	Half of them can be flat
Top rack		Not for cutlery		
Knives				Rubber in the upper rack
Moveable top rack (to fit wine glasses on the rack below)	Yes. Both sides	Yes. One side	No. Already narrow.	Yes. Both sides
Space between wires	Narrow	Lot of space	Narrow	Lot of space
Filters	Together with spray arm	No handle. No accent colour	Handle and accent colour	No handle but accent colour

1. Test dishwasher 1

User is placed in front of the dishwasher 1 and a table with dishes.

Test facilitator presents scenario:

Now we'd like you to imagine that you've just had a dinner party with friends or family and used these dishes. After eating a wide variety of appetisers, spaghetti, meat, chocolate cake and having some drinks, the dishes are slightly soiled and there are few food residues on some items. It's the end of the night and all the guests have left. You are in your kitchen and need to do the dishes, at your disposal you have your dishwasher, your sink, all your kitchen equipment. You just carried the dishes from the table you ate at to the countertop. If your dishwasher is here, where would your sink be? Ok, imagine the sink here then. How would you begin?

Please think out loud how you reason throughout the test.

User loads dishwasher

Test facilitator asks the user questions about their behaviour:

- *What would you do with the dishes that did not fit?*
 - *Why did you decide to clean those items manually?*
 - *Why did you decide to leave those items for the next cycle?*
- *What made you put the dishes in that layout?*
- *Does it look like a usual loading you would do at home?*

Test facilitator takes a picture of the loading placement

Now please start the machine and run a cycle. Think aloud throughout the process.

User starts a cycle

Test facilitator asks about their choices

Describe your thought process throughout this stage.

Test facilitator proposes a break

Now we are at the midpoint of the test, would you like to take a 5-minute break (fika, toilet...) or continue until the end?

The dishwasher is emptied by the test facilitator and the dishes are placed on the table in the same layout as before.

2. Test dishwasher 2

User is placed in front of the dishwasher 2 and a table with dishes.

Test facilitator briefly presents scenario again:

The scenario is the same as for the last machine. The guests have just left after a dinner party you hosted. Now we would like you to once again do the dishes.

User loads dishwasher

Test facilitator asks the user questions about their behaviour:

- *What would you do with the dishes that did not fit?*
 - *Why did you decide to clean those items manually?*
 - *Why did you decide to leave those items for the next cycle?*
- *What made you put the dishes in that layout?*
- *Does it look like a usual loading you would do at home?*

Test facilitator takes a picture of the loading placement

Now please start the machine and run a cycle. Think aloud throughout the process.

User starts a cycle

Test facilitator asks about their choices

Describe your thought process throughout this stage.

The dishwasher is emptied by the test facilitator and the dishes are placed on the table in the same layout as before.

5. Reflection

Test facilitator offers fika

After the participant has finished the test with the last dishwasher, they are asked some more questions. *How do you think that went?*

- Questions regarding maintenance
 - *Have you noticed differences in the filters design?*
User looks at the filters of the four dishwashers
 - *How do you deal with maintenance? How often do you empty the filter in your dishwasher? How do you clean it?*
 - *What makes you decide it's time to empty the filter?*
- Questions regarding loading
 - *How do you usually handle dishes not fitting in the dishwasher?*
 - *Was there any machine where you think you were able to fit more dishes than in another?*
 - *Did any of the dishwasher make it easier for you to load it?*
- Questions regarding their programme choice during the test
 - *What made you pick the programme you chose during the test?*
 - *Is it the same programme you usually pick?*
 - *Do you think the dishwasher influenced your choice in some way?*

Now we have some questions regarding all four dishwashers, feel free to examine them as you wish to answer the questions.

- Questions regarding the information availability
 - *Did the dishwasher guide you in how it should be used?*
 - *Is there any information that you would want to know that the dishwasher doesn't provide you? Any more comments about the two dishwashers that you tested?*
 - *Imagine you have just bought a new dishwasher, do you read the user manual to understand all its features? Then, where do you store the manual? Easy to reach?*
- Questions regarding their overall experience
 - *What aspects or features would you highlight (positive and negative)? Why?*
 - *Do you think you would have loaded the other dishwashers any differently?*
- Questions regarding sustainability
 - Looking at the whole process of doing the dishes, what do you consider sustainable dishwashing practices? Where did you get this information from
 - How aware do you think you are of the environmental impact of a dishwasher?
 - Do you try to reduce the impact? How and why (or why not)?

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