CHALMERS
UNIVERSITY OF TECHNOLOGY

Designing the Next-Generation Water Faucet with focus on Sustainability and Efficiency

Master`s thesis in Industrial Design Engineering

DENIS TAHRIC

DEPARTMENT OF INDUSTRIAL AND MATERIALS SCIENCE
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2023

MASTER´S THESIS 2023

Designing the Next-Generation Water Faucet with focus on Sustainability and Efficiency

DENIS TAHRIC

Department of Industrial and Materials Science
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2023

Designing the Next-Generation Water Faucet with focus on Sustainability and Efficiency
DENIS TAHRIC

Supervisor: Håkan Almius, Division of Design & Human Factors, Department of Industrial and Materials Science, Chalmers
Supervisor: Simon Dybeck, Bättre Design
Examiner: Håkan Almius, Division of Design & Human Factors, Department of Industrial and Materials Science

Master´s thesis 2023
Department of Industrial and Materials Science
Chalmers University of Technology
SE-412 96 Gothenburg Sweden
Telephone + 46 (0)31-772 1000

Gothenburg, Sweden 2023

Abstract

The present study was brought out to design a next generation water faucet concept that has an integrated heat exchanger from Bättre Design. Having integrated heating in the water faucet implies a more energy and water efficient solution. The main reasons for this are because of the efficient heat transfer the heat exchanger provides and the fact that it eliminates the need of having to store large amounts of hot water in tanks as it heats the required water in real time (Dybeck, 2023). To be able to implement this type of faucet in people's household bathrooms, research was done on the interactional process between humans and water faucets. Identifying what factors had an impact on the overall user satisfaction was crucial in trying to get people to implement a more water conservative behavior at the sink.

Research and observations of users interacting with different types of water faucets resulted in identifying that a faucet design should be deemed as *Creative, Minimalistic, Modern, Intuitive and Unique* to be considered an attractive solution. These keywords were considered throughout the project to be able to develop a faucet that promotes behavior change.

The project resulted in developing a water faucet that combines functions of physical and touchless activation of water flow, provides additional control of temperature and water flow and enables easy interchangeability of top parts of the design. The combination of the chosen functions was deemed to intrigue a variety of users which results in easing them into adapting a more water conservative behavior in their household bathrooms. Providing the option for users to choose how to perform different tasks at the sink implied great flexibility and adjustability.

The developed faucet was received well by users in terms of *Minimalism, Creativity, Uniqueness, intuitiveness and Modernity.* The expressions that got the highest score from users were *Modernity and Minimalism* due to its great balance between many features and simple design. To be able to validate the concept further it would need to be produced and tested by users to provide insights on the actual user satisfaction and whether the faucet manages to change people's behavior at the sink or not.

.

Acknowledgements

I would like to express my deepest gratitude to Simon Dybeck from Bättre Design and my supervisor Håkan Almius for making this work possible. Their advice and guidance carried me through all the stages of the project. I would also like to thank Mikael Johansson for additional guidance in writing the report.

Table of content

1. Background

In Sweden the average usage of water per person is approximately 140 liters per day (RISE, 2023). This is quite a bit over the recommendations for water usage according to the World Health Organization (WHO). To ensure that most basic needs are met and prevent health concerns WHO state that approximately 50-100 liters per person is enough (UN, 2023).

Being conservative with water usage is crucial from both a global and local perspective (RISE, 2023). Globally around two billion people live in areas where retrieving a few liters of water per day is a challenge. In Sweden there are complications when there is dry and hot weather that increases the demand of water supply.

Households in Sweden account for 23 percent of the total water usage in the country (Statistikmyndigheten, 2017). Developing solutions that facilitate less water usage in the household will therefore have a big impact on the total water usage of the country.

This project aims to develop a next generation water faucet for future households to try and decrease the water usage per person in Sweden. This will be done in two ways, by implementing the technologies from Bättre Design and Altered and studying the field of human behavior and interaction at the sink to get people to adapt a more water conservative behavior.

The heat exchanger from Bättre Design heats the water in real time resulting in not needing to store large amounts of hot water in tanks (Hedges, 2022). The nozzles from Altered use an atomization technology that breaks up the water into millions of droplets resulting in a heavy mist with a greater contact efficiency (Altered Company, 2023). The atomization technology results in up to 98 % less water needed for performing the same task.

1.1 Aim

The aim of the project is to explore the interactional process between humans and water faucets together with human behavior at the sink. The identified factors found from both research and user testing will be used throughout the project as a base for developing a faucet, to modernize people's household bathrooms, that is water and energy efficient.

Furthermore, the electrical heat exchanger from Bättre Design and Altereds water-saving nozzles should be integrated into the product to achieve a more sustainable and efficient solution.

1.2 Limitations

The set design restrictions are that the heat exchanger from Bättre Design should be integrated into the faucet. Therefore, the developed faucets dimensions should be large enough to store the heat exchanger internally (Figure 1.1). Furthermore, the faucet design should fit one or more of Altereds nozzles at the head. Additionally, the concept should be able to be 3D printed.

Figure 1.1. The dimensions of the heat exchanger from Bättre Design (Dybeck, 2023).

1.3 Process

A plan was made that visualized the complete process of the project which consisted of five different steps with underlying categories. The process plan can be seen in Figure 1.2.

Firstly, it is important to understand the goals of the project and why it was carried out. Therefore, the first step was to learn more about areas such as *Water Efficiency and Sustainability*. Furthermore, learning about the solutions from Bättre Design and Altered helped to understand what they wanted to achieve.

The research of the project consisted of user- and market research. There were a lot of different areas that needed to be studied to be able to develop a successful water faucet. The studied areas would then be the base for the requirements that were set on the development of the concept.

When having set requirements and it was clear what to focus on it was time to ideate. The ideation phase was quite free and different solutions were explored to identify the most optimal ones to go further with. The result of the project should be a description and 3D visualizations of the developed water faucet.

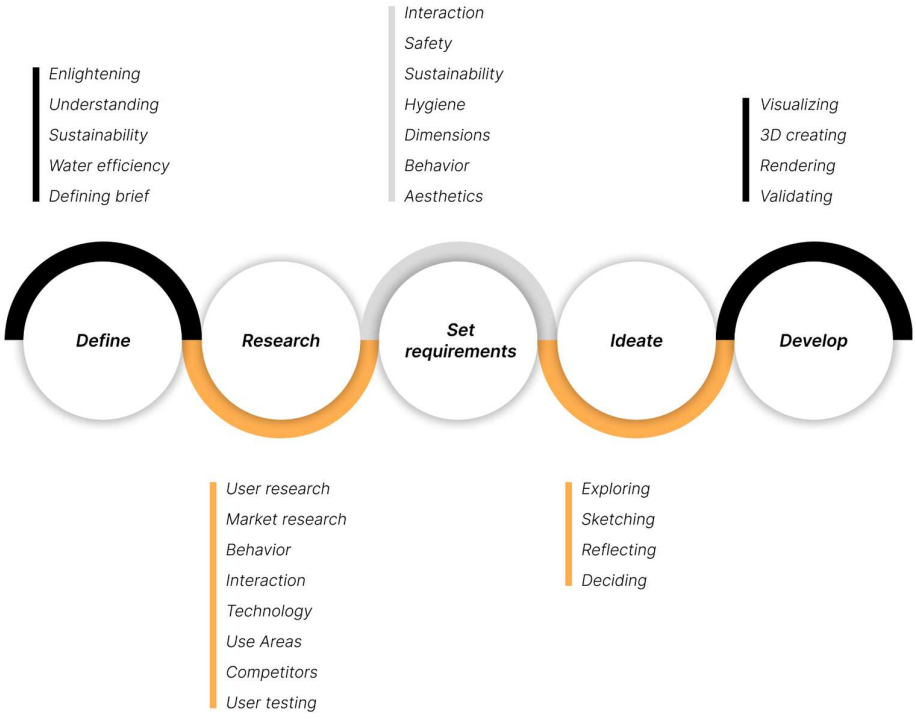


Figure 1.2. Visualization of the process of the project.

2. Research

This chapter covers the interactional aspect between humans and different types of water faucets to identify key factors in the areas of behavior, user satisfaction and user emotions. Multiple existing energy- and water efficient solutions are presented to showcase different methods of sustainable design. Furthermore, opportunities within development of innovative solutions in the market are explored and what area to focus on in the project is decided.

2.1 User research

A big part of the project was designing for user satisfaction. Customers are longing for the feeling of satisfaction by a product that meets or even exceeds their expectations (Manning, 2017). Therefore, gaining knowledge within the field of how humans interact with water faucets and what kind of impact different types of design language could have on user satisfaction was deemed as a crucial activity for the project. This part of the report identifies factors that have an impact on areas such as user emotions and user behavior. Furthermore, different methods of getting people to change their behavior at the sink towards a more sustainable behavior are explored and reflected upon.

2.1.1 Sustainable behavior

The sustainable user behavior that is sought for in this project is people becoming more water conservative at the sink. Getting people to change their behavior is not an easy task as many people find it difficult and daunting (Celestine, 2021). Therefore, different case studies about human behavior at the sink are examined to identify successful examples of behavioral change. The methods used within the case studies will be considered throughout the project.

2.1.2 Behavioral change

The user's behavior at the sink is an aspect that is of great importance for the project. A design that successfully manages to influence user’s behaviors and attitudes towards sustainable water usage is sought for. This can be achieved in many ways, so it is therefore important to study the field of behavior at the sink and identify different factors that have an impact on this area.

Both the heat exchanger concept from Bättre Design and the nozzle technology from Altered aim to reduce water usage by its technology and not by changing the user’s behavior in any way. Therefore, focusing on this aspect for the faucet concept may add great value to the total design and result in an even more sustainable option than before.

Processes such as washing your hands and face are quite easy to perform and since people have done it thousands of times previously there is not much

reflection about the action itself. The repetitiveness of the task has made it quite automated which results in a harder challenge of trying to change people's behavior. Therefore, creative features that intrigues users are deemed as a key characteristic for facilitating the change of behavior.

Arroyo et al. (2005) explored feedback and persuasive techniques at the sink with four different concepts. Results from the study showed that to understand some of the persuasive features a learning process was necessary (Arroyo et al., 2005). Therefore, these kinds of features may not be applicable in some public settings as it may evoke irritation and frustration within users using it for the first time. On the other hand, if used in households it may add value to the product as it may intrigue users to master the function. Arroyo et al. (2005) state that a possible approach to dealing with the struggles of the learning process would be to firstly introduce users to the hard-to-identify features before dealing with the more intuitive ones.

The study showed that simple prompts could be very effective in getting the users aware of their water usage (Arroyo et al., 2005). Features such as timers or LED lights getting brighter the longer the tap is on resulted in users becoming more aware. Simple features like these require no learning process and may therefore also be efficient in public settings. The mentioned aspects should be considered during the ideation of the project because they could facilitate the behavioral change of users.

Additionally, Arroyo et al. (2005) points out that: *"Any device that seeks to promote behavior change must offer pleasing interaction modalities and aesthetic design."* It is important that the interaction aspect is directly connected to research of the areas of use as it may differ tremendously depending on where it is applied.

A study performed by Beaulieu et al. (2019) showed that an autonomous sink that adjusts to users' preferences could reduce water usage by 26 %. This was done by the Wizard of Oz (WoZ) technique where one of the team members was behind the function of the "automatic sink". The experiment showed great results in successfully changing behavior patterns at the sink when washing dishes. After the test with the "autonomous" sink users got to do the task once again with a manual sink, which resulted in 10 % less water usage than the first time performing it with a manual sink. Even though users had no understanding that the experiment was about water conservation they adjusted their habits when washing the dishes, a third time.

The case study from Beaulieu et al. (2019) highlights that it is possible to change users' behavior at the sink by nudging them to develop more water-conscious habits. This can be done in many ways, but it seems as if the most successful techniques are those that do not require more effort from users. Introducing people to other behaviors at the sink could result in them adjusting their habits. Beaulieu et al. (2019) managed to do so by a simple experiment and without putting any focus on getting the user to understand why they would do so. This goes to show that creative ways to nudge people in changing their behaviors

could be very successful even without putting any emphasis on the benefits of the behavioral change.

Fitriyah et al. (2017) explored the efficiency of forcing users to change their behavior at the sink by adjusting the process of handwashing. The study aimed to get people to use soap when washing their hands due to its benefits regarding hygienic reasons. This was done by an automatic faucet that made soap and water exit from the tap simultaneously. Furthermore, the duration of the scrubbing was indicated by the sound of a buzzer and the light of an LED. Participants got to perform their usual hand-washing procedure with a conventional faucet at first to then try the developed automatic faucet.

Results from the study showed that the use of the automatic faucet made people on average scrub their hands for a longer period than they would have used a conventional faucet (Fitriyah et al. 2017). Additionally, it eliminated the risk of people not using soap at all. According to the usability questionnaire completed by participants, they strongly agreed on its usefulness, satisfaction and ease of use.

The study from Fitriyah et al. (2017) shows that it is possible to achieve user satisfaction when forcing behavioral change. However, it is important that the behavioral change is understood and valued by users. It should also not imply too much of a change in procedure as it may cause irritation and result in users refusing to adjust their behavior.

Applying the developed automatic faucet concept from Fitriyah et al. (2017) in realistic situations may not work as well as it did during the testing. Users may be more prone to change their behavior during the experiment because of their curiosity towards the concept. These emotions may turn into negative feelings when using the automatic faucet concept by themselves when they are in a hurry for example. Therefore, further testing should be done on people that are not aware that they are a part of an experiment.

The balance between achieving behavioral change and user satisfaction should be greatly analyzed when developing a faucet concept. Is the behavioral change important enough to risk the satisfaction of the user or would it result in a failed product. Forcing users to change may result in them refusing to use the product and therefore no behavioral change is achieved. On the other hand, giving people the option to choose themselves may result in them neglecting the behavioral change or going back to their old habits after a while. The choice of how behavioral change should be introduced to users is dependent on the application area and what kind of feature it is. Nevertheless, focusing on aspects such as facilitating the behavioral changing process for users and providing knowledge of the importance of the change is crucial when trying to achieve some sort of behavioral change.

Changing users' behavior at the sink towards a more sustainable option may influence other important factors such as hygiene, safety and user experience. The case study from Fitriyah et al. (2017) resulted in people washing their hands

for a longer period, which could indicate an increase of water usage. Therefore, it is important that different factors are considered to find the right balance for the faucet concept.

2.1.3 User interaction

Mihailidis et al. (2012) performed a case study on the usability assessment of three different types of faucet designs (Figure 2.1). The study was focused on the older adult population with dementia with the aim to identify operational difficulties when performing different actions during handwashing. The case study was separated into three different segments during handwashing, *Turn-on water, Adjust water flow and temperature & Turn-off water*.

Figure 2.1. The three different types of faucet designs that were studied (Mihailidis et al., 2012)

A total of 221 video analysis showed that the dual knob and dual lever faucet types were more efficient when it came to turning on the water and adjusting the temperature and water flow. However, the single lever faucet type was more efficient when it came to turning off the water. When looking at the whole process of washing hands the total percentage that was dedicated to these three steps for the different faucet designs were the following: Dual knob faucet (20,5%), Dual lever faucet (14,7%) and Single lever faucet (16,2%). These results show that according to the case study the Dual lever faucet was the most efficient type closely followed by the Single lever faucet (Mihailidis, 2012).

The Dual lever faucet type combines the actions of turning on the water and adjusting the temperature in an efficient manner compared to the other types. The Dual knob faucet's function is quite similar but takes much more time because of the rotating knobs. On the other hand, the precision of achieving desired temperature and water flow is generally higher because of its slower function. The case study showed that the Single lever faucet required more effort to acquire the right temperature and water flow (Mihailidis, 2012). This may vary depending on what group of people are studied. The older adult population may have more difficulties handling a single lever faucet compared to other groups.

The case study performed by Mihailidis et al. (2012) only focuses on which faucet type is the most efficient in terms of time. There are many other factors that are relevant to the project such as comfortability, sustainability and aesthetics to name a few. Therefore, it is important that design decisions are based on all relevant aspects of the project.

Helander and Lo (2004) compare how different systems can differ in complexity while achieving the same user goals. The comparison is made between two

different types of water faucets, one with a single handle for temperature and flow adjustments and the other with two knobs for hot and cold water. Helander and Lo (2004) explain that the single handle faucet is an uncoupled design while the faucet with two knobs is a coupled design. An uncoupled design is preferred because it enables the user to construct a straightforward mental model, while a coupled design implies a more complex system that requires more adjustments for achieving the same goal (Lo & Helander, 2004).

Therefore, when taking the users mental models into account a single lever faucet concept may be preferred because it would imply a less complex solution. Lo and Helander (2004) state that users are becoming less willing to tolerate complex design. However, in this case there is not a major difference in complexity between the two solutions. The study from Mihailidis et al. (2012) showed that the dual lever type was the most efficient type while not being the least complex one. Conclusively, both designs can be argued to be more sustainable than the other depending on where it will be applied and who is going to use it.

Hemmert et al. (2009) experimented with different life-like shapes (Figure 2.2) of faucet designs to see what kind of effects it would have on users. The case study showed that people were cautious at first because it was something they had not experienced before. The different shapes caused irritation and frustration within users which highlights the importance of that the design language should not be too foreign.

Figure 2.2. Some of the different postures: Seeking, curious and rejecting (Hemmert et al., 2009)

On the other hand, the life-like shapes also resulted in people being curious to interact with the faucet (Hemmert et al., 2009) A balance between the traditional design language and creative design is desired for the project. The traditional design language is important to provide users with comfortability while interacting with the faucet while the creative design could spark feelings such as curiosity and excitement that results in an overall added value to the product.

From a sustainability standpoint the question is whether a creative design could result in being used more than necessary which implies more water consumption. A faucet design that intrigues users to interact with it may therefore result in a less sustainable solution. These aspects will be crucial to consider when taking decisions around the design of the faucet concept. Furthermore, different requirements may arise that have an impact on these decisions as well.

To conclude the chapters about human behavior and interaction at the sink the most important factors relevant to the project will be presented. The project should focus on implementing features that are simple, creative and intuitive to the product that imply a minimal learning curve to avoid triggering feelings of irritation and frustration within users (Arroyo et al., 2005). To achieve a change of behavior there should be as less effort as possible from the user to not hinder the user satisfaction of the product (Beaulieu et al., 2019). The reason for the change of behavior should be clearly expressed to educate users about the importance and value of it (Fitriyah et al., 2017).

There should be consideration around developing the faucet as non-complex as possible. This is important because it will facilitate users creating a straightforward mental model (Helander and Lo, 2004). Even though some research showed that a more complex design could be more efficient in some cases (Mihailidis et al., 2012), to achieve the overall goal of creating an intuitive product the aim should be to make it as non-complex as possible.

The words that were taken from research to use as inspiration for future design work were the following:

Minimalistic (Provides straight forward mental model and aesthetic design)
Creative (Facilitates behavioral change)
Intuitive (Provides comfortability)
Modern (Modernizes people's households)
Unique (Intrigues users)

2.2 Growing market for technological solutions

One of the aims of the project was to modernize people's households by developing a modern faucet. Therefore, it was important to investigate whether this was in line with the market and how prone people were to implement more technologically advanced products in their households.

The market for more technologically advanced home devices is growing and expected to keep growing over the next couple of years (Statista Technology Market Outlook, 2022). Consumers are getting more interested in upgrading their households with smart devices. Technological advancements alone are projected to result in a nearly 40% increase in the efficient utilization of water and electricity (Oras, 2023). However, water faucets in households tend to look the same as they have for the last couple of years. Therefore, to keep up with the times and be updated with consumers' new requirements it is important to be at the forefront of the development of innovative solutions within this area. It is clear to imply that there is great interest in new water heating faucet designs that help modernize people's households.

The most common technological feature within a water faucet is touch sensors that enable the faucet to be operated touchless. There are great benefits of touchless water faucets in areas such as hygiene and energy consumption (Oras, 2023). Touchless faucets are mandated in Norway by government charter for all

public establishments serving food to maintain good hygiene (Oras, 2023). Furthermore, it includes locations such as public restrooms in hospitals, schools, daycare centers, and other similar premises, as they are known to effectively prevent the spread of bacteria.

Despite the benefits of touchless faucets, they are still not very common in today's households. However, it is becoming more and more common in Scandinavian households (Oras, 2023).

There are examples of more advanced technological features that are used in water faucet concepts which bring further benefits for consumers. There are plenty of smart faucets on the market that lets consumers control their faucet remotely and track their water usage. Remote controlling of the faucet provides features such as, setting presets for volumes of water, turning on and off water remotely, voice control and adjusting temperature and flow remotely to name a few.

In conclusion, only imagination stops what features can be added to water faucets today. However, most technologically advanced features that are new to users require a learning process which was not sought for in this project. Therefore, it will be important to reflect upon whether some features are necessary to the product and what kind of impact they have on the intuitiveness. Having to many features may result in a more complex product which could lead to evoking feelings of irritation and frustration within users. The design of the faucet should strive for being deemed as modern while not loosing the intuitive aspect of the product.

2.2.1 Heat Transfer

There are three types of heat conversion, *Convection, Conduction* and *Radiation* (Velo3D, 2021). *Conduction* is the transfer of heat energy via solids and *Convection* is the transfer of heat energy via fluids. This chapter will focus on conduction as it is the most relevant to how heat is transferred in the heat exchanger concept from Bättre Design.

Heat transfer in gases and liquids occurs through the collision and diffusion of molecules in their random motion. Meanwhile, in solids, it takes place through a combination of molecule lattice vibrations and energy transport by free electrons (Ghassemi et al., 2020).

Equation for heat transfer rate (Q) via conduction (Velo3D, 2021):

$$Q = kA(\Delta T/t)$$

The thermal conductivity of the material is represented by k, A is the cross-sectional area perpendicular to the direction of heat transfer, the temperature gradient in the direction of heat transfer is represented by ΔT and t is the wall thickness.

To achieve a design with optimal heat transfer rate it is therefore important that all these metrics are considered. Many of the aspects are contradicting which could result in confusion when designing a heat exchanger. One example of this is that the increase of surface area is tied to the pressure drop (Velo3D, 2021). Therefore, in a lot of cases it is important to aim to achieve the best balance between different metrics.

Heat exchangers are the core of every thermal management system (nTopology, 2022). There are multiple different types of heat exchangers such as Oil coolers, Heat sinks and radiators to name a few. Their main target is to transfer thermal energy from hot to cold regions. Figure 2.3 helps visualize how a typical additively manufactured heat exchanger looks from the inside to facilitate understanding the function.

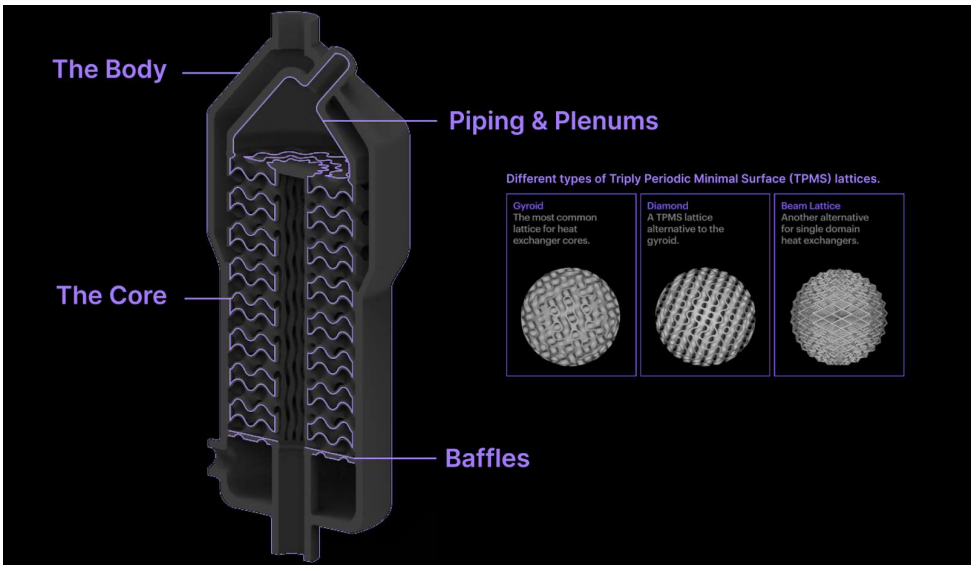


Figure 2.3. Visualization of a Heat exchanger's parts and different types of Triply Periodic Minimal Surface (TPMS) lattices (nTopology, 2022).

A heat exchanger typically has three or four different parts internally, depending on how the liquid is heated: *the Body, the Core, Piping & Plenums and the Baffles* (nTopology, 2022).

The Body varies regarding shape depending on the application area and spacing requirements. It stores all the other parts internally and keeps them in place for the function to work properly.

The Core often consists of some type of lattice structure. This is where the liquid flows through the heat exchanger and gets heated by the boundary walls, that are either heated by electricity or an additional liquid.

The Piping & Plenums gradually introduce the liquid into the heat exchanger and releases it when it has been heated.

The Baffles are needed in a heat exchanger that heats the liquid by using a secondary flow. *The Baffles* then prevent the cold and hot flow from mixing. If the

liquid is heated by electricity the main purpose of the baffles is to spread the heat around.

2.2.2 Additive manufacturing

A big part of this project is that the developed faucet concept should be able to be 3D printed to fit the design of the water heater from Bättre Design. Additive manufacturing facilitates the production of more complex solutions as it implies fewer design restrictions than traditional manufacturing methods do (nTopology, 2022). The water heater concept from Bättre Design requires additive manufacturing as its complex miniscule design would not be possible to manufacture with traditional methods.

There are many benefits with using additive manufacturing for heat exchangers. These will be listed and further explained below:

- The use of lattice structures
- Producing it in one part
- Less material waste

The use of lattice structures in miniscule settings is made possible by additive manufacturing (nTopology, 2022). The lattice structures are to be preferred when designing heat exchangers because of its positive impact on the effective surface area (nTopology, 2022). The effective surface area is a key aspect when optimizing the balance between weight and heat transfer efficiency. Furthermore, the lattice structures induce swirling of the fluid that has a positive impact on the heat transfer coefficient.

Another major benefit of using additive manufacturing when designing heat exchangers is that it can be fabricated in one part (nTopology, 2022). The joining of multiple parts implies a less reliable design because of its higher risk of failure and leakage. Furthermore, it reduces the inventory and labor costs. Using additive manufacturing implies less material waste when compared to other methods such as CNC machining (Dughi, 2022). The ratio of fabricated parts to the final product is an important aspect especially when working with expensive raw material.

The possibilities of 3D printing are endless. The use of additive manufacturing has been validated to optimize the design of many industrial parts. One example of this is the 3D printed Porsche pistons that provided 30 PS more power and were regarded as more efficient than the previous solution (Dughi, 2022). It has typically been used for small-scale or custom production runs because of the time needed for powder bed technologies (Dughi, 2022). However, emerging technology sets to increase production runs and decrease the operational costs. There are examples of this happening already, such as Ford Motor Company's announcement that implied that 200 000 aluminum parts were set to be 3D printed yearly (Dughi, 2022).

Additive manufacturing is a growing market and has since the start reduced manufacturing costs per part by about 50 % (Kircher, 2020). However, it is still more expensive than traditional methods. Looking at the history of additive manufacturing and the advancements made from emerging technology it is safe to assume that it is only going to get cheaper as the years pass by. Together with the benefits in terms of sustainability and efficiency it will grow to be a more popular alternative for mass produced products.

2.2.3 Instant Water Heaters

In households today the most common way of distributing hot and cold water is done via centrally placed boilers and cold-water storage tanks (Robinson, 2021). The hot and cold water run through separate pipes to get to the water taps in the household. The use of centrally placed boilers implies less energy efficiency than using instant water heaters (Dybeck, 2023).

Figure 2.4. Centrally placed boilers versus instant water heaters (IWH) (Dybeck, 2023).

Instant water heaters, also referred to as tankless water heaters, are a type of water heating system that provides hot water instantly (Hedges, 2022). In contrast, boilers store a substantial amount of water in a tank and heat it for later use. Furthermore, with instant water heaters, the water is heated as it passes through the device (Figure 2.4)

According to Hedges (2022), instant water heaters offer several benefits compared to boilers from a sustainability standpoint. The primary advantage is that they are more energy-efficient, as they only heat the water as required instead of maintaining a large volume of hot water in a tank. This leads to a lower energy consumption and fewer greenhouse gas emissions, making them a more environmentally friendly choice.

According to CLAGE GmbH (2023) a decentralized hot water supply implies a reduction of 13x in energy losses when compared to a centralized system (Figure 2.5). Separating the general heating system of households from the hot water supply results in a more energy efficient solution. Buildings' heating needs are gradually decreasing and supplying 60 degrees Celsius solely for hot water is inefficient in terms of energy consumption (CLAGE GmbH, 2023). Thus, it makes

sense to separate the two systems. Separating the hot water supply according to demand using electric instantaneous water heaters, for example, allows a heat pump to operate optimally in the low-temperature range for space heating.

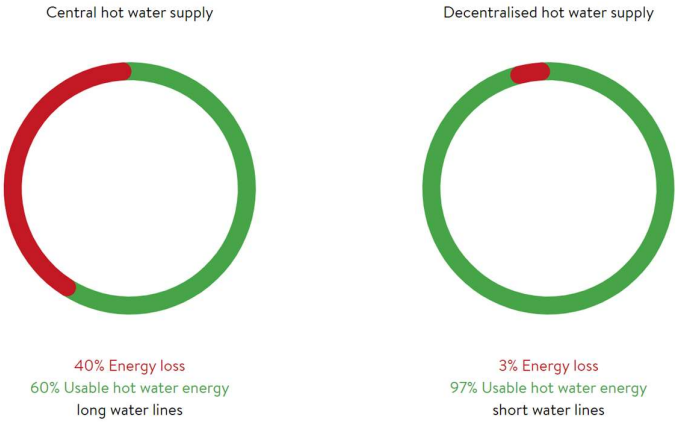


Figure 2.5 Differences between a centralized and decentralized hot water supply (CLAGE GmbH, 2023).

Another advantage of instant water heaters is that they occupy less space than boilers, making them an ideal solution for households with limited space (Hedges, 2022). Additionally, instant water heaters generally have a longer lifespan compared to boilers, which can be prone to corrosion and other forms of tear over time (Energy Saver, 2023).

2.2.4 Water Heater Concept by Bättre Design

Understanding the water heater concept from Bättre Design was crucial when getting started on the project (Figure 2.6). Getting in terms with what the concept aimed to achieve made it clearer what results were to be expected from this project.

The water heater concept from Bättre Design is 3D-printed because of its complex design. Its sinusoidal pathways increase the “swirl” or the spinning of the fluid which results in more efficient heat transfer as heat is always transferred at the boundary walls (Velo3D, 2021).

The water heater is quite miniscule with the purpose of being able to integrate it into a faucet concept. A successful integration of the water heater would imply a more energy efficient solution compared to centrally placed boilers, which is a typical solution in the market today.

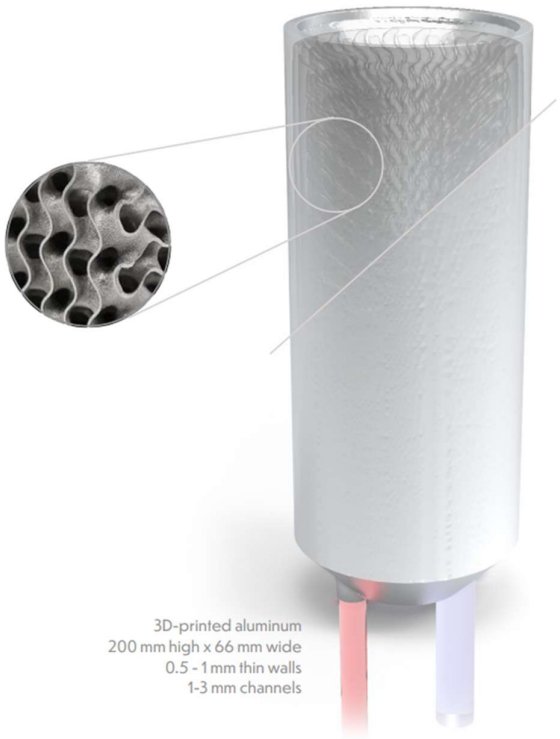


Figure 2.6 Water heater concept (Dybeck, 2023).

The main aspects that the water heater concept from Bättre Design aims to optimize are:

- Quick heat up of water
- High efficiency
- Small size

The heat up of water and thermal efficiency will be optimized due to aspects such as sinusoidal patterns, effective surface area and wall thickness. However, most areas are contradicting which results in considering an optimal balance between them. The increase of surface area for example is tied to a greater pressure drop, which is not desirable as it requires more energy (Velo3D, 2021).

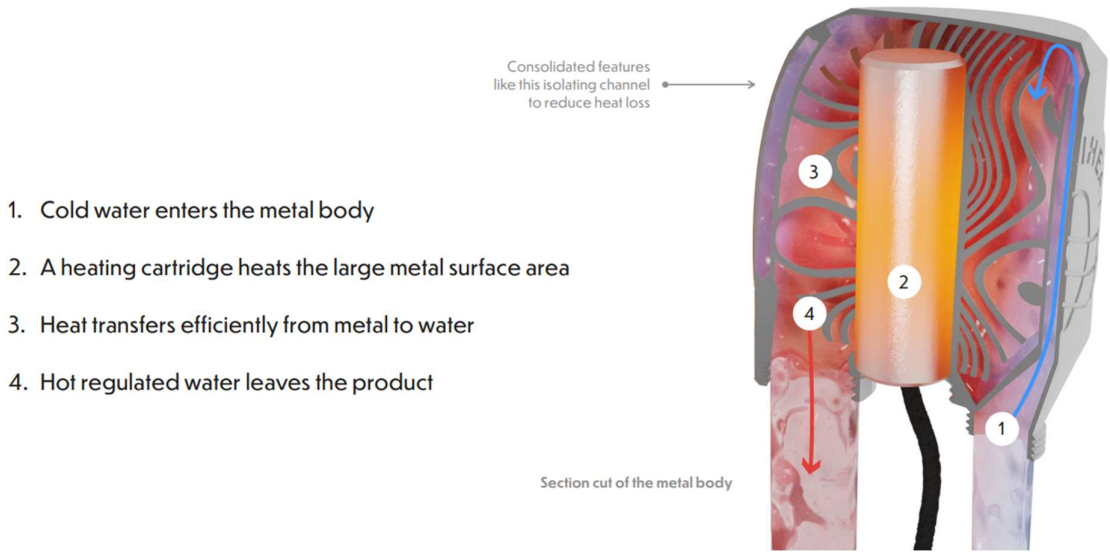


Figure 2.7. Visualization of the process of heat transfer in the water heater concept (Dybeck, 2023).

The cold water enters one side of the water heater and flows through the sinusoidal pathways that leads it out the other end (Figure 2.7). The metal body is heated up by a heating cartridge that is placed in the middle of the water heater. The heating cartridge is from International Heating Products (IHP) and is uniquely designed to provide large amounts of heat transfer in limited spaces (IHP, 2023). The heat from the metal body is transferred to the fluid as it is flowing through the water heater. When the fluid has flowed through the entire pathway it has been warmed up to the desired temperature.

2.2.5 Altereds Nozzle Technology

As the project aims to combine the water heater from Bättre Design and the developed faucet concept together with one or more of Altereds nozzles it was important to gain knowledge about the Altered nozzle technology.

The company Altered has produced three different nozzles that save as much as 98% water without losing any functionality due to its patented atomization technology (Altered Company, 2023). The atomization technology breaks up the water into millions of droplets that creates a heavy mist which results in a much greater contact efficiency. This results in less water required for performing the same task. The nozzles are fitted to existing taps and are easy to install. Choosing between the different nozzles comes down to preference and intended area of usage.

The three different types of nozzles are described below (Figure 2.8):

The *Dual Flow Pro* consists of two different modes, mist and spray mode. The mist mode is the most efficient one saving up to 98 % water while the spray mode saves 85 % (Altered Company, 2023). The *Dual Flow Pro* is aimed towards households due to its flexibility of switching between the two different modes.

The *Dome* nozzle creates a water dome that diffuses into water spray (Altered Company, 2023). Its main target is public areas because of its high efficiency and water savings up to 96 %. This is made possible because of a water flow of only 0,4 L/min.

The *Spray* nozzle provides the highest water flow but still saves up to 85 % water (Altered Company, 2023). Its main usage field is public areas that require a slightly higher water flow than what the *Dome* nozzle provides.

Figure 2.8. The three different nozzles produced by the company Altered (Altered Company, 2023).

2.3 Existing solutions

Researching the market for how existing solutions deal with the challenge of implementing modern features into the design was deemed a beneficial activity for getting inspiration on different ways it could be done. Some of the competitors on the market are presented because their design sparked an interest in some way, either in terms of function or aesthetics.

2.3.1 Switching from traditional to modern

Switching from traditional water faucets to more modern ones can be a complicated process and a step that many people may not be ready to take. One of the reasons for this could be the uncertainty around how these faucets function and whether they are necessary.
Additionally, some people may be intimidated by the new features that come with these modern faucets, which can be associated with new technologies. The fear of not understanding these features could also prevent people from making the switch.

There are different directions to take with the design, either to go all in on the technological aspect of the product and optimize the functionality or on the other hand focusing on compromising a bit of the technological side and finding a balance between manual and automatic operation.

There are examples of products on the market today that combine technological features with traditional ones. This is a great way to ease consumers to using a more technologically advanced solution. Additionally, it may operate more efficiently because it offers multiple ways to perform tasks.

One example of a faucet that combines traditional and modern features is the Oras Optima Style (Figure 2.9). The water flow can be activated either through the side sensor or manually using the side lever, as per the user's preference. It is described as “the ideal entry for households that want to convert to touchless faucets” (Oras, 2023).

Figure 2.9. Examples of faucet design from Oras that combine traditional and modern design (Oras, 2023).

Another product from Oras that follows a similar path is the Oras Vega faucet. This faucet has a "Eco-button" at the back of the lever that can be turned on and off when desired. Pressing down the button while lifting the lever will provide the user with a greater water flow. Like the Oras Optima Style it allows users to choose between alternative ways to perform tasks.

Combining traditional and modern functions may be a good idea for the project. However, it needs to be studied further whether it is necessary for the use application. There is a possibility that additions of traditional functions to the faucet concept are deemed as redundant and may be negative for the product.

2.3.2 3D-Printed Faucets

There are plenty of 3D-printed faucet concepts on the market, some of them are shown in figure 2.10. The concepts focus heavily on aspects such as aesthetics, creativity and minimalism. Additive manufacturing enables more complex designs that result in the aim to stand out from traditional faucet design. A common feature of these faucets is the hiding of water flow. This is done to spark feelings such as confusion and curiosity within the user. It almost works as a magic trick as it looks like water appears from nothing.

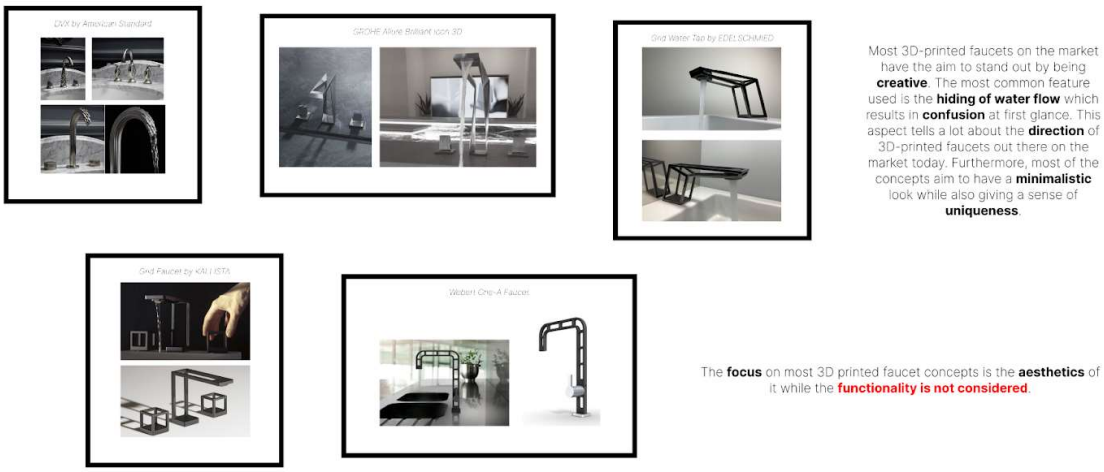


Figure 2.10. 3D-printed faucet concepts on the market today.

The fact that this feature is as common as it is within 3D-printed faucet design clearly highlights what sort of design language is aimed for. Most of the concepts try to combine aspects such as creativity and minimalism. It is important that the faucet design stands out from traditional designs while not being too complex. The faucet should be easy to handle to result in successful user interaction. The feelings of confusion should be directed towards innovation and not on the operation of the faucet. Therefore, the hiding of water flow is a perfect example of how to achieve this balance. The feature is intriguing because of its innovativeness, and it is not interfering with users' previous knowledge on how to handle the product. Identifying other features that could have similar effects on users could result in an edge in the market of faucet design.

The bottom concept of *DVX* by American Standard is one of the few designs that does not include the feature of hiding water flow. However, it still succeeds with evoking the same sort of feelings within users. The fact that it manages to do so in its own way may put it at the top in terms of creativity and uniqueness. Its complex form where water exits from multiple separate holes is balanced with two easily interpretable handles for hot and cold water. This concept shows that unique design provides further value in some situations. Users that have already encountered the feature of hiding water flow will be more intrigued by this sort of design. The aesthetically pleasing waterflow that is created by the *DVX* may also be valued for longer since the mystery of appearing water flow may lose its magic after understanding how it works.

2.3.3 Areas of use

The requirements of what a faucet concept should achieve is heavily dependent on where it is to be used and what the main goals with it are. Therefore, it is important to choose what direction to take in the project to be able to highlight the main targets of the work.

This project will focus on developing a next-generation water heater faucet concept for household bathrooms. The main reason for this direction is the fact

that there is a growing market for more advanced water faucet design in private homes, for example the use of touchless faucets (Oras, 2023). The development of a more technologically advanced faucet that is to be implemented in people's household bathrooms would be imply great benefits in terms of efficient water and energy use. Focusing on the bathroom was deemed as a great starting point to modernizing people's households, as the tasks performed at the bathroom sink were seen as less complex than the ones performed in the kitchen.

The clear advantages that a touchless water faucet implies within areas such as hygiene and water conservation make it a valid option for public spaces because of the huge amounts of people in motion. Furthermore, there are less requirements from users when it comes to aspects such as aesthetics and adjustments of temperature and water flow. Therefore, the implementation of these kinds of faucets is deemed as a harder challenge in households than in public spaces. However, the advantages that more technical solutions imply within areas such as hygiene, sustainability and efficiency could be of great value even in households.

Water faucets in households are essential components of the bathroom and they are used for a wide range of purposes beyond just supplying water. Unlike public water faucets, which are usually designed for limited use, household faucets are required to be versatile and able to perform various tasks.

Household bathroom faucets are used for many activities such as brushing teeth, washing hands, face and hair, rinsing contact lenses and even filling up water bottles. Therefore, the water faucet needs to be designed in a way that it can accommodate all these functions while being easy to operate.

Another important consideration is water pressure. Public water faucets often have lower water pressure to conserve water while household faucets usually have higher water pressure to provide more efficient cleaning and filling. It is also important that the water flow can be adjusted, allowing for different pressure levels as required for different tasks.

In conclusion, household faucets are required to be versatile, durable, and easy to use, which is why they are designed differently from public faucets. Their ability to handle a variety of tasks and their ease of maintenance make them essential components of any household bathroom. Therefore, when designing a faucet for households it is important to consider its intended use, water pressure, durability, and ease of cleaning and maintenance.

3. User testing

From the research it became clear that additional observation of the use area was needed to be able to make decisions about interactional aspects in the project. As the chosen use area for the project was household bathrooms it became important to look deeper into the different types of tasks that were to be performed.

3.1 Observation of tasks within chosen Use Area

Many of the tasks that are performed at the sink in the bathroom area are quite non-complex such as washing your hands and brushing your teeth. However, there are more complex tasks that require more control of water flow and temperature. The chosen tasks that were deemed to be the most challenging were *Washing away makeup and shaving beard.*

Observing these tasks would therefore provide knowledge about how to optimize the design of the water faucet. Decisions based around if it would be problematic to perform the same task with a touchless faucet or if a combined technique would be needed could be reflected upon after the observation. The reason for asking the participants about using a touchless feature instead was because it is a feature that most people have used and can relate to. It would also provide insights about how prone people were to implement more technological features at their bathroom sink.

There were five participants in total, two women and three men. The ages of the participants were between 24 - 57. The women performed the task of washing away their makeup and the men shaved their beard.

During the observations there were notes made regarding how many times the user adjusted the water flow and temperature. Additionally, if it would be possible for the water to be turned off at all during the process. After the observation the user would be interviewed regarding their thoughts about whether a touchless faucet would hinder the process in any way.

Results from the task of washing away makeup showed that the average time spent for performing the task was 1 minute and 46 seconds. The water was running the entire time in both cases which resulted in a lot of water waste as there were times when water was not needed. However, most of the pauses of users not interacting with the water were quite short. It was only about 10% of the total pauses that lasted longer than five seconds.

Even though the task of washing away makeup was deemed complex compared to other tasks that are performed at the bathroom sink it did not include many interactions with the faucet itself. The participants only adjusted the water flow and temperature a few times during the observations. Finding the right water

flow and temperature from the start seemed to be pretty much enough for being able to perform the whole sequence.

When looking at the task of the men shaving their beard the average time spent performing the task was around 4 minutes. The completion time of the tasks were quite similar for all the three participants. However, there were great differences in total water usage. One of the participants had water running from the tap throughout the entire task while another one had it turned off for most of the time, and the third participant chose to turn the water on and off during the task.

The main differences between the users were that the ones that had water running during the task washed their shaver in between shaving their beard. The third participant trimmed his beard without the need of washing the shaver. The pauses of not interacting with the water were far longer and occurred more frequently than those in the previous task. The task ended with all participants cleaning the sink with a constant water flow for about 30 seconds.

After the tasks were performed all participants were interviewed about their performance. It became clear quite quickly that the performances were automated as the users have performed them hundreds of times previously. There were no reflections about the constant running of water until it was brought up by the interviewer which shows that they are used to performing the task that way. When reflecting around that area and being asked whether they would be positive to switch completely to a touchless faucet there were shared meanings.

The men were more positive towards the idea than the women. This response felt logical as the women's task implied much more interaction with the water flow. They shared that they felt like it would just be annoying if the water turned off at times and would hinder the performance of the task. However, they would be willing to try it out to see if they would change their minds. The main reason for them being open to try was the sustainable benefits that a touchless water faucet implies.

The men shared that they felt like they could perform the task with a touchless faucet without it hindering the performance in any way during shaving. However, two of the men mentioned that it may be annoying when cleaning the sink afterwards and that they would like to have constant water flow when doing so.

Telling the participants about the idea of combining the touchless feature and the manual lever to have the option of what to use in different scenarios was received well. All participants thought that the idea of having the option to choose was interesting. One of the women shared that this type of solution would facilitate her trying out the touchless feature in her household without having to make the tough choice of switching to a completely touchless design.

Some participants expressed their need to have control over the temperature of the water at the bathroom sink and that they were not ready to give that up. Scenarios such as washing your face with hot water or filling a water bottle with cold water were shared as examples of needing to have control over temperature. Most participants felt that the faucet would lose its flexibility if there was a constant temperature of the water, like the typical ones in public restrooms.

The observations and interviews clearly highlighted the need of providing users with control of the situation. Most of the users were positive about trying out the touchless feature in their homes. However, they were not ready to switch completely to a touchless design. Therefore, a hybrid solution is preferable that facilitates getting used to the touchless feature when performing tasks in household bathroom sinks. Furthermore, additional control over temperature was desired by users or otherwise the concept would lose some of its flexibility.

4. User needs and requirements

4.1 User needs and demands

Consumers are in search of flexible solutions that fulfill a broader scope of needs (Oras, 2023). This includes saving water and energy, presenting distinct styles, and ensuring effortless usability through an array of customizable features available through applications. More and more homeowners are directing their attention towards intelligent methods of preserving resources and keeping track of their daily water and energy consumption (Oras, 2023). On the other hand, it is important that users do not get overwhelmed with features because it will have a big impact on the perceived complexity of the product. Focusing on simple and creative features that do not hinder the user satisfaction of the faucet will be key in developing a successful design.

The interactional process between user and faucet needs to be consistent and intuitive. Research showed that if a water faucet does not meet these needs, it may evoke feelings such as frustration and irritation within users (Hemmert et al., 2009). Therefore, it is crucial that the water faucet is easy to understand and easy to use at first glance. This is especially important for the main functions such as turning on/off water and adjusting water flow or temperature. Additional features may add value when there is a learning curve involved. Nevertheless, designing the water faucet with intuitiveness in mind throughout the whole process is the safe direction to take when trying to meet the needs of the users.

Research highlighted that sparking emotions such as excitement and curiosity within users could add value to the product (Hemmert et al., 2009). Optimally, this would be done by creative and intuitive features. Therefore, creative ideas that arise during ideation need to be followed by simple realistic

implementations so that the product does not lose its intuitiveness. There needs to be a balance between all aspects to achieve the optimal solution. If there is no possibility of finding a balance, there may be more value in scratching some features and focusing completely on the overall intuitiveness of the product.

Consumers are becoming more and more interested in energy and water efficient products (Oras, 2023). Therefore, there is a need for more sustainable solutions. Some users are more ready than others to change their behavior at the sink for a more sustainable one. This project has covered two different directions to take regarding behavioral change, either forcing users to change or providing them the option to change. Both directions have their positives and negatives, but this project chose to focus on providing users the option to change. Therefore, the developed faucet concept should not force users towards behavior change in any way.

There are user needs linked to the aesthetics of the product, but they are more about what the design should express. Words such as modernity, creativity, minimalistic, intuitive and uniqueness are sought for. However, there is a lot of freedom in the design work that is to be performed. Keeping those words in consideration during the ideation phase of the project will be key when trying to develop a design that consumers will be pleased with.

4.2 Requirement- & Wishlist

A requirement- & Wishlist was developed to highlight the different types of needs that were identified during the project (Figure 4.1 & 4.2). The requirements and wishes were grouped in 7 different categories: *Interaction, Safety, Sustainability, Hygiene, Dimensions, Behavior and Aesthetics.* Furthermore, the requirements were weighted representing how important they were deemed to be to the project.

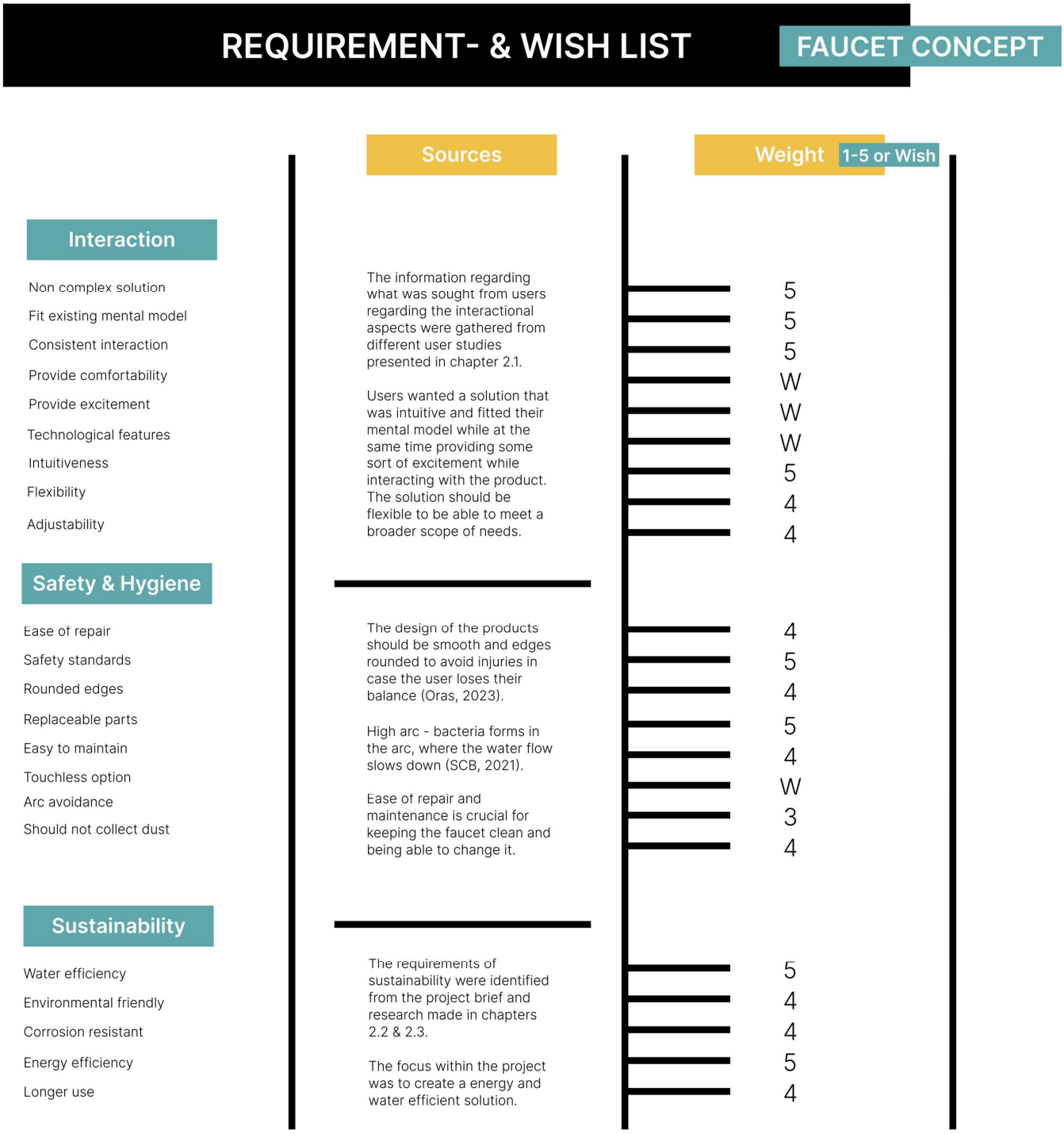


Figure 4.1. Part 1 of the requirement & wishlist for the water heater concept.

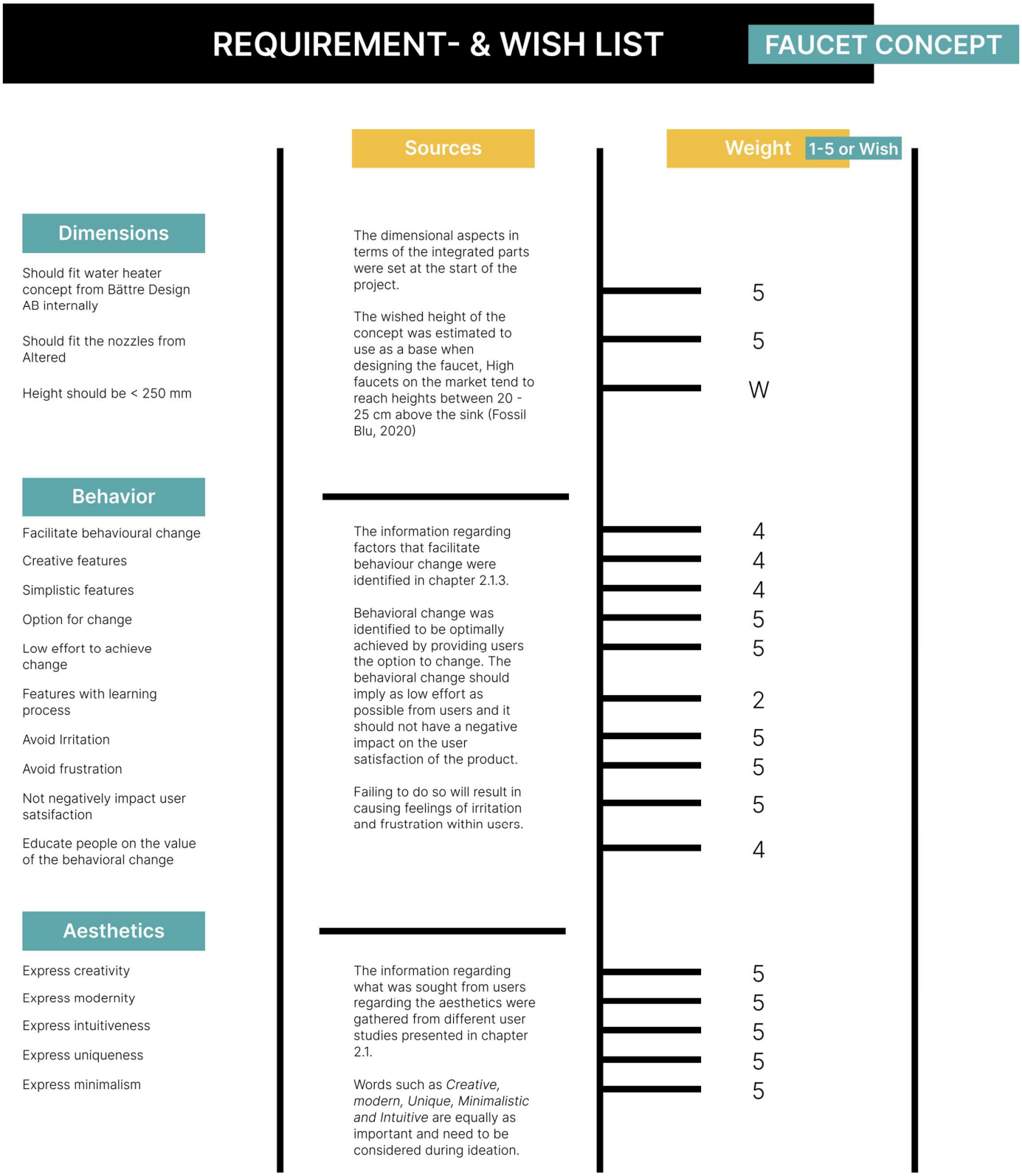


Figure 4.2. Part 2 of the requirement & wishlist for the water heater concept.

5. Ideation

As the research of the project was gathered and requirements and wishes were set on the desired design it was time for the ideation phase to take place. This chapter will go through the process of ideation and the thoughts that arose during the different steps.

From what was gathered in the research phase it was quite clear that the design of the water faucet concept should be quite minimalistic. However, it should still be deemed as a modern and innovative solution while expressing creativity and uniqueness. As it was meant for use in household bathrooms it was decided that there should be no boundaries in terms of innovative thinking during the ideation. The intuitiveness of the product was still an important factor but not as important when designing for the public space. Research showed that users getting used to and learning more about the product resulted in better use and a relation towards the product was formed (Arroyo et al., 2005).

The definitions of the expressions *Modern, Minimalistic, Intuitive, Creative and Unique* were tough to identify. The research performed during the project helped with guidelines around what was sought after. The expressions could be supplemented with clear directives such as non-complexity, fitting users' mental models and implementation of technological features. However, some design decisions made along the way were mainly done by my own perception of what the expressions meant.

5.1 Placement of Predetermined Parts

As one of the requirements of the project was to integrate the water heater concept from Bättre Design it was important to look deeper into the measurements of the water heater (Figure 1.1). Different solutions were explored in regards where the water heater should be integrated. There were some thoughts about placing the water heater separately somewhere outside of the water faucet to clearly highlight the process of instantaneous water heating. Even though this kind of solution would be quite innovative it was quickly decided that it would be too cumbersome and not as minimalistic as what was desired. Additionally, it defeated one of the great purposes of the project which was that the solution should be space efficient.

One of the main reasons that the water heater concept from Bättre Design was 3D-printed was because of the possibility of producing it in a smaller size to fit inside of a water faucet if possible. Otherwise, the solution would be identical to water faucets with separately placed instant water heaters. Therefore, it was decided that the optimal design of the water faucet would be one that fits the water heater internally.

When this decision was established the placement of the water heater became quite clear. Even though the water heater is deemed as miniscule there were still not many places it could fit internally. High faucets on the market tend to reach

heights between 20 - 25 cm above the sink (Fossil Blu, 2020). Therefore, the water faucet concept developed in this project would be somewhere in this category when fitting the water heater internally. The water heater would therefore be placed in the base of the water faucet design. Additionally, this placement would be logical in terms of the function as well. The water pipe and heating cartridge cable should be inserted at the bottom of the base.

Research and observation from the chosen use area showed that it would be the most optimal to provide users with control over both temperature and water flow. Some of the tasks that were performed in household bathrooms required some sort of control to not hinder the process. As one of the project's goals was to integrate Altereds nozzle technology their Dual Flow Pro was chosen (Figure 5.1). This type of nozzle is aimed towards households due to its flexibility of switching between mist and spray mode (Altered Company, 2023).

Figure 5.1. Altereds Dual Flow Pro nozzle made for household use (Altered Company, 2023).

5.2 Developing a Flexible Solution

Research showed that consumers of today are in search of flexible solutions that fulfill a broader scope of needs (Oras, 2023). This fact sparked thoughts about how the design of the water faucet could fulfill needs other than the obvious ones. Some of the needs that are linked to the sustainability and efficiency of the product will be achieved by the integrated parts, the water heater from Bättre Design and the nozzles from Altered. Therefore, it was decided that additional value would be created from areas such as the aesthetics and interaction of the product.

Research showed that there was great value in the water faucet being consistent in terms of interaction (Hemmert et al., 2009). Therefore, it seemed as if the flexibility factor that users valued were to be more relevant for the aesthetics of the water faucet. A flexible type of interaction between faucet and user could result in confusion and worsen the intuitiveness of the product.

When reflecting about how to achieve flexibility with the aesthetics of the products ideas regarding separable parts arose. As the water heater was to be integrated into the base of the water faucet it seemed most convenient to have a separable base and top. The main reason for having separable parts would be the flexibility provided by being able to change between different designs without having to install a completely new faucet. Therefore, the most convenient way to go about it was decided to be by having one base design and multiple interchangeable top designs. Being able to easily change between different top designs would be a great feature in terms of flexibility. The purchase of the function would be less hindered by subjective taste of design, as there would be multiple alternatives.

5.3 Designing the Base

When having decided about going further with the idea of developing a concept with separable parts it was time to start thinking about how the base should look like. Different shapes were explored to visualize how small changes could result in completely different design languages (Figure 5.2). The different concepts were developed with inspiration from the user research that was done during the project. Words such as *Minimalistic, Unique, Modern, Intuitive, Creative and Intuitive* were considered during ideation as those were identified aspects that were sought for in a water faucet.

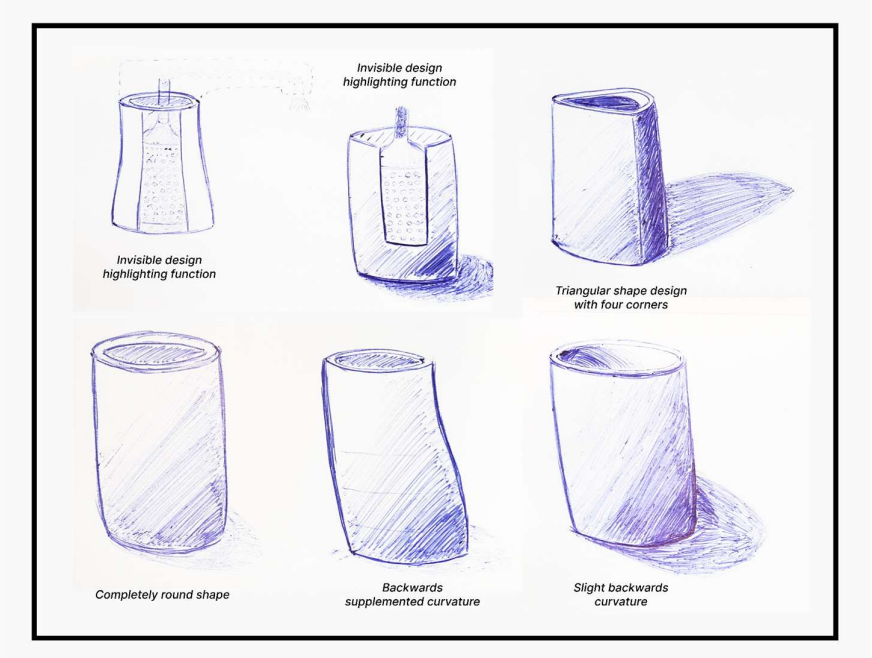


Figure 5.2. Sketches of different shape designs of the base.

The main function of the base is that it should be able to store most of the internal parts of the product. The largest part that should fit is the heat exchanger from Bättre Design. The fact that the heat exchanger is quite big in regard to being integrated into a water faucet implied that there was less design freedom when developing the base. The concept should not be considered clunky, so it was important to try and keep the base as minimal as possible. Therefore, it would be logical to make the shape of the base quite like the shape of the water heater to keep the dimensions as low as possible.

With the design freedom for the base being quite low and the fact that it is to be mounted to the sink it was decided that the most intuitive solution would be to stick to only one base design while making the top parts interchangeable. Going with this direction would be beneficial for developing a flexible solution that is easy to upgrade. However, the decision of choosing only one base design made it more important to focus on that it should suit all users. Therefore, effort was put on choosing the design that expressed *Minimalism, Modernism and Intuitiveness* as those were the most basic requirements from users. The challenge of creating a concept that was *Unique and Creative* was therefore left to be focused on the top parts because of the interchangeability.

Different shapes were explored from the top view of the water faucets base to get an understanding of different possible solutions for storing the water heater (Figure 5.3). This helped tremendously going forward with sketching different ideas of the base design. The fact that the base design should be minimalistic made the different concepts only separate in terms of small changes in shape. There was one concept that consisted of a large hole on the front of the base to enable users to see the integrated heating of the product. This was deemed as an interesting thought because it would highlight the unique function of the product. Even though this type of solution would intrigue users it could also result in people disliking the aesthetics of it. Therefore, the feature may be more applicable to one of the top designs. In conclusion, the complete focus was turned to developing the base by creating minimalistic changes to the shape.

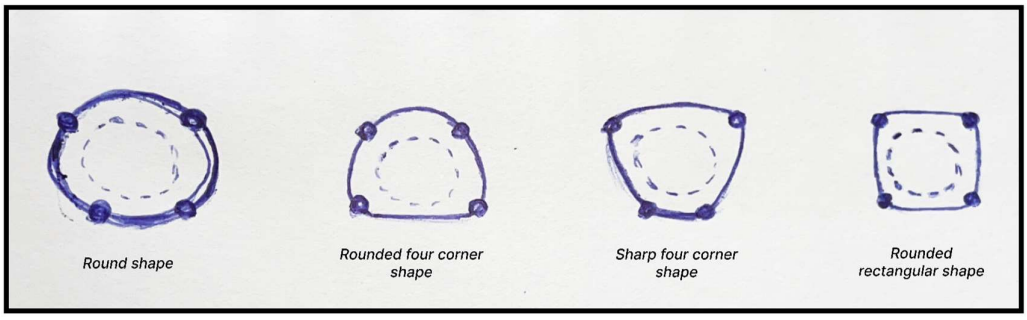


Figure 5.3. Sketches from top view of different possible shapes for storing the heat exchanger internally.

The shapes were drawn in both perspective and front view to highlight all types of curves and edges that were thought of. The thought throughout the ideation of

the base was to make small tweaks to the circular shape, because of the circular shape of the water heater from Bättre Design. A slight curve backwards in the side view of the base was identified to be aesthetically pleasing (Figure 5.2). Curves were further explored in the front view (Figure 5.4). As the dimensions of the base were already quite big it was decided that the shape should not widen any further. Therefore, if there was curvature on one side it should be supplemented with curvature on the respective side. The slight curvature into the center of the base in the front view was deemed interesting as it gave the illusion of a narrower shape.

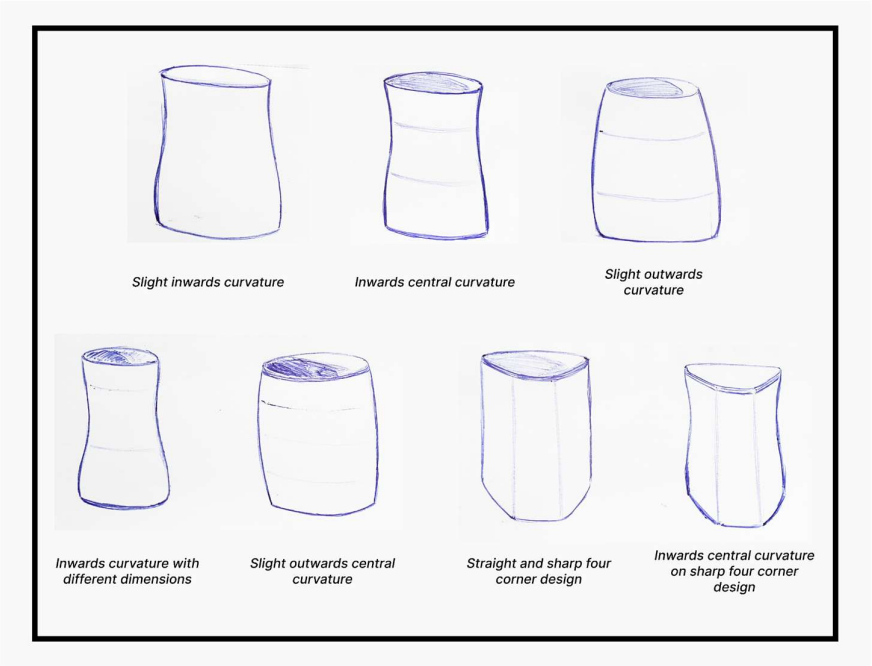


Figure 5.4. Sketches from the front view of different shape designs of the base.

After exploring with different types of shapes of the base it was decided that the most appealing one was the sharp four corner design, in combination with an inwards central curvature from the front view and a slight backwards curvature from the side view (Figure 5.5). The combination of these design choices gave the concept a modern and minimalistic look. Furthermore, the sharp four corners together with a backwards curvature provided an aggressive and stable touch to the design language, which was deemed aesthetic. The main purpose of the inward central curvature was to make the base appear narrower, as the dimensions of it were quite large.

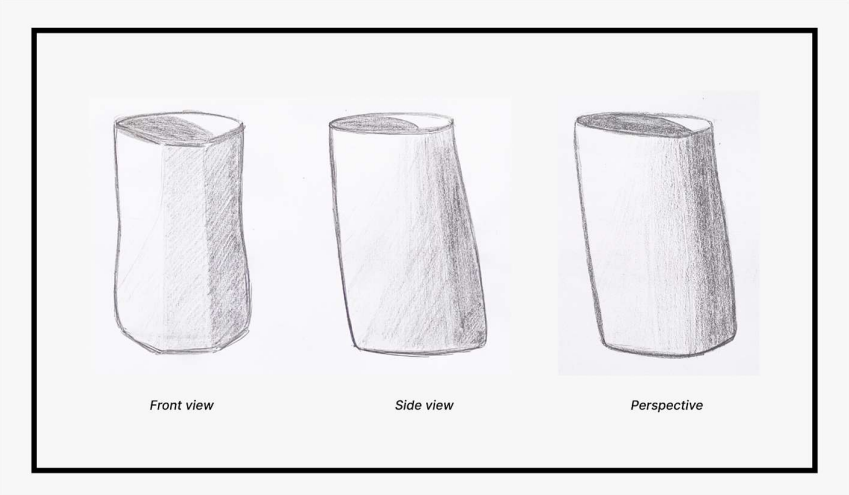


Figure 5.5. Chosen base design concept from different views.

5.4 Designing the Top

The design freedom of the top was quite large. The boundaries set beforehand were that it should be able to be mounted easily on the base of the faucet, store one internal pipe for water flow and that the height of the overall concept should optimally not exceed 250 mm.

During the ideation of the top design, it was quite clear from the start that the goal would be to design one minimalistic part that would fit a variety of users and one creative top design that would intrigue users. Going forward with two different designs was deemed as a great strategy to be able to showcase the flexibility of the overall concept.

Having chosen the base design provided ideas of what the overall concept should express. The backwards curvature of the base design made it express feelings of stability and comfortability. Therefore, it would be optimal to match these feelings with the top design. However, the design language of the two top designs that are chosen should still differ quite a bit.

Different ideas were explored for the minimalistic design (Figure 5.6). Examples of different shapes in all views were sketched to get a feeling of what was sought after. As the base would be quite large it seemed logical to follow that direction when designing the top part to make the overall concept match. Therefore, the choice between making the handle in a narrow or thicker shape became obvious. However, the overall design should not be seen as clunky so there are limits to the dimensions.

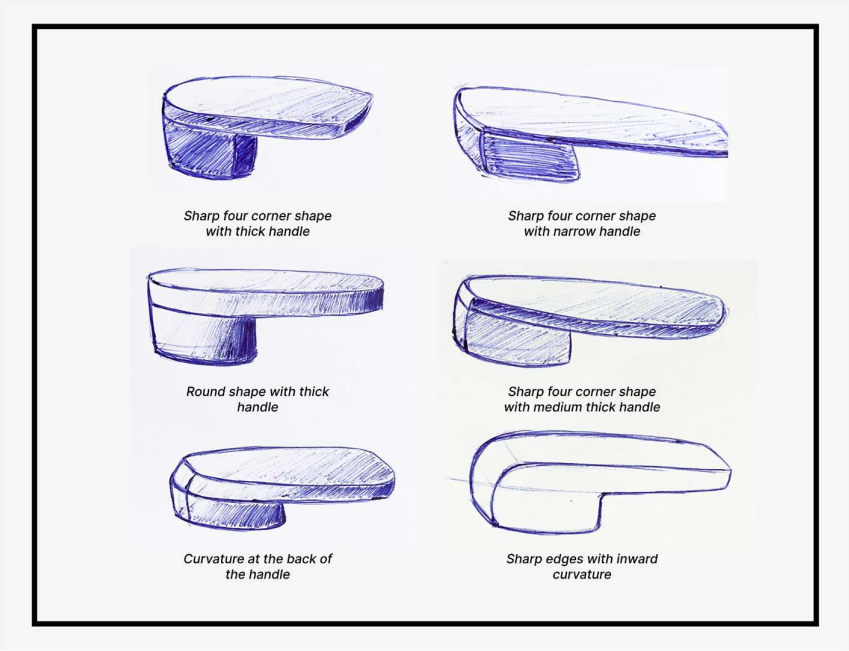


Figure 5.6. Sketches of different designs of the minimalistic top design.

Different shapes from the top view were produced (Figure 5.7). Because the top design should express minimalism and modernity while matching the design language of the base, small tweaks of the usual oblong shape were to be preferred. Designing with consideration of people's mental models of water faucets was deemed a great strategy for achieving an intuitive design that would suit a big portion of people.

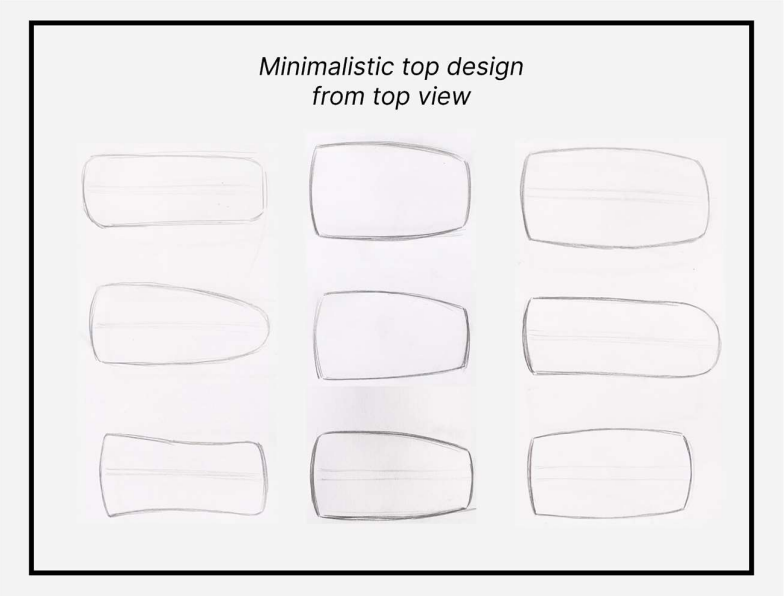


Figure 5.7. Sketches of different minimalistic top designs from the top view.

The slight inward curvature joint with almost a straight line at the end of the handle was deemed the most aesthetic and was deemed to match the expression of the base design, which was comfortability and stability. The sharp four corner

design that narrows down combined with a thicker handle provided the same kind of aggressive touch that the base design did (Figure 5.8). On the other hand, the two designs were both still quite minimalistic which sought to intrigue a variety of users.

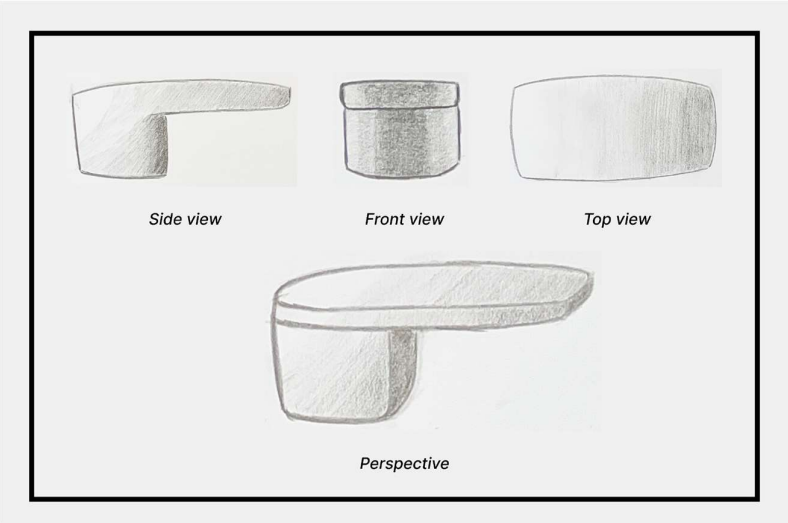


Figure 5.8. Sketches from different angles of the chosen minimalistic design concept.

An additional top part was designed to highlight the concept's flexibility of interchangeable top parts. The idea that was neglected during the design phase of the base that regarded visualizing the integrated heating was brought back to life. Being able to show the integrated heating when using the faucet was deemed to be both a creative and unique design. The main purpose of showing the integrated heating was to make people aware of what was going on inside the faucet. The fact that integrated heating in water faucets is rare would intrigue users. However, the aesthetic aspect was important to reflect around since it is an important factor in users choosing to purchase the product. Therefore, different types of concepts that visualized the internal function were sketched to see how it could be done (Figure 5.9).

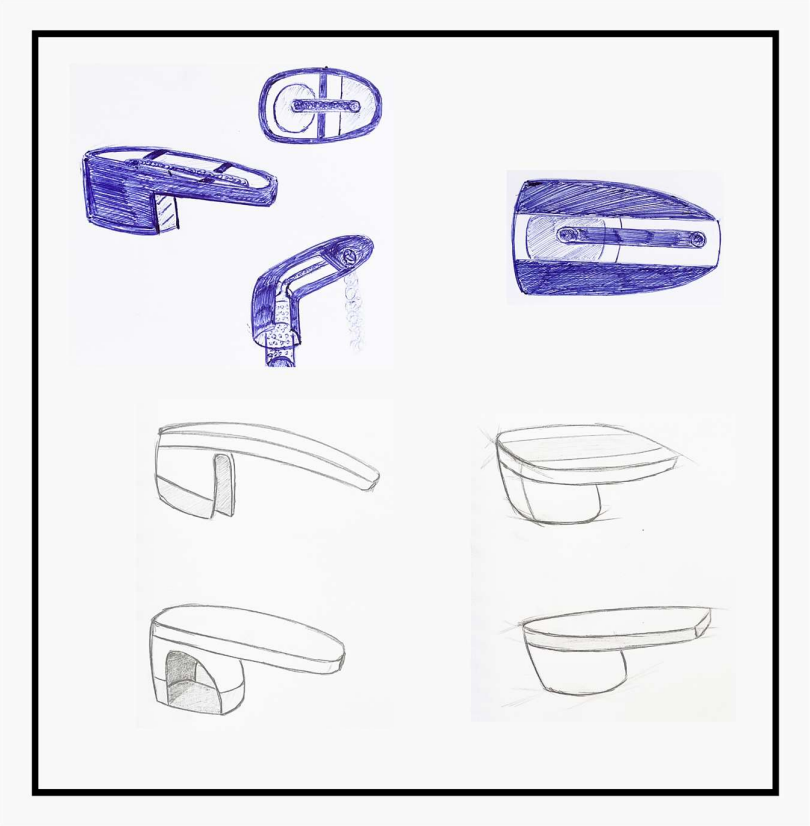


Figure 5.9. Different methods of visualizing the integrated heating.

The most important internal part to showcase was the heat exchanger from Bättre Design to highlight the feature of integrated heating. The most logical placement of the see-through part was then deemed to be at the sides, because of the clear view provided of both heat exchanger and pipe fittings. There were some reflections around whether to have a hole in the design or to use glass parts. Due to the requirement that the faucet should not collect dust, it seemed to be more efficient to make the see-through parts out of glass. Furthermore, to have some more design differences to the other top part the handle was chosen to be a lot thinner.

The work regarding the creative top part was not as detailed as the minimalistic one. The reason for this was because the main purpose of developing the second top part was to highlight the feature of interchangeable top designs.

5.5 Combining the base and top designs

To be able to develop a functional concept consisting of the chosen base and top designs there had to be work done regarding how to fit them together optimally without hindering the function of providing water. The parts should be easily installable and dismountable for ease of maintenance and replaceability. The top part should especially be easy to install and dismount because of the intuitiveness of the interchangeable aspect. Failing to achieve this would result in the concept losing its flexibility, which is one of its main purposes.

Different methods of joining the base and top design together were explored (Figure 5.10). There were some ideas whether the flow of water should be integrated to the walls of both the base and top design. However, that kind of solution would be quite complex and the only benefit of it would be the possibility of adding the feature of "hiding" the water flow which would only be relevant to the creative top part. Going through the struggle of enabling this kind of function was simply not worth it, as it would only be visible for one specific type of design.

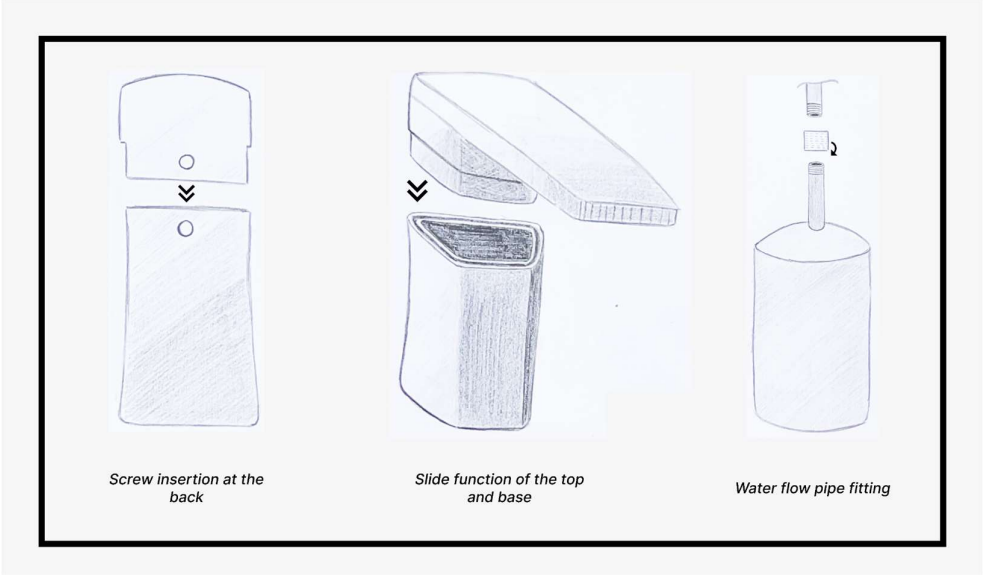


Figure 5.10. Methods chosen to combine the different parts.

The most intuitive method seemed to be letting the top design slide into the surrounding hole of the base and keeping the water flow in the center of the product. Doing it this way would result in only having to join the pipe from the water heater with the pipe that comes from the top part, for enabling the function.

Having the heat exchanger integrated into the faucet enables only having one pipe with water flow. The temperature of the water is decided by the amount of current provided to the electrical cartridge. A desired cold-water flow therefore only runs through the heat exchanger without any current.

To be able to connect the pipes before sliding down the top on the base one of the pipes needs to be a bit longer. Designing it this way facilitates both installment and removal of the top design. Furthermore, when the top design is mounted on the base a screw is inserted in the back for additional stability to the faucet.

5.6 Combining Traditional and Modern Functions

The last step of the ideation phase was to reflect around which functions to include in the concept. One of the aims of the project was to modernize people's

household bathrooms together with developing a more water conserving solution. Therefore, the touchless feature would add great value to the concept because it is both modern and proven to be more water conservative than traditional methods (Oras, 2023). However, switching completely to touchless faucets in household bathrooms would not go down well with a lot of people. Observation of the use area provided information regarding that further control was desired in terms of temperature and water flow adjustments. Control in terms of water flow adjustment would be provided by integrating the Dual Flow Pro nozzle from Altered. However, the observations provided insights that further control was needed for some tasks, such as having the option to stop the water flow from turning off at times. This was to be preferred when performing different types of tasks where the constant turning off of water flow was deemed to be annoying.

Reflecting on observations and research done on how to facilitate performing the switch from a traditional function to a more modern one resulted in deciding that it was important to provide users with the choice of making the switch. Having the option to use a manual lever for certain situations, for both temperature and water flow adjustments, was deemed to be a great solution for trying to intrigue people that are afraid of making the switch completely. Different placements of the sensor, temperature adjuster and manual lever were explored on the faucet concept to see what would be the most intuitive solution (Figure 5.11).

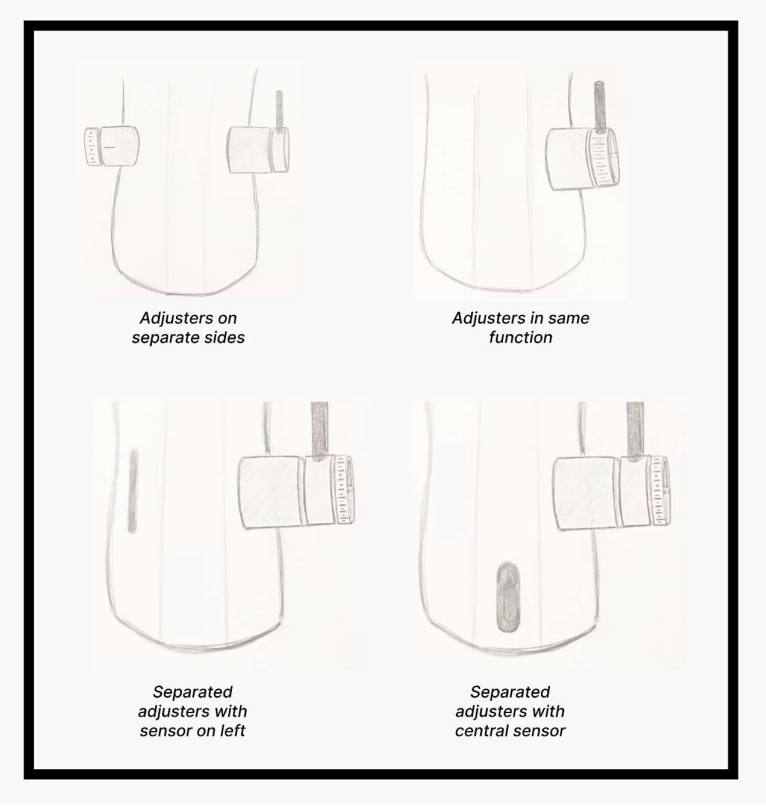


Figure 5.11. Showing different placements of sensor, temperature adjuster and manual lever.

It seemed most logical to place the different features on the base design to facilitate the interchangeability of the top parts. This was also made possible by the large dimensions of the base.

The placement of the sensor was decided to be in the middle of the faucet concept. The reason for this was because it was deemed to be the most intuitive solution because of the direct visibility of it and the fact that it activates when people's hands are under the water outlet.

There were plenty of different thoughts about how to design the temperature and water flow adjusters and where they should be placed. When looking at the different possibilities of placement it became clear that it should be placed on either of the sides of the concept. Having the sensor placed in the middle meant that neither of the adjusters could be placed there as well, as it would activate the water flow when trying to interact with them.

It was important that the interaction with the adjusters did not result in the user getting wet by activation of the sensor. To prevent this, it would be beneficial to place the adjusters a bit by the side of the faucet. The least complex solution then implies that both adjusters are placed on the same side. This would result in having both functions at the same place which enables a cleaner look and a more intuitive solution.

There were ideas around making the adjusters digital. However, it did not seem that intuitive to interact with digital screens with wet fingers. Additionally, a big reason for implementing the adjusters was to combine traditional and modern functions so making them digital would defeat some of the purpose of the whole concept. Therefore, it was decided that both the adjusters would be manual.

The manual lever for adjusting water flow should only have two different modes, on and off. The main purpose of this is to provide users the possibility of having more control over when the water flow should be turned off. The function of adjusting the water flow is already provided by switching between the two different flows on the nozzle from Altered.

It was deemed important to make the manual lever and temperature adjuster intuitive, so that the traditional functions could be understood. Placing the manual lever on the right side and enabling it to be moved in the x direction for turning on the water was seen as an intuitive solution. The temperature adjuster was placed after the manual lever and made as a separate bit, to facilitate the function. Icons for cold and hot water can be spotted on the rotator from the front view of the water faucet so that users can easily achieve the desired temperature of water (Figure 5.12).

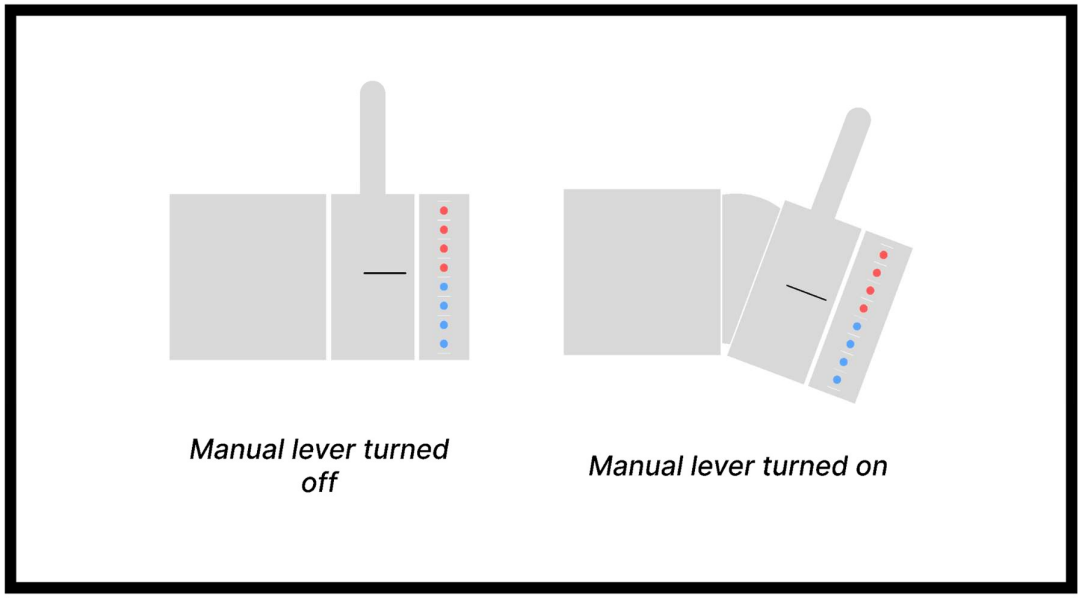


Figure 5.12. The chosen design and function of the manual lever and temperature adjuster.

There were ideas around having some additional information about the temperature on the side of the rotator (Figure 5.13). However, it was seen as unnecessary as the information that the front view provided would be enough. Adding an additional feature such as a digital screen could result in too much information which could make the water faucet be deemed a complex solution, which was not sought after in the project.

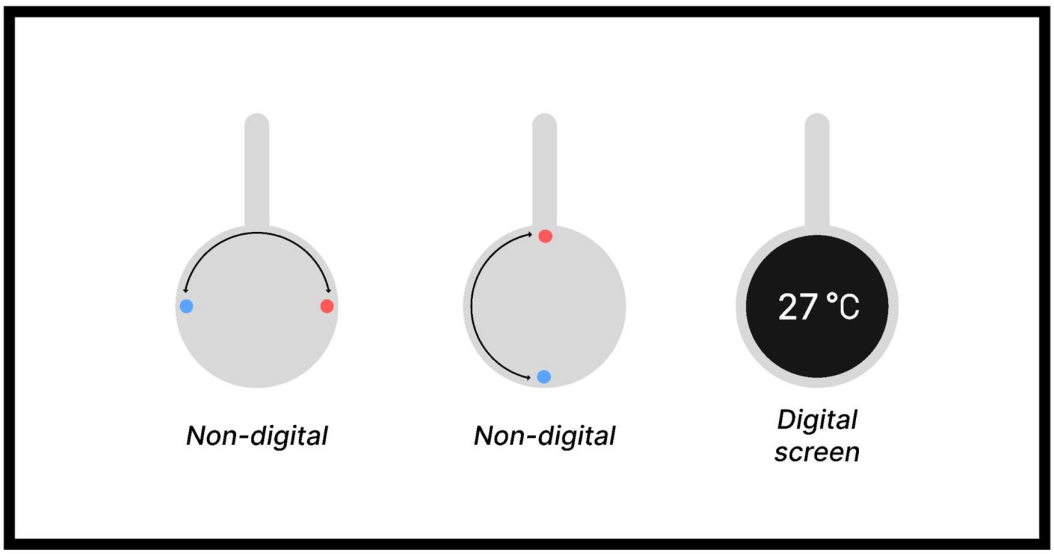


Figure 5.13. Ideas around additional information regarding the temperature from the side view of the temperature adjuster were neglected.

6. Faucet Concept

The water faucet was developed with the aim of facilitating water conservancy in people's households. With its modern and minimalistic design together with its unique function of integrated electrical heating it aspires to reach a broader audience. The combination of traditional and modern design provides the best of both worlds. Its touchless function is beneficial for easier tasks such as washing your hands and brushing your teeth while the manual lever can be used for more complex tasks that require a constant water flow. Having the option to choose how to perform any given task provides great flexibility for a variance of users.

Further control of water flow is provided by Altereds nozzle that has two different modes, mist and spray mode. Either of the modes are more water efficient compared to normal nozzles and contribute to the overall flexibility of the concept. Additionally, changing the temperature of the water is done by a rotator placed beside the manual lever.

Figure 6.1. The faucet concept in a bathroom.

6.1 Features

This chapter will go through all the features of the product to visualize what they look like from up closely and to provide information about how they work.

6.1.1 Internal parts

The concept consists of an integrated electrical heat exchanger from Bättre Design that heats the water in real time when either the touch sensor or the manual lever on the faucet is activated (Figure 6.2). Providing heating of water in real time means that only the required water is heated and there is no need for storing large volumes of hot water. This leads to less energy consumption which implies a more environmentally friendly solution (Hedges, 2022).

Figure 6.2. Render of integrated heat exchanger and pipe for water flow.

The integrated heat exchanger is 3D printed which enables the creation of miniscule sinusoidal pathways where the water flows through. The sinusoidal shapes, together with its effective design of surface area results in a more efficient way of heating water (Dybeck, 2023).

Another advantage of the concept having integrated heating is that it occupies less space which makes it an ideal solution for households with limited space (Hedges, 2022). There is only one pipe with water flow needed to enable the function of water flowing through the water faucet and exiting from the nozzle. Furthermore, a cable needs to be connected to a wall socket to provide current to the electrical cartridge for the possibility of heating the water.

The top part is slid down into the base while the two pipes are pressed against each other with a gasket in between. The top and base are then further mounted together by a screw at the back of the faucet (Figure 6.3).

Figure 6.3. Screw inserted at the back to connect the top to the base.

6.1.2 Touchless feature

The sensor (Figure 6.4) for the touchless feature is placed in the bottom center of the base design. This placement facilitates for users to spot where they should place their hands to activate the touchless feature. Additionally, having the sensor activate when placing your hands, or other, under the nozzle is an efficient way of receiving water where it is desired quickly.

The touchless feature is a great alternative to perform tasks at the sink without interacting physically with the water faucet. Using the touchless feature provides great benefits in areas such as hygiene and energy consumption (Oras, 2023).

Figure 6.4. The sensor enables touchless interaction with the faucet.

6.1.3 Adjusting temperature and water flow

The water faucet provides multiple ways of adjusting the desired temperature and water flow. Having control over these areas are crucial for performing different types of tasks in the bathroom.

The temperature is adjusted by rotating the control part in the y axis placed on the side of the manual lever (Figure 6.5). Red and blue icons are used to highlight which way to rotate for hot and cold water respectively. The rotating of the temperature control sends a signal to how much current is needed for the electrical cartridge in the heat exchanger. Maximum current sent to the electrical cartridge implies maximum temperature provided from the tap, and vice versa.

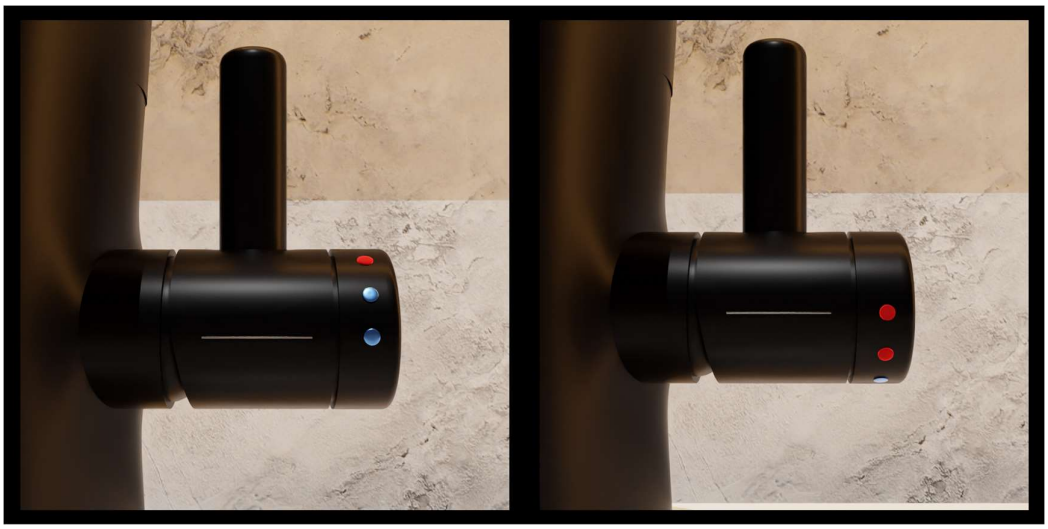


Figure 6.5. Render of temperature adjuster indicating minimum temperature (left) and maximum temperature (right).

The water flow can be adjusted by rotating the integrated Dual Flow Pro nozzle from the company Altered 180 degrees (Figure 6.6). The nozzle consists of two different modes, mist and spray mode. The mist mode is the most efficient one saving up to 98 % water while the spray mode saves 85 % (Altered Company, 2023). The Dual Flow Pro breaks up the water into millions of droplets that creates a heavy mist which results in a much greater contact efficiency. This results in less water required for performing the same task.

Figure 6.6. Altereds nozzle is rotated to switch between mist and spray mode.

Further control of water flow is provided by the manual lever placed on the right side of the faucet (Figure 6.7). More complex tasks that are performed in the bathroom were identified to require a constant water flow. Therefore, the manual lever enables the function of keeping the valve for water flow open until the manual lever is turned off. The manual lever has two modes, on and off. Turning the lever to the right opens the valve and activates the water flow. To turn off the water the manual lever needs to be turned back to the left.

Figure 6.7. Manuel lever is turned to the right to enable constant water flow.

6.1.4 Interchangeable top parts

Providing the opportunity to change between different top designs of the faucet gives the user the flexibility of easily switching the complete expression of the bathroom. To install the top design to the base the pipes for water flow need to be connected. Then the top is slid down into the hole of the base design and stabilized with a screw at the back.

There was only one top that was developed in the project due to time restriction. However, by just keeping the same bottom design as the developed top to insert into the base enables a variety of different options of handle designs.

6.2 Production and material

The faucet concept should be 3D-printed in stainless steel. Stainless steel is commonly used in water faucets because of its many benefits within areas such as (SRS Group, 2022):

- Corrosion resistance
- Fire and heat resistance
- Hygiene
- Strength and impact resistance
- Sustainability

The attribute of heat resistance is relevant because of the internal heat provided from the integrated heat exchanger from Bättre Design. The hygienic aspect of the product is important because it is to be installed in people's household bathrooms. It is easy to clean and maintain and it makes bacteria struggle to establish on the surface (SRS Group, 2022). Using stainless steel enables the

faucet to be made from 70 % scrap metal and can be 100 % recycled (SRS Group, 2022).

Performing a matte black finish on the stainless steel results in the faucet being fingerprint resistant and makes it easier to keep it looking pristine.

The main reason for 3D-printing the water faucet is to match the production with the heat exchanger from Bättre Design. This production method will provide the faucet with further value within being deemed as a modern concept. Additionally, the design freedom of the interchangeable top parts will be much greater than it would have been when using other production methods, as 3D-printing enables the creation of more complex shapes (nTopology, 2022).

6.3 Validation

A validation of the concept was needed to see whether the design achieves the set requirements of the project. To be able to validate this it was important to look back at what the concept should accomplish and reflect around whether it does so or not.

A survey was created and sent to users to try and validate the aesthetics of the faucet concept. The complete survey can be found in Appendix A. The survey started off by visualizing the final concept and its visible features, such as the sensor, temperature adjuster, manual lever and ability to change top parts. These features were described briefly to highlight the purpose of them. The reason for not including any information about the integrated heating and the nozzle technology was because the validation from users was mainly focused on the design language of the faucet. Therefore, information about parts that did not impact the design language were not included in the visualization.

The main purpose of the survey was to validate with users whether the faucet concept expressed what was aspired in the project. Words such as *Minimalistic, Creative, Modern, Intuitive and Unique* were desired to be linked to the developed concept. Therefore, asking users about how well the concept manages to express this design language was deemed as a great validation method for the design work performed in the project.

A total of 15 people rated the faucet concept in regard to expressing *Minimalism, Creativity, Modernism, Intuitiveness and Uniqueness.* The users got to put a rating between 1 - 10, where 1 did not express that word at all and 10 clearly expressed the word.

The average rating from users of how well the concept managed to express the sought-after words were the following: *Modern* (7,9 points), *Minimalistic* (7 points), *Intuitive* (6,8 points), *Unique* (6,5 points) *and Creative* (6,3 points). All expressions were deemed to be somewhat relevant to the concept which could be seen as a great result for the design work performed during the project. The

main target of the design was to find a balance between the different expressions to manage to reach a broader consumer group.

Looking deeper into the user's reflection of their rating in the survey resulted in being able to identify factors that had the most impact on the overall rating.

Modern (7,9 points)

Participants shared that the main aspects of the concept being deemed as modern were due to its clean and simple design. Words such as *Elegant, Flexible, Sleek, Minimalistic, Smooth and Futuristic* were used to describe the feel of the design language. Some reasons behind the concept not receiving a higher rating, from some users, was because the design was not deemed to be innovative and because of the less elegant shape of the manual lever and temperature adjuster.

Minimalistic (7 points)

The users deemed the faucet to be quite minimalistic in its design considering the faucet's great flexibility and adjustability provided by its different features. Many users shared that the design of the manual lever and temperature adjuster was the reason for it not getting a higher rating in terms of minimalism. Some of them shared that an easier design, such as a discreet button instead to enable the features would result in a higher rating. Additionally, some thoughts around removing the color indicators for hot and cold water were deemed to provide a more minimalistic look.

Intuitive (6,8 points)

The perception of the intuitiveness of the faucet was quite shared by the participants. Some thought that the functions were very clear and straightforward while others were unsure whether they would interact with the faucet correctly when trying it out for the first time. Some aspects around the uncertainties of the interaction were shared, such as difficulties getting used to different controls for temperature and water flow, trying to turn the lever back and forward instead of to the side and the unusual placement of the lever.

Unique (6,5 points)

The participants' opinions of the uniqueness of the faucet were quite equal. The concept was considered unique mainly due to its combination of touchless and manual control of water flow and the fact that the top parts were interchangeable. The main reason for the faucet not receiving a higher score in terms of uniqueness was because the shape was familiar and basic.

Creative (6,3 points)

Like the rating of uniqueness, the perception of the creative aspect of the faucet was quite shared between the participants. They shared that the features of the

faucet made it creative while the shape lowered the scoring. The features that were mentioned the most were the interchangeable top parts and the combined function of touchless and manual control of water flow.

Many of the expressions are tough to combine in a design without directly contradicting each other. Therefore, managing to do so and receiving positive feedback from users in all areas can be deemed as a successful validation of the faucet. The uncertainties from users around some areas of the faucet would have to be explored further and tested to receive insights about what needs to be improved.

7. Discussion

This chapter will discuss how well the faucet concept meets the different areas of requirements gathered during the project. Additionally, the overall project method will be reflected upon.

7.1 Safety, Hygiene and Sustainability

Some validation was needed to see whether the concept meets the requirements within areas of safety, hygiene and sustainability. The integrated heating of the faucet implies less piping for the water to flow through since there is no need for boilers that store water. Less piping results in less risk of the pipes getting clogged. Furthermore, the concept avoids the design of high arcs as they could result in formation of bacteria where the water flow slows down (SCB, 2021).

The touchless feature of the faucet provides users with a more hygienic interaction. Research has shown that touchless faucets imply significantly less microbial biomass on its surfaces which results in preventing spread of different diseases (Oras, 2023). Furthermore, it contributes to a more water efficient use, as the tap turns off when users do not interact with the faucet.

The faucet is an energy efficient solution because of its integrated heating made possible by Bättre Design. Having integrated heating in the faucet implies less water waste, as the water that is needed is heated in real time. Compared to centrally placed boilers that store large amounts of heated water.

Being able to change the top part of the faucet provides users the ability of changing the expression of the faucet without buying a completely new one. This results in the faucet meeting a broader scope of human needs which could lead to longer use.

7.2 Facilitating behavioral change

The water faucet concept aspires to change people's behavior at the sink towards being more water conservative. Some of the features such as integrated heating and new nozzle technology results in a more water efficient behavior directly when activating the water faucet. The change of behavior is therefore already done when taking the decision of purchasing the water faucet. According to Fitriyah et al. (2017) it is important that these types of forceful features for behavior change highlight the purpose of it and that it is valued by users. Furthermore, it should not imply too much of a change in procedure as it may cause irritation and result in users refusing to use the water faucet. Therefore, it is important that these features of the water faucet are marketed by highlighting the sustainable benefits of integrated heating and the nozzle technology in terms of energy and water efficiency. This will be a crucial part of getting people to purchase the water faucet for its function and being in terms with adapting a more sustainable behavior at the bathroom sink.

There was identified to be great value in providing users the option between traditional and modern functions. Observations and interviews provided valuable insights especially about the touchless feature. Some people were more prone to apply it in their bathroom than others. However, all the users deemed that a combination of touchless and manual functions would be interesting to try out. The main reason behind people not wanting to have a completely touchless water faucet was because they thought that some more complex tasks would be harder to perform.

According to Arroyo et al. (2005) to facilitate behavioral change by features it is important that they are deemed as creative, aesthetically pleasing and intriguing users. The insights from users about the combined functions matched some of the areas that Arroyo et al. (2005) discuss, such as creative and intriguing. Therefore, combining the touchless and manual feature is deemed as a great method of getting people to change their habits. Over time users may get used to the touchless feature and adapt the function even when performing more complex tasks.

Beaulieu et al. (2009) state that introducing people to other behaviors at the sink could result in them adjusting their habits. Therefore, there are great possibilities of nudging people into using the touchless option more frequently. The value especially lies within the users that were not ready to switch completely to a touchless function and getting them to perceive the benefits of the touchless feature. According to Beaulieu et al. (2009) the most successful techniques for behavior change are those that do not require more effort from users. As the water faucet concept provides users the option of being more water efficient it can be seen as a solution that requires minimal effort to change the behavior at the sink.

The aesthetical aspect of the design was hard to pinpoint to a science and therefore resulted in taking design decisions based on my own preferences. Therefore, a survey was made were users got to rank how well the faucet

managed to achieve the sought design language. The survey showed that users agreed with my own perceptions of the expressions *Modern, Creative, Unique, Intriguing, Minimalistic and Intuitive.* Succeeding with developing a design that users deem as aesthetic will result in more people willing to purchase the product which implies a greater chance of achieving behavioral change.

7.3 Interactional process

The water faucet concept aims to be an intuitive product that tries to optimize the interactional process with users. Research around the interaction between humans and different types of water faucets showed the importance of the product being a non-complex solution (Helander & Lo, 2004). This idea has been a basis throughout the development of the water faucet in terms of what features to include and where they should be placed. Helander & Lo (2004) state that users are becoming less willing to tolerate complex design. Therefore, it has been important to make the features intuitive and not include too many of them, as it would result in an overall complex product.

Features such as the manual lever and temperature adjuster were placed beside each other to try and create a less complex product. Helander & Lo (2004) discuss the increase of the complexity when having more prompts for achieving the same goal. Keeping the features close to each other enables users to construct a straightforward mental model.

Some features were dismissed to keep the concept as non-complex as possible. The features that were rejected were those that were not directly linked to improving the function. An example of this was the idea to implement a digital screen at the side of the temperature adjuster that showed the exact temperature of water. However, the information provided was deemed unnecessary and only added complexity to the overall concept.

Throughout the development of the concept there has been cautiousness around making the water faucet unique and foreign. The main reason for this is because research showed that users experiencing outlandish design of water faucets resulted in evoking emotions such as irritation and frustration because they were not sure how to act (Hemmert et al., 2009). Therefore, a minimalistic approach was to be preferred. However, it should be supplemented with some creativity and uniqueness.

The creativity and uniqueness of the water faucet is expressed mainly by its creative features. The interchangeable top part design provides the feeling of a flexible and unique solution while not hindering the actual interaction. The focus was to provide users with a comfortable and intuitive interactional process. Clearly indicating the purpose of the function was important, such as red and blue icons on the temperature adjuster for hot and cold water. The sensor is placed centrally on the water faucets base for visibility and useability purposes.

7.4 Project method

A lot of the focus in the project went to researching multiple different areas within the field of water faucet design. A lot of time was dedicated to understanding the water heating technology from Bättre Design at the start of the project. It was deemed important to identify the benefits of integrated heating and to understand the main purpose of the project. Realizing what kind of areas were important to the project took time. The original plan got changed throughout the process as new areas relevant to the project were identified. At times I felt that there were too many fields that needed to be studied which resulted in losing focus on what was important. In hindsight, clearing up what the project should focus on at the start would have been of great value to hinder scattering around subjects that were not important for the project.

The interactional and behavioral research of the project was mainly done by searching for case studies within the field. Most of the studies regarding this area were done on quite specific use areas which resulted in having troubles to relate them to the project. Some of the studies that were found and identified relevant in terms of providing insights about interactional and behavioral aspects between humans and faucets, were quite old and often had a specific niche of participants. Therefore, it was hard to draw any conclusions because it was not clear that specific user studies could be perceived as facts. Additionally, some of the studies contradict one another which resulted in uncertainties around the field. Therefore, a lot of the interactional and behavioral aspects identified resulted in points to consider instead of any clear guidance on how to do it.

Often it was about finding the right balance between two contradicting points. A clear example of this is that research showed that consumers today are in search of a flexible solution that fulfills a broader scope of needs (Oras, 2023) while on the other hand they are becoming less willing to tolerate complex design (Helander & Lo, 2004). Even though this may not be directly contradicting, the points have a clear impact on eachother. Ultimately, a lot of the design choices that were made were hard to explain and were often based on my own understanding of research, observations and interviews about users that were done in the project.

In hindsight, the project should have focused more on performing user studies instead of searching for literature. The observations and interviews that were done in the project resulted in great insights about relevant areas that could be directly linked to some of the design choices that were made to the faucet. Performing user studies on more people and more types of tasks would be of great value for the design process of the project as there would be less uncertainty around some of the design decisions.

The validation of the concept was done both by revisiting the requirements set on the faucet and asking users how they perceived the concept. The survey was created to get insights from users mainly about what the faucet expressed, as that was a big part of the project. Trying to get users' insights from a quick survey that did not explain the purpose of the faucet in full detail and included a

sketch of the final concept was not the most optimal method. Some uncertainties about the concept from users could have been avoided by a more detailed description about the project and providing information about the reasoning behind the design choices. Furthermore, it would have been interesting to see how the ratings within the different areas would change when switching to the other top design. However, the method was still very beneficial in terms of receiving validation from users about what their overall view of the concepts design and features was.

Going forward with the work it would be important to validate the concept further with the users (Figure 7.1). Exploring how the interactional process of the faucet is perceived by observations and interviews would provide great insights about the actual user satisfaction to identify aspects that can be improved.

Future work regarding the overall concept could consist of exploring different types of use areas. Identifying what kind of new requirements are set on the concept if it is to be implemented in other parts of people's households where more complex tasks are performed. Researching whether it is possible from a user satisfaction standpoint to implement the function of integrated heating in every faucet in the household and what kind of effects it would have on water and energy efficiency. Implementing the function of integrated heating in peoples' household bathrooms is only the start for the vision of creating more water efficient households in the future.

Figure 7.1. Further testing should be performed where users get to interact with the developed faucet concept.

8. References

Altered Company (2023). Dual Flow Pro. Retrieved from: https://alteredcompany.com/products/altered-nozzle-dual-flow-pro

Arroyo, E., Bonanni, L. & Selker, T. (2005). Waterbot: Exploring Feedback and Persuasive Techniques at the Sink. Retrieved from: https://dl.acm.org/doi/epdf/10.1145/1054972.1055059

Beaulieu, S, M., Jou, W., Lim, A, K. & MacDonald, E, F. (2019). A Wizard-of-Oz Experiment to Demonstrate Water Reduction and User Training With an "Autonomous" Faucet. Retrieved from: https://asmedigitalcollection.asme.org/IDETC-CIE/proceedings-abstract/IDETC-CIE2019/59278/1070212

CLAGE GmbH (2023). Energy efficiency. Retrieved from: https://www.clage.com/en/energy-efficiency/less-energy-losses

Dybeck, S. (2023). THE NEXT-GENERATION WATER HEATER. Retrieved from: https://secure-res.craft.do/v2/MFZrMG2uFkqdUqnovovSGGAkTNTT4iVHN45uzAjsHwULF3NKxHKPsDxBGRXQ1btP1fKYhJAjUaqJ31mmRYg4Lv132PCn3fdjAA3TkH7Gvr2pVbmWnnqfUfPjXPBkXJGBE8ryNAX1vhYdCcY9QAK4zRMDEmAPXihy5GKuzoEL2JSgTxWRfp8mb7DEpPSrC4bbYQN4tVjpKWjk4qWJE5QWBxCpZCc7NfDBe6s21uoUQRNcdXNBt8pBF377DMSNbNQyM9RGqLWGLLxDND7trxNr9jD8agDVLrG5qVjmthbHQCzu7iXwUWEY8A27PA9fwY9CxDJdn4HUcn4nbPTGya7bjjLKx4yA2Cz72jik8Y9oXYKhswciTBL/Next-generation%20water%20heater%20development%20plan.pdf

Energy Saver (2023). Tankless or Demand-Type Water Heaters. Retrieved from: https://www.energy.gov/energysaver/tankless-or-demand-type-water-heaters

Fitriyah, H., Kusuma, B, A., Setiawan, E. & Widasari, E, R. (2017). Interaction design of automatic faucet for standard hand-wash. Retrieved from: https://www.matec-conferences.org/articles/matecconf/pdf/2018/13/matecconf_icet4sd2018_03003.pdf

Fossil Blu (2020). HOW TO CHOOSE THE PERFECT KITCHEN FAUCET. Retrieved from: https://www.fossilblu.com/blogs/news/how-to-choose-the-perfect-kitchen-faucet

Ghassemi, M., Hashemi, M., Mohammadi, J. & Shahidian, A. (2020). Bio-Engineering Approaches to Cancer Diagnosis and Treatment. Retrieved from: https://www.sciencedirect.com/topics/engineering/conduction-heat-transfer

Helander, M, G. & Lo, S. (2004). DEVELOPING A FORMAL USABILITY ANALYSIS METHOD FOR CONSUMER PRODUCTS. Retrieved from: https://www.academia.edu/en/67785406/Formal_Usability_Analysis_Method_for_Consumer_Products

Hedges, C. (2022). What are instant water heaters and are they any good? Retrieved from: https://www.thermosphere.com/blog/what-are-instant-water-heaters

Hemmert, F., Togler, J. & Wettach, R. (2009). Living Interfaces: The Thrifty Faucet. Retrieved from: https://dl.acm.org/doi/epdf/10.1145/1517664.1517680

International Heating Products (IHP, 2023). Värmepatroner 750°C. Retrieved from: https://www.ihp.se/varmepatroner-750c/

Kircher, R. (2020). Reevaluating the cost of metal additive manufacturing. Retrieved from: https://www.additiveindustries.com/news/news-and-press/cost-metal-additive-manufacturing

Manning, Q. (2017). Improving User Satisfaction Through Design. Retrieved from: https://www.uxmatters.com/mt/archives/2017/02/improving-user-satisfaction-through-design.php

Mihailidis, A., Snoek, J. & Taati, B. (2012). Video analysis for identifying human operation difficulties and faucet usability assessment. Retrieved from: https://www.sciencedirect.com/science/article/pii/S0925231212003918

nTopology (2022). Thermal Management Guide. Retrieved from: https://secure-res.craft.do/v2/2BAwh3yVqGSfAfoCGGDxpkVcKcMTUwz8jr1GzEGgvFSNWHCfJDveEXLEVZTD7tUjvP9KA4DTvCysYcmpEXgk8b4EcCNhq8BKNbitFfUHLzFc7YbPfFybYNs8KEzy3CFum5raywHvQTCWwvBX9jPsrhuYNkZssvs4riWRSoajVbS2iPAGoANFJs6VRmSju9tuViSkEorhVxwNfgF22svsXym6NkyEch1V6gnkRkcaS5FMvizVsherqpjTKid7Zch9N8hs3E9EB1yPX7CiqvcHyAPHY1ibB4jSRjEEPk8NQWDV7fWaxhnYqarB4pjf85rFD1yGfPo6/Thermal-Management_Guide_Q1_22.pdf

SRS Group (2022). 7 BENEFITS OF STAINLESS STEEL. Retrieved from: https://www.srsgroup.co.nz/blog/7-benefits-of-stainless-steel/

Oras, 2023. Retrieved from: https://www.oras.com/en/home

Robinson, S. (2021). Home water systems explained. Retrieved from: https://www.homeserve.com/uk/living/plumbing-and-drainage/home-water-systems-explained/

StarCraft Custom Builders (SCB) (2021). Keeping Faucets Safe & Reliable. Retrieved from: http://starcraftcustombuilders.com/sources.faucets1c.htm

Statista Technology Market Outlook (2022). Smart devices to boom over the next 5 years. Retrieved from: https://www.weforum.org/agenda/2022/04/homes-smart-tech-market

UN (2023). The Human Right to Water and Sanitation. Retrieved from: https://www.un.org/waterforlifedecade/pdf/human_right_to_water_and_sanitation_media_brief.pdf

Velo3D (2021). VELOVirtual: Next Generation Heat Exchangers. Retrieved from: https://www.youtube.com/watch?v=ZatwRYn8OHQ

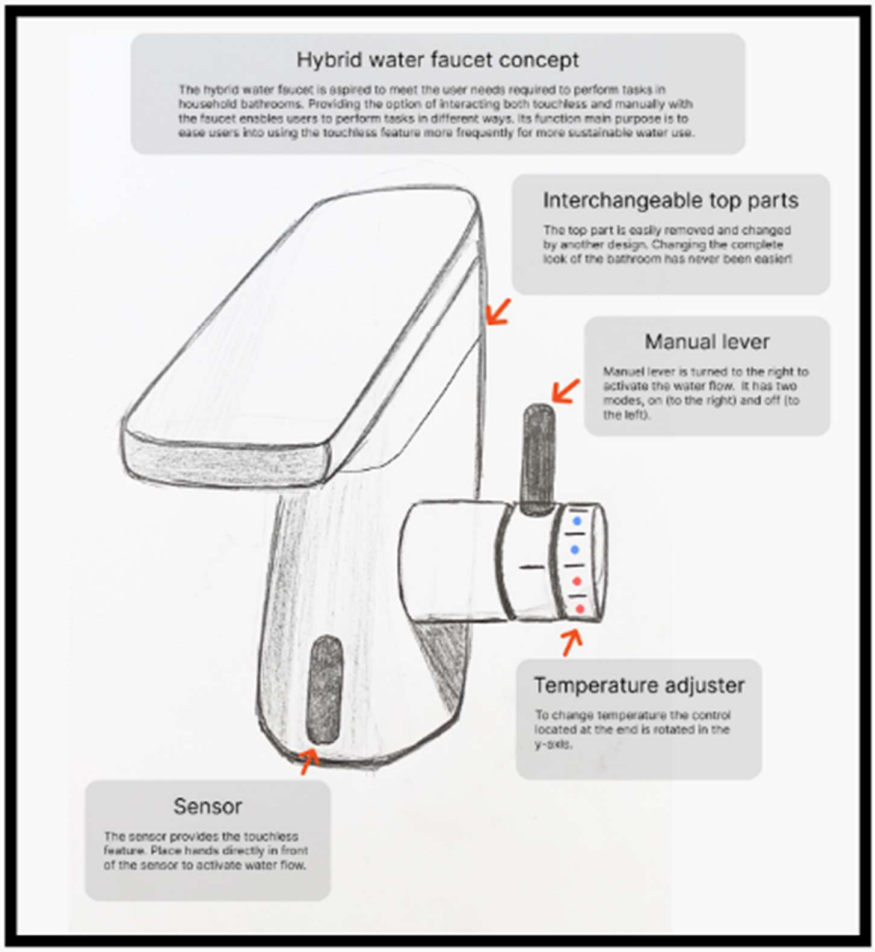
9. Appendix

A. Validation survey

Hybrid Water Faucet

What does the design of the Hybrid Water Faucet express? Take some time to read about the water faucets different features. Thank you for participating :)

Hybrid Water Faucet



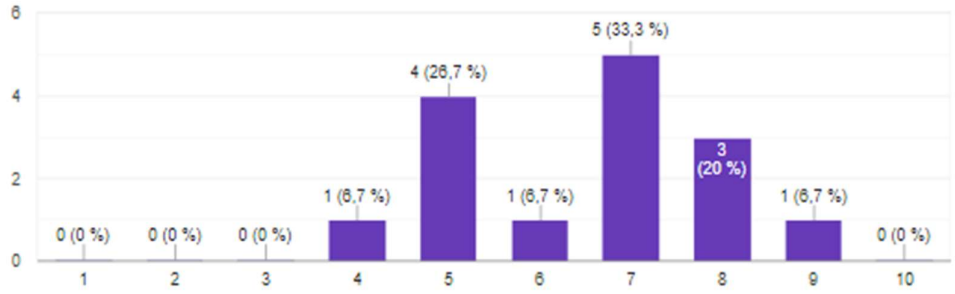
Questions:

- How unique is the faucet according to you (1-10)? (1 = Not unique at all, 10 = Very unique)
- How modern is the faucet according to you (1-10)? (1 = Not modern at all, 10 = Very modern)
- How minimalistic is the faucet design according to you (1-10)? (1 = Not minimalistic at all, 10 = Very minimalistic)
- How creative is the faucet design according to you (1-10)? (1 = Not creative at all, 10 = Very creative)
- How intuitive is the faucet design according to you (1-10)? (1 = Not intuitive at all, 10 = Very intuitive)

How unique is the faucet according to you?

Kopiera

15 svar



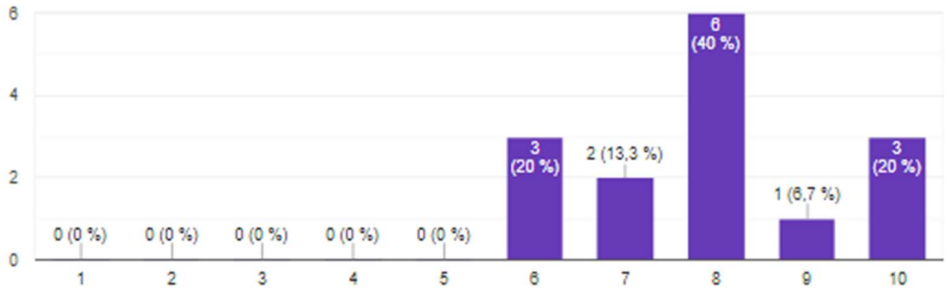
Answers:

- Never seen a combination of manual and toucless, the possibility of changing the top is also very impressive
- Utbytbar toppdel, både manuell och automatisk aktivering av flödet.
- I haven't seen a modular faucet like this before which makes it quite unique. However, the controls on the right does feel familiar.
- Formen är basic eller igenkännbar som en kran, men funktionerna är mer unika
- Pga att man kan ändra utseendet på kranen och för att det är en på och avstängning som en "stång" (och den är inte integrerad med värmejustering). Anledningen till att den inte är en 10:a är för utformningen känns väldigt mycket "kran" (nära grundtecken)
- Having the double usage (automatic + manual) is very clever and nothing I've seen before.
- The concept of blending manual/automated functions seems new to me and the idea to switch the top of the faucet also seems new. The shape itself is a bit familiar I would say but it does not have to be a bad thing really
- Kändes inte unik vid första anblick, men unikt att kunna justera flödet av vattnet och mer intuitiv design med temperaturreglaget än vad man tidigare har använt
- Det är en rätt klassisk modell (vi har nästan likadana på jobbet), men med temperaturreglage på sidan som lite udda detalj. Det formspråket har varit inne de senaste 10-15 åren. Det är enkelt, snyggt och stilrent, men kanske inte så nytänkande (vilket det inte behöver vara om det inte är det man satsar på)
- Touchless faucets are quite common, but the added option of using the manual lever and the interchangeable top parts adds to the uniqueness.
- It's unique for the fact that it's a hybrid faucet, but the design and semantics is similar to a lot of other faucets.
- It seems unique in its functions but not so much in its looks

How modern is the faucet design according to you?

Kopiera

15 svar



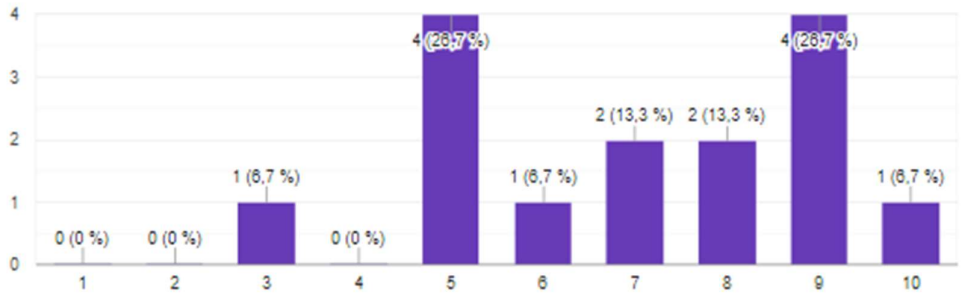
Answers:

- Seen the tech before but separate, a tap can only be so modern hence lower score
- Sett formerna förut, dock modern design och ett vred som man inte sett förut.
- The shape looks quite modern and the sensor makes it feel modern, but the controls to the right seems less elegant than the rest of the design, in my opinion
- Robusta former men ändå mjuka hörn/radier, som typ allt annat
- Den ”snabba” och enkla formen. Den känns elegant
- The flexibility it enables gives it a modern touch.
- Geometric sleek shapes
- Modern med sensorn och formuttrycket som är väldigt minimalistiskt och enkelt
- Modernt formspråk, men inte särskilt nytänkande
- The design is simple and clean, with sweeping shapes which add to the modern feel.
- Clean, smooth edges, futuristic. I think it sends out modern vibes

How minimalistic is the faucet design according to you?

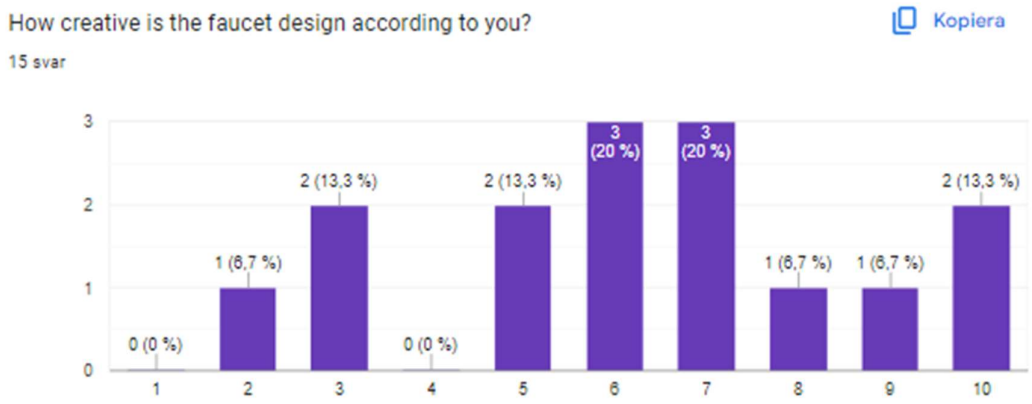
Kopiera

15 svar



Answers:

- For the amount of flexibility and adjustability it is minimalistic, definitivt. But with this many vissible features it gets a medium score
- Inga överflödiga aspekter
- The controls to the right makes it less minimalistic in my eyes.
- Samma svar som 2
- Den är minimalistisk men av och på stången tar bort från den minimalistiska looken. Finns kanske en tanke bakom den, men tänk om det var en diskret knapp?? Då hade den vart ännu mer minimalistisk
- Clean and simple.
- Consists of basic geometric shape with a smooth surface without any extra decorative details
- Enkel design med fokus på funktion, släta medföljande ytor
- Hur minimalistisk den är beror väll påhitt de utbytbara delarna ser ut. I denna utformning är den varken eller. Jag har sett motsvarande koncept som är betydligt mer minimalistiskt och reglaget på sidan lägger till ”plotter”, samtidigt så hade en krannockså kunnat vara betydligt mindre minimalistisk än denna
- It is minimalistic in all aspects except for the lever. More minimalistic would've been some sort of buttons instead of something poking out from the faucet
- It’s simple yet logic and have a nice finish. Maybe you don’t even need the colored dots for a even more minimalistic look.
- Very clean design with few details



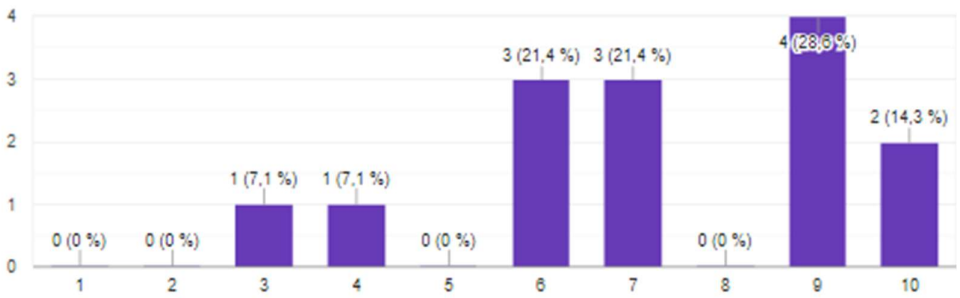
Answers:

- As creative as a tap can be while keeping it minimalistic and clean
- I have seen similar concepts before, but they way you can control the water flow makes it more creative I think.
- Kreativ i funktioner men inte utseende
- De utbytbara delarna är så cool!!!
- Since it incorporates flexibility of use.
- Especially the changeable top is to me quite creative.
- Sett så gott som samma design förut. Kul idé med utbytbara delar dock
- Seen before, but a nice design

How intuitive is the faucet design according to you?

Kopiera

14 svar



Answers:

- Beskriver sina funktioner tydligt
- On the first glance, I would believe that the lever would turn the faucet on and off, but I would soon realise that it controls the flow when activated by the sensor. Before I read the texts, I also thought that it was redundant at first and that it had is sensor and lever which would activate the faucet.
- Känns som jag skulle ha dragit spaken fram och bak och inte höger/vänster. Om man inte visste man kunde byta toppen hade man nog inte fattar det. Men köper man denna kran lär det ju vara tydligt i marknadsföringen att man köper en kran med utbytbar del och då fattar man.
- Intuitive, but where I can usually regulate both water flow and temperature in one movement, I now need to perform a two-step process. Would take some getting used to.
- To me the design and placement of the lever could be more clear. For instance could the lever be placed on top as in manual faucets but clearly communicate its automated function?
- Det känns rätt uppenbart hur den ska användas
- The use is understandable. Perhaps not if the user has never seen an automatic faucet
- It contains the stereotypic basic character for a faucet. The only thing is that the censor may not be used, because you reach for the lever instead of just putting your hands under the tap. Then the censor won't be used because you're so used to reaching directly at the lever.

DEPARTMENT OF INDUSTRIAL AND MATERIALS SCIENCE
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2023
www.chalmers.se