Creating a milk-foamer for Quooker B.V.

MASTER THESIS

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I would like to thank my coaches, Quooker, and my friends and family for their support during this graduation process.

Executive Summary

This thesis explores the design and development of an integrated milk foaming solution for Quooker's upcoming Coffee Tap — a compact, under-counter espresso system designed to minimize kitchen clutter while delivering a premium coffee experience. While the Coffee Tap enables high-quality espresso through a capsule-based system, it lacks a milk foamer — despite the fact that nearly half of consumers regularly drink milk-based coffee. Introducing a separate device would contradict Quooker's clean-counter philosophy, making the integration of a foamer both a strategic necessity and a design opportunity.

The core challenge was to create a milk foamer that seamlessly integrates with Quooker's hardware and interface, remains compact and easy to clean, and appeals to a broad but clearly segmented user base. To address this, the project followed a structured user-centered process based on an adapted Triple Diamond model. The methodology combined quantitative and qualitative research: segmentation surveys, emotional self-tracking, in-depth interviews, and product testing. Five user segments were defined, with special focus on Automation Seekers — users who prioritize speed, simplicity, and minimal maintenance.

These insights guided the selection and development of a Venturi-based solution, using steam from the Coffee Tap's under-counter Coffee Box to draw milk through a narrowed channel, mix it with air, and create high-quality foam. The device is composed of two detachable, dishwasher-safe components, and is controlled entirely via the Coffee Tap interface, maintaining Quooker's seamless user experience.

The technical development phase involved over fifteen iterations of the Venturi mechanism, each aimed at improving foam quality, air intake, turbulence, and user handling. The final lab-tested prototype produced stable, user-approved microfoam that met both technical and user criteria. A Technology Readiness Level (TRL) assessment places the solution at TRL 5 — validated in a relevant environment — indicating clear potential for future integration and upscaling.

Although further development is needed to reach market readiness, including manufacturing optimization, certification, and full software integration, this thesis presents a validated and strategically aligned solution that fits within Quooker's ecosystem and meets the needs of its future coffee users.

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1 Introduction

Not too long ago, the average kitchen counter might have looked like the one in Figure 1. On your counter, you could have had a coffee machine, SodaStream, soap dispenser, water tap, electric kettle, and a water filter. As kitchens modernized, houses became smaller, and the desire for a clean, uncluttered counter grew (Souaid, 2024). Quooker, a company located in Ridderkerk, The Netherlands, seized the opportunity to integrate many of these items into a single tap. This new kitchen setup, shown in Figure 2, combines the water filter, SodaStream, and kettle into one tap. The soap dispenser was also redesigned and neatly integrated into the counter.

However, if you look closely at Figure 2, you might notice something is still not quite right. The kitchen counter still features a large coffee machine. Now, Quooker plans to address this issue as well. The coffee tap, a compact device with most of its components housed below the counter in the coffee box, is designed to align with modern kitchen aesthetics and Quooker's clean counter philosophy (See Figure 3).

But Quooker faces a challenge. In their current R&D (Research & Development) roadmap, they do not plan to integrate a milk foamer into the coffee tap, despite the fact that nearly 50% of people report drinking milk-based coffee beverages (Van Maarschalkerweerd & Van Teeffelen, 2024). Asking customers to purchase a separate milk foaming device contradicts Quooker's vision of a clutter-free kitchen. Additionally, installing the coffee tap requires customers to drill an extra hole in their kitchen counter. This demands a level of trust that the solution will remain relevant and valuable for years to come, a trust that would be strengthened by an integrated milk foamer.

Designing a milk foamer is no simple task, due to the wide variety of preferences within the coffee-drinking community. From French press enthusiasts to Nespresso users, opinions on what makes a good cup of coffee differ greatly. The same applies to milk foam. Espresso machine owners often desire a premium milk foaming experience and are willing to invest more time and effort. In contrast, Nespresso users tend to prioritize speed and convenience in preparing their cappuccinos.

This brings me to the central challenge of this graduation thesis: **to design a milk foamer that fits the needs and expectations of Quooker's customers.** To do this, we must understand Quooker's coffee tap, their customer base, and their daily routines, and develop a solution that integrates seamlessly into their system and lifestyle.

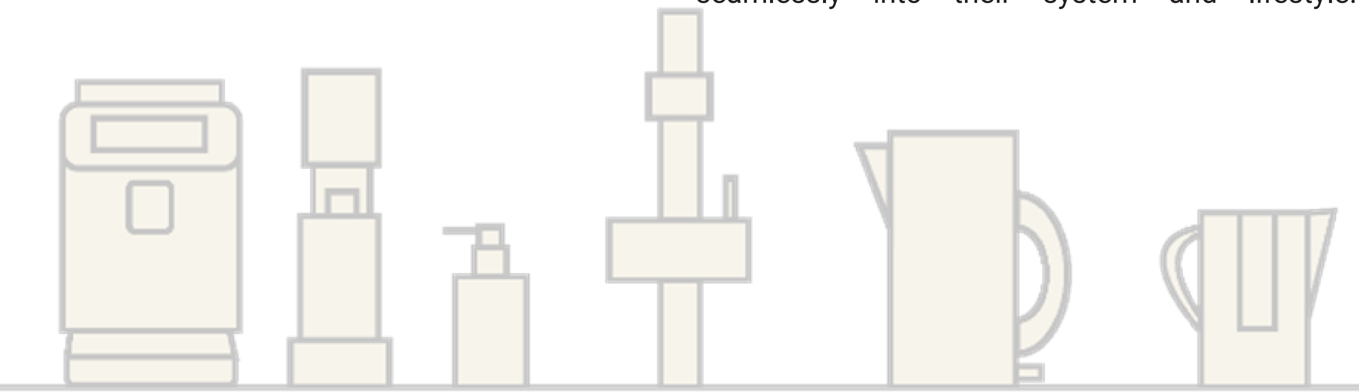


Figure 1: The kitchen counter before the Quooker tap

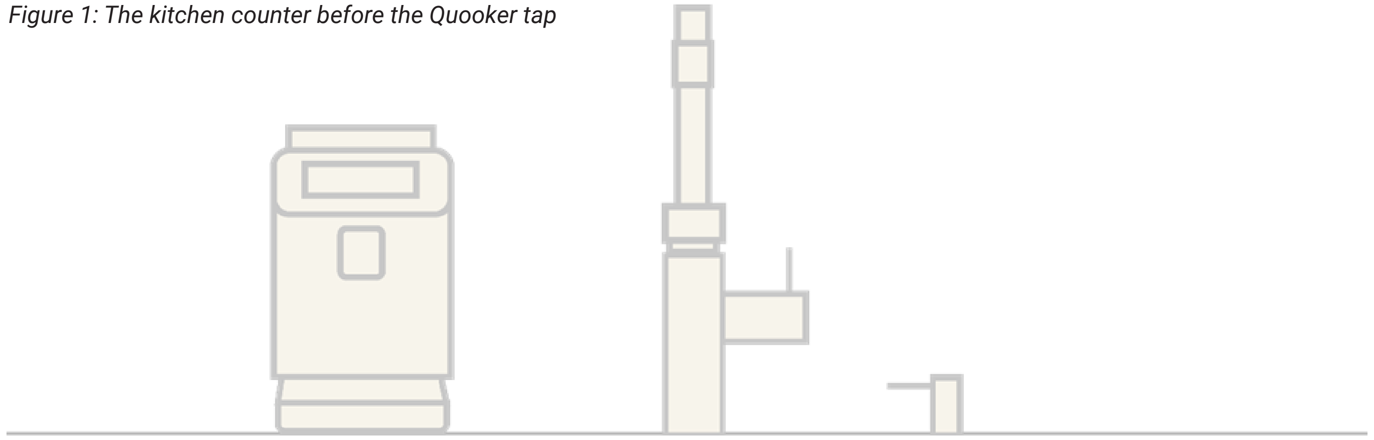


Figure 2: The kitchen counter with a Quooker

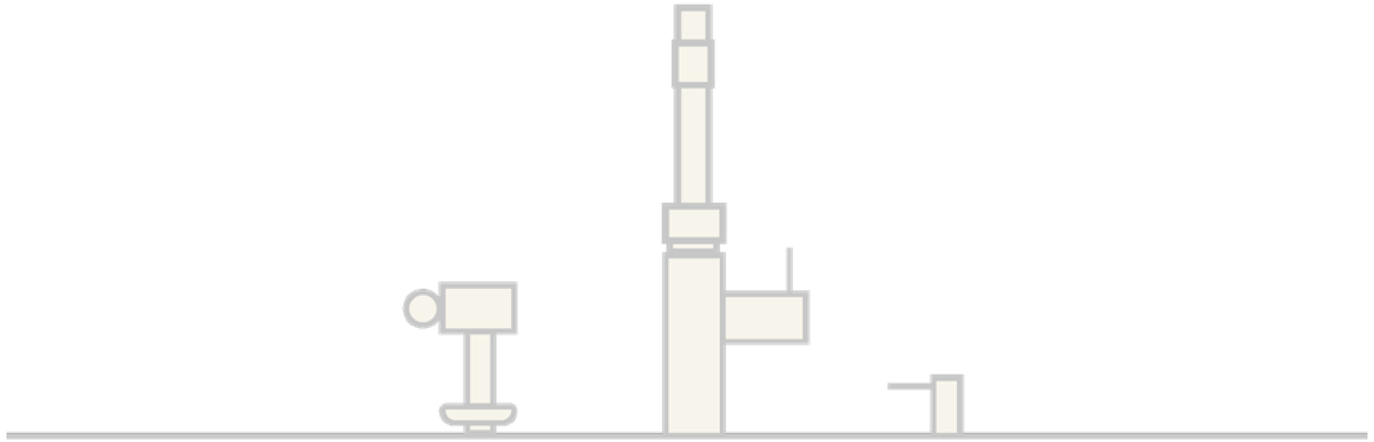
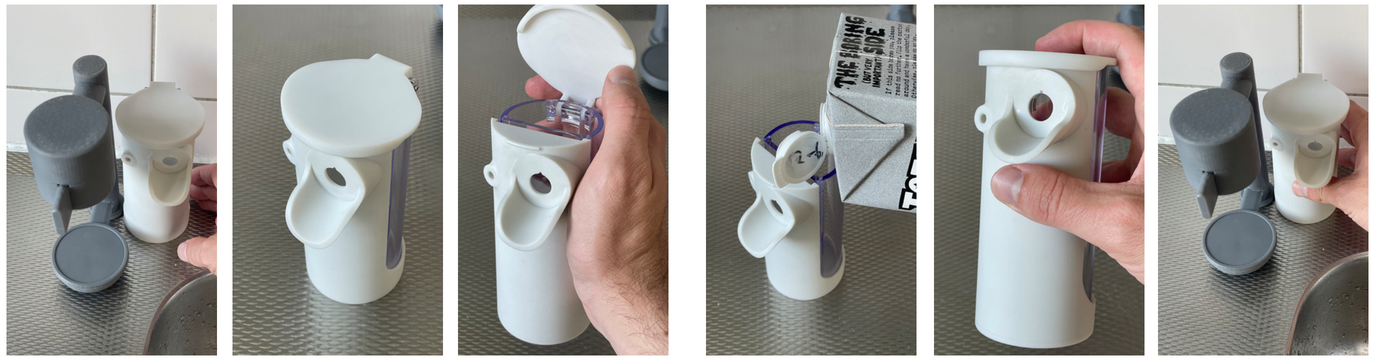


Figure 3: Quooker's Coffee tap in the kitchen

1.1 Solution

The final design proposed in this graduation thesis is a milk frothing system that integrates seamlessly with the Quooker Coffee Tap. It uses steam pressure from the existing under-counter Coffee Box to power a Venturi valve, which draws milk from a dedicated container and transforms it into fine, barista-style foam. The system consists of two detachable parts with a tight seal in between, allowing for easy disassembly and dishwasher

0. The Venturi system next to the Coffee Tap, showing the intended integrated setup.



1. The Venturi system is twisted and removed from the Coffee Tap. *2. Venturi system placed separately on the counter.* *3. The lid of the milk container is opened.* *4. Milk is poured into the milk container.* *5. The lid is closed.* *6. The Venturi system is placed onto its base and twisted into position.*

7. A coffee recipe with milk is selected on the Coffee Tap. *8. The Venturi system foams and pours milk into the cup.* *9. Fresh coffee is dispensed by the Coffee Tap.* *10. The milk container is removed from the Venturi system.* *11. The gasket is removed for cleaning.* *12. All three components are placed into the dishwasher.*

Figure 4: Image of the solution (0) and storyboard (1–12).

cleaning. Once activated, the device automatically dispenses the frothed milk directly into the user's cup, and is fully controlled via the Coffee Tap interface, maintaining the clean, single-touch experience central to Quooker's brand (see Figure 4.)

This solution aims to solve Quooker's problem: Quooker currently lacks a milk frothing solution to complement its Coffee Tap, despite the high number of users who drink milk-based coffee. The goal was to develop a system that meets these user needs while remaining compact, intuitive, and fully integrated with Quooker's existing hardware and brand philosophy.

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It is important to clarify the distinction between my contribution and Quooker's existing developments. The Coffee Tap itself, which dispenses espresso and lungo, was developed independently of this project. The version referred to in this thesis, shown in Figure 5, is a low-fidelity representation due to confidentiality restrictions. It is designed to sit on the kitchen counter and is powered by the Coffee Box, which houses the pump, heater, and electronics (see Chapter 2.2 for more detail). My focus lies in the design and development of the Venturi system, a milk frother intended as an integrated extension to the Coffee Tap. The name Venturi system is deliberately technical, emphasizing its embedded role rather than positioning it as a standalone product — a separate branding approach would conflict with Quooker's unified and minimalist design philosophy.

To structure the complexity of this design challenge, the project is approached through three interrelated perspectives: Human, Strategic, and Technological. These perspectives represent the core dimensions that must be considered to create a product that is not only functional, but also desirable, feasible, and viable. Drawing on both design and engineering expertise from my double master's trajectory — combining Strategic Product Design (SPD) and Integrated Product Design (IPD) — this structure ensures a balanced approach that simultaneously addresses user needs, brand alignment, and technical integration. Each of the following sections introduces one of these perspectives and outlines the specific challenges and insights it contributes to the design process.

Figure 5: Distinction Between the Quooker Coffee Tap and the Venturi System

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Human perspective

From a human perspective, the foamer must integrate effortlessly into the routines and expectations of Quooker's coffee-drinking users. These routines vary greatly, for some, coffee preparation is a mindful ritual, for others, it is a quick, functional task. While nearly half of users consume milk-based coffee beverages, their underlying needs, emotional drivers, and pain points are often unspoken or unconscious. To prevent misalignment with user expectations, this project began with in-depth research, including segmentation, emotion tracking, interviews, and hands-on product testing. Only by clearly defining the expectations of key segments, such as the Automation Seekers, could the foamer be designed to feel both natural and meaningful in use.

This human-centered foundation informed all major design decisions throughout the project. The following key insights summarize how user needs were translated into design outcomes and indicate where these aspects are further explored in the thesis:

- The Venturi system is designed around the **Automation Seekers** segment, which was defined through survey analysis and clustering (Chapter 3.2).
- Latent needs such as **low maintenance and easy cleaning** were uncovered through user tracking and hands-on product testing with existing foamers (Chapter 3.3 and 3.5).
- Qualitative interviews confirmed the importance of minimal interaction and seamless integration into the morning routine (Chapter 3.4).
- Personas and behavioral insights provided a foundation for aligning the design with emotional triggers and expectations (Chapter 3.6).

Strategic perspective

From a strategic perspective, the solution had to reinforce, not dilute, Quooker's established brand identity. This meant adhering to Quooker's clean-counter philosophy, which involves no extra clutter, no visible cables, and no redundant countertop devices. The solution also had to align with Quooker's positioning as a provider of high-end, long-lasting, and tightly integrated kitchen solutions. Additionally, the product needed to resonate with target demographics such as YUPs (Young Urban Professionals) and DINKs (Dual Income, No Kids), who often invest in premium kitchen upgrades and value aesthetic coherence and minimalism. Thus, the design needed to balance functionality with a sense of timeless elegance and trustworthiness.

These strategic considerations guided both conceptual and detailed design decisions to ensure alignment with Quooker's long-term vision and market positioning. The following points summarize the main strategic insights and indicate where each topic is discussed further in this thesis:

- The milk foamer is designed as an **extension to the Quooker Coffee Tap**, not a standalone product. This aligns with the clean-counter philosophy and reinforces modularity in the ecosystem (Chapter 7.2).
- It is strategically targeted at **YUPs and DINKs,** Quooker's current target customers (Chapter 2.4).
- The design is made **backward compatible**, allowing the milk foamer to be added without modifying the kitchen or the tap installation (Appendix 16).
- A **strategic roadmap** was developed to position the product within Quooker's planning cycle, including market launch windows and stakeholder communication (Chapter 7.1).
- The system supports **milk alternatives**, responding to emerging plant-based consumption trends. Although settings

are optimized for cow's milk, decent foam quality is also possible with alternatives, and optimization is optionally supported via the Quooker app (Chapter 7.3).

- Insights from coffee expos suggest a growing **Pro User** group, extending the Automation Seeker profile. This has implications for optional advanced functionality via the app (Chapter 7.3).

Technical perspective

From a technical perspective, the constraints were equally demanding. The foamer needed to operate using the existing Coffee Box infrastructure, sharing steam and pump capabilities without introducing safety risks or performance issues. It had to deliver high-quality milk foam, be compatible with dairy and plant-based alternatives, and meet strict requirements for hygiene, size, and energy efficiency. The final solution had to be easy to clean, support regular dishwasher use, and be manufacturable at scale. Achieving this required multiple iterations of the Venturi mechanism, careful thermal and pressure management, and a mechanical design that supports both usability and reliability.

These technical demands shaped every aspect of the system's development, from early feasibility tests to the final prototype. The following key points highlight how specific technical challenges were addressed and where these efforts are documented in more detail throughout the thesis:

- The foamer uses the **Venturi principle** to draw and mix milk with steam, enabling a passive, compact, and energy-efficient system (Chapter 5.4 and Appendix 13).
- Integration with the Coffee Tap relies on **shared use of the Coffee Box**, which supplies both steam and control signals (Chapter 7.2 and Appendix 12).
- **Steam testing** using a custom-built rig validated safety thresholds, temperature control, and flow rate under realistic conditions (Appendix 12 and Chapter 5.5).
- Extensive **iteration cycles** (Venturi V1–V9) optimized foam quality, air intake, and turbulence effects inside the mixing chamber (Appendix 13).
- The final prototype delivered **stable and user-approved microfoam**, meeting criteria derived from both technical and user-oriented testing (Chapter 6.1 and Chapter 7.4).
- A separate **embodiment phase** refined the device for manufacturability, disassembly, and visual alignment with the Coffee Tap (Chapter 6.1 and Appendix 14).

1.2 Methodological overview

The aim of this graduation project is to design a milk foaming system that seamlessly fits into the existing Quooker Coffee Tap — not only in terms of physical integration, but also in terms of user experience, brand identity, and technical feasibility. Achieving this requires more than a traditional design process. It demands a method that supports deep exploration of user needs, strategic alignment with Quooker's ecosystem, and careful technological validation. For this reason, the design process follows an adapted version of the **Triple Diamond method.**

This method is a well-established design framework that guides projects through structured phases of **discovery, definition, and validation**. In this case, the method is modified to place stronger emphasis on the **early discovery phase**, as visualized in Figure 6. The traditional second diamond — which typically focuses

on solution testing — has been replaced with an extended exploration of the problem space. This shift reflects the need for a deep understanding of **what kind of milk foaming experience fits the Quooker user**, both functionally and emotionally.

The expanded discovery phase includes segmentation, emotion-based testing, in-context product evaluation, and persona development. This approach draws on the complementary strengths of Strategic Product Design (SPD) and Integrated Product Design (IPD), combining user insight with technological feasibility from the outset.

Throughout this process, the project draws on theoretical grounding from Cooper (2018), who highlights the high failure rate of new product launches and the value of **front-end loading** in successful New Product Development (NPD). Cooper's success drivers — including early market exploration, structured stage-gate decision making, and integrated stakeholder communication — are reflected in Chapters 2 through 4, as well as in the strategic roadmap developed in Chapter 7.1.

In parallel, the process is informed by Schweitzer (2013), who outlines the shift from a Manufacturer Active Paradigm (MAP) to a Customer Active Paradigm (CAP). This thesis incorporates that shift by embedding the user's voice throughout the process, from segmentation (Chapter 3.2) to iterative concept testing (Chapter 5.5). Instead of treating the user as a passive evaluator, the user is positioned as a co-creator, shaping the experience through emotion tracking, qualitative insight, and usability testing.

In summary, this methodology deliberately balances human, strategic, and technological

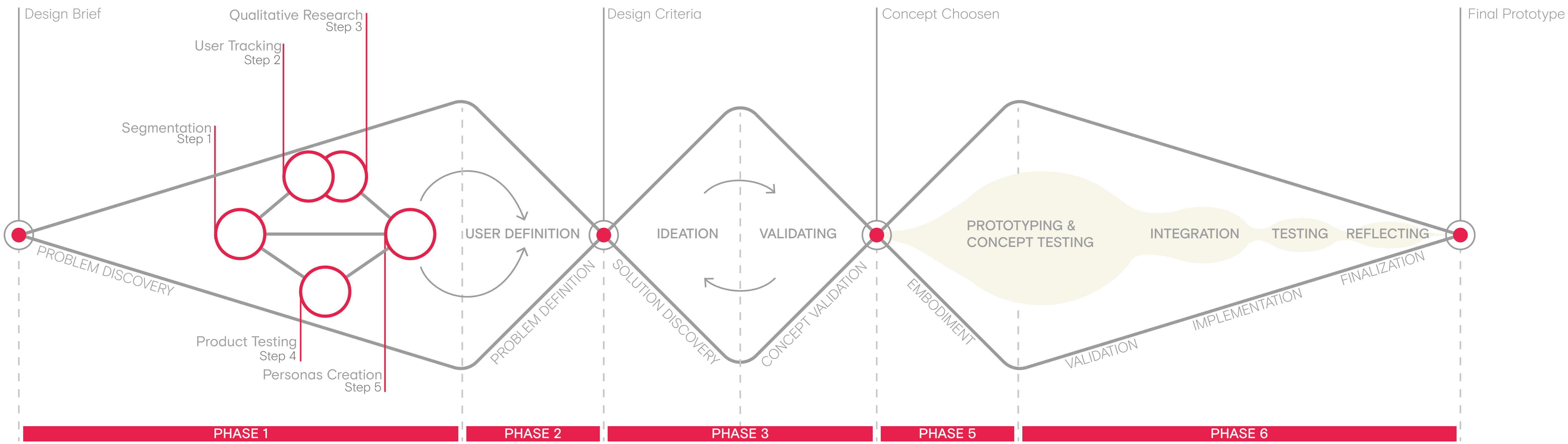


Figure 6: Adapted Triple Diamond Methodology for the Quooker Milk Foamer Project

considerations at each stage. By adapting the Triple Diamond to prioritize deep discovery and aligning with both academic and industry-proven frameworks, the process increases the likelihood that the resulting product is desirable, feasible, and aligned with Quooker's brand and market strategy.

Additionally, design insights, strategic insights, and Criteria are highlighted throughout the report. While these are also discussed in detail within their respective chapters, they are presented in concise boxes, as shown below. These boxes provide clearer insights and emphasize the relevance of specific sections to the overall design process. Criteria are marked in red, design insights in dark red, and strategic insights in grey. This should help you quickly find the information you need.

Criteria: Opportunities, conclusions, and criteria boxes must be placed through the report. (example of a criteria and box)

1.2 Personal development Goals

In addition to the project objectives, this graduation thesis also includes a set of personal development goals. These goals were defined to ensure that the project not only delivers a meaningful design outcome, but also contributes to my growth as a designer and engineer at the intersection of SPD and IPD.

Develop User-centric research Skills

As a designer, I often make the mistake of trusting my gut feeling too much. During my SPD master's program, I learned how to conduct in-depth user research, but primarily in a theoretical way. I must admit that I feel more comfortable with the technical side of Industrial Design Engineering, which is why I want to challenge myself to truly understand the needs of Quooker coffee drinkers before designing a solution. To support my ambition, I have chosen a chair and mentor who can guide me through this process and help me learn how to conduct data-driven user research. I believe this skill will make me a more valuable designer for companies and startups.

Refine Prototyping and technical skills

Prototyping is something I enjoy and have experience with, though this is often only at a conceptual level. One reason I chose Quooker as my graduation company is because of their extensive production knowledge; they are one of the few companies in the Netherlands that designs and assembles all their products in-house. I hope to learn from them how to create a fully developed prototype, refined down to the details.

2 Background

In this chapter, we will explore the kitchen environment, focusing on Quooker's role within this space, as well as the broader context of coffee and milk. This phase will involve examining existing solutions and understanding their impact on users. We will also analyze the Quooker brand, its identity, and who its customers are. By understanding Quooker's brand identity and their customer base, we aim to determine how Quooker can enhance the coffee experience for its users.

2.1 Quooker company and context

Quooker, established in 1987 by the Dutch Peteri brothers , introduced a new concept in kitchen technology with the development of the boiling water tap (Quooker, 2025-a). The idea originated from Henri Peteri's observation that the preparation of "instant" noodles was delayed by the time required to boil water. Since the early 2000s, Quooker has experienced significant growth, now selling over 300,000 systems annually (Quooker, 2025-a). Despite its international presence (explained more in Chapter 2.3), the company continues to assemble all models at its headquarters in Ridderkerk, the Netherlands.

With more than 500 employees (Quooker, 2025-b.), including a substantial research and development department, Quooker remains committed to innovation. This dedication is reflected in the continuous expansion of their product offerings, such as the integration of cooled and sparkling water functionalities into their boiling water systems, reducing the need for additional kitchen appliances.

Quooker context

The basic Quooker system consists of two parts. The first part is the boiler (labeled with number 5 in Figure 7), available in 3 and 7 liters, which is housed beneath the sink. This boiler uses an innovative vacuum housing with a stainless-steel gas spring, efficiently keeping the water above 100 degrees Celsius. Due to the gas spring, the water is pressurized, preventing it from boiling in the reservoir.

The second part of the system is the tap. The Quooker tap replaces the regular kitchen tap and, in addition to the traditional cold and hot water supply, features a double-tap, child-safe boiling water control. When this knob is twisted, boiling water is dispensed from the tap. Depending on the system, the warm water leaving the tap can be supplied by the reservoir and mixed with cold water. The temperature can be adjusted beneath the counter.

The ability to always supply boiling water not only makes instant noodles truly instant, but also appeals to tea enthusiasts or people who use the Quooker for cooking, thereby reducing the time it takes to boil water in a pan.

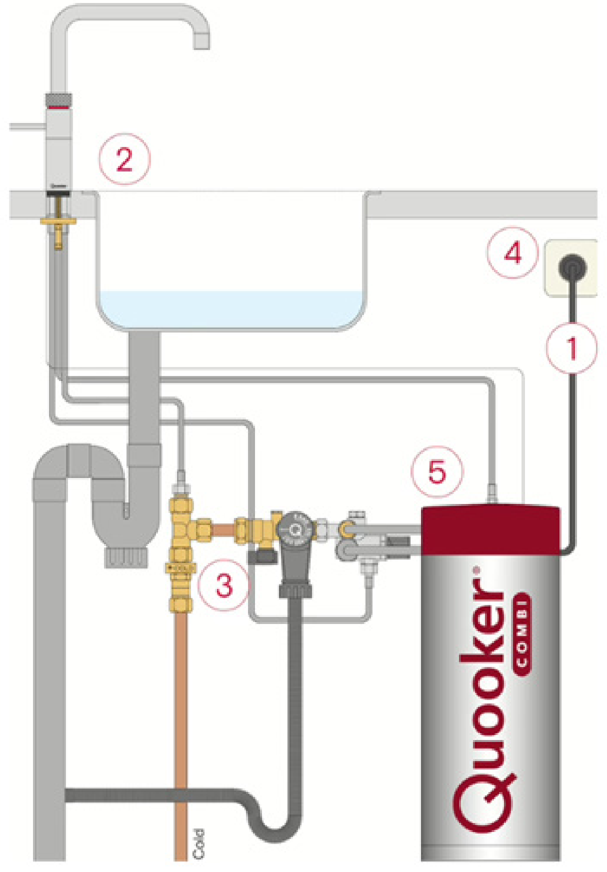


Figure 7: Diagram of the Quooker System (Quooker, n.d.)

Quooker context

In 2022, Quooker added the Cube (see Figure 8) to their product portfolio. This line extension allowed for chilled and sparkling water to come out of the same tap. This innovation was new to the market as Quooker now not only replaced the water kettle, but also became a direct competitor to sparkling water machine brands like SodaStream.

The Quooker coffee and milk foamer will also be viewed as a category extension. According to Beverland (2021), category extensions are more challenging because a brand must establish its relevance in the new category. However, failure in this context possess less risk to the parent brand, as Quooker would still retain its reputation for producing high-quality hot water systems. For this project, it is important to recognize that a category extension into milk foaming will require significant marketing efforts to establish Quooker's position in this new segment.

For more context on how the milk foamer could physically and functionally integrate into the kitchen environment, see Appendix 3 – Quooker in the Kitchen. This section explores ergonomic design principles and food safety considerations, helping ensure that the final product fits both Quooker's clean-counter philosophy and modern kitchen workflows.

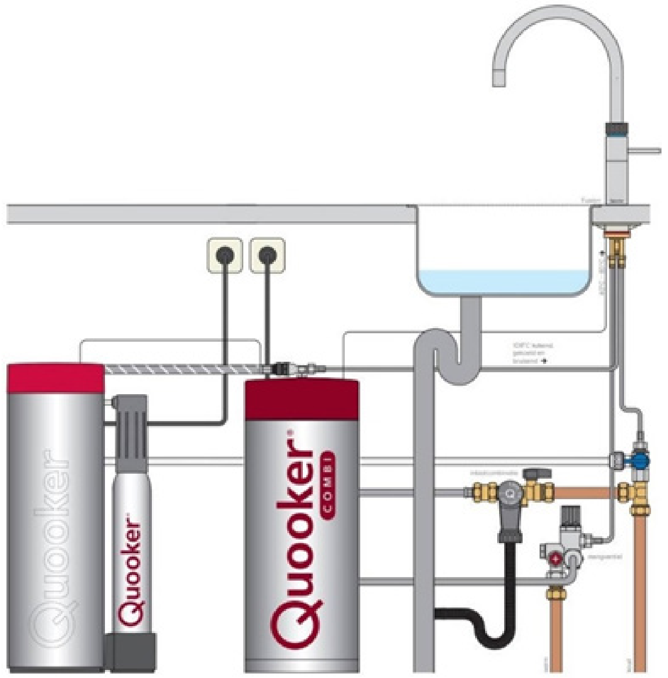


Figure 8: Diagram of Cube and Combi (Quooker, n.d.)

2.2 Understanding Quooker's Coffee solution

Quooker's coffee solution, referred to here as the Coffee Tap, is a separate tap that utilizes hot water from the Quooker reservoir to brew coffee directly within the tap itself. The design features a low-profile aesthetic that aligns with Quooker's established design language. In Figure 9, a simplified and modified version of the tap is shown to illustrate the design language without revealing specific details. This Mock-up tap will henceforth be used to provide context for the milk foaming solution throughout this thesis.

The quality of the coffee produced is likely to be comparable to products such as Nespresso, easily surpassing low-grade coffee. However, it may not achieve the same level of flavor complexity as espresso machines commonly used in cafés. This is due to the choice of using capsule coffee instead of freshly ground coffee beans.

The Coffee Tap is the visible part of the system that the consumer interacts with. Beneath the counter, a box will house essential components such as a pump and a heater. This section of the Coffee Tap will be referred to as the Coffee Box.

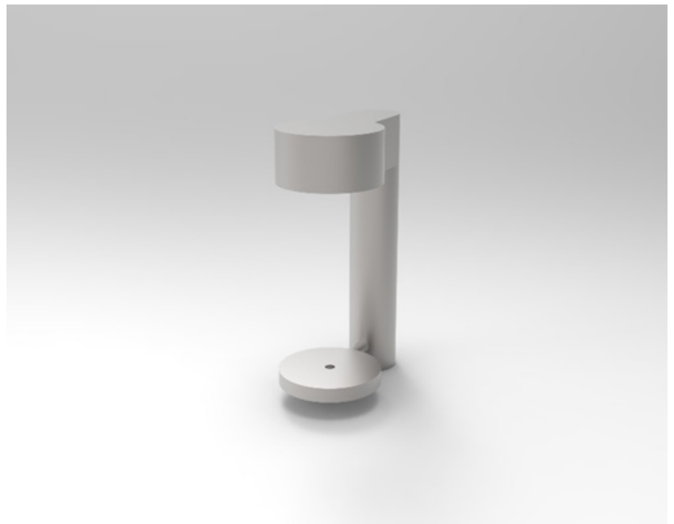


Figure 9: Mock-up of Quooker's Coffee Tap, with simplified and altered design to comply with non-disclosure requirements.

2.3 Coffee and Milk context

A comprehensive understanding of the coffee roasting and preparation process is essential, particularly when aiming to harmonize it with milk foam. The quality of the milk foam must align with the coffee produced by the Quooker system. Any disparity in quality, whether a finely crafted milk foam paired with lower-quality coffee, or vice versa, would result in an imbalanced user experience. Since the coffee module and milk foaming device are likely to be purchased and used together, it is critical that their quality standards are consistent. Therefore, evaluating the quality of the coffee produced by Quooker's coffee project is essential to creating a cohesive coffee experience.

An in-depth exploration of coffee making and coffee culture, detailed in Appendix 4 – Understanding Coffee, revealed the critical factors required to produce a balanced coffee with a taste that is seen as desirable by most people. These include the quality of the beans, the grind size, the pressure applied during extraction, and the resistance offered by the coffee grounds or pad. Each of these elements must be carefully managed to ensure optimal results.

The culture of milk in coffee

The use of milk in coffee varies significantly by country. In the Netherlands, cappuccino is the second most popular coffee type, just after black coffee (Van Maarschalkerweerd & Van Teeffelen, 2024). The amount of milk added to coffee also varies depending on the type of recipe. Generally speaking, the most popular types are shown in Figure 10. For this project, it is essential to determine the maximum amount of milk required for a single coffee serving, as this will define the minimum amount of milk the device should be able to foam. We will use 150 ml as our baseline, as this is the maximum amount needed for common coffee recipes.

Figure 10: 6 most common coffee recipes and Quantities of the 6 most common coffee recipes. (exact quantities depend on cup size and preference (Nespresso, 2025))

Criteria: The maximum amount of milk required for a single serving of coffee with milk is 150 ml. Therefore, the milk foaming solution must have a minimum capacity of 150 ml.

The science behind milk foam

The science behind milk foam is complex, and there are relatively few rigorous scientific studies on the subject. Most available information comes from barista lore. While practical experience is essential for producing good milk foam, understanding the science is crucial for achieving consistent results. The formation and stability of milk foam are influenced by several factors, including milk composition, temperature, and processing methods.

Milk consists of water, proteins, fats, carbohydrates, and minerals. Proteins, particularly caseins and whey proteins, are critical in foam formation due to their surface-active properties, which stabilize air bubbles within the liquid matrix. Caseins, existing as micelles, and whey proteins like β-lactoglobulin adsorb at the air-water interface, reducing surface tension and promoting foam stability. However, the fat content in milk can have the opposite effect. High fat levels can result in larger air bubbles and less stable foam, as fat disrupts the protein network essential for stability. This phenomenon is explored in the study "Influence of Milk Fat on Foam Formation" (Ho et al., 2020).

Temperature also plays a significant role and is one of the most easily controlled factors. Heating milk causes partial denaturation of whey proteins, enhancing their ability to stabilize foam. However, excessive heating can lead to over-denaturation, resulting in a thinner consistency and reduced foam stability. For this reason, the optimal foaming temperature is typically between 55°C and 65°C (Maldonado-Valderrama et al., 2013). While this is the ideal temperature for making milk foam, it is often perceived as too cold by most people. This is why cappuccino cups are often preheated. Research by Oetjen et al. (2014) found that 25 degrees Celsius is considered the absolute minimum temperature for achieving good milk foam. They also noted that at temperatures above 40 degrees Celsius, the quality of the foam depends significantly on the type of milk used. Klimanova et al. (2022) mentioned that temperatures above 70 degrees Celsius should be avoided as it decreases the stability of microfoam.

Milk processing methods also significantly affect foam quality. Processes like homogenization reduce fat globule size, creating a more uniform distribution and potentially improving foam stability

(Borcherding et al., 2007). This highlights the importance of selecting properly processed milk for achieving consistent and high-quality foam.

The addition of water can also decrease the foamability of certain milk types; however, a study by Deeth and Smith (1983) showed that adding 15% water had no effect on the foamability of milk.

This visual perception of milk foam

In a study by Van Doorn et al. (2015), the effects of latte art, a decorative technique applied to milk foam in coffee, were examined. The presence of latte art was found to significantly increase the perceived value of coffee for customers. Additionally, the quality and visual appeal of the foam were associated with an enhanced taste experience.

Milk alternatives and their foaming properties

The foaming of alternatives to milk presents a considerable challenge due to the significant variation in properties between different types and brands. This variation is often linked to the "barista" alternatives that many brands offer as specialized versions of regular milk replacements. These barista alternatives typically contain additives designed to mimic the properties of traditional milk, enhancing their ability to produce foam. While achieving the perfect milk foam with these alternatives is difficult, producing a decent foam is generally comparable to the process used for regular milk.

Table 1 provides a comparison of various milk alternatives against regular cow milk based on key attributes relevant to milk foaming properties. The table highlights differences in factors such as protein and fat content, which play a critical role in foam stability and air retention. Among milk alternatives, soy milk is the closest to full-fat and skimmed cow milk in protein content, allowing it to better trap air during frothing . However, the lower fat content in most milk alternatives compared to full-fat cow milk reduces the stability of the resulting foam.

Research by Cook's Illustrated (2025) indicates that many milk alternatives incorporate additives designed to improve frothing performance. A common additive is gellan gum, a naturally occurring fermented sugar that interacts with calcium in the milk alternative to form a stable foam structure (Petre, 2019). Although gellan gum is recognized as food-safe, it may slow down the digestive process in some individuals. Not all milk alternatives rely on gellan gum. For instance, Oatly, a well-known brand of oat-based beverages, uses beta-glucans in its barista-grade oat milk (Oatly, 2025). These plant-derived carbohydrates trap air and contribute to foam formation. Table 1 further details the properties and additives of different milk alternatives, with significant differences highlighted in red for clarity.

The data in Table 1, shows that many milk alternatives have significantly lower protein and calcium content compared to dairy milk — two factors known to contribute to foam stability. Soy drinks perform relatively well in both categories, while options like oat, almond, and coconut drinks often require additives such as gellan gum or beta-glucans to achieve acceptable foam quality. These nutritional and additive differences have direct implications for foam performance and user experience. Therefore, although dairy milk remains the most reliable option for consistent frothing, milk alternatives should remain within the scope of the design, especially given their growing popularity and the technical feasibility of supporting them with minor optimizations.

Component	Full fat milk	Skimmd milk	Soy drink	Almond drink	Oat drink	Coconut drink	Hazelnut drink
Energy (kcal)	61.0	46.0	38.0	20.1	46.3	44.0	46.7
Saturated fats (g)	2.2	1.0	0.3	0.1	0.2	1.4	0.2
Unsaturated fats (g)	1.2	0.5	1.6	1.2	0.9	0.2	1.9
Sugars (g)	4.5	4.7	1.4	1.1	4.1	4.2	2.3
Fibers (g)	0.0	0.0	0.5	0.3	0.7	0.0	0.2
Proteins (g)	3.0	3.4	3.3	0.5	0.6	0.2	0.5
Salt (g)	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Calcium (mg)	124.0	123.0	73.0	77.6	60.0	0.0	0.0
Vitamin B2 (mg)	0.45	0.45	0.05	0.11	0.04	0.00	0.00
Vitamin B12 (µg)	0.45	0.45	0.13	0.25	0.09	0.00	0.00
Vitamin D (µg)	0.00	0.00	0.19	0.44	0.19	0.00	0.00

Table 1: Properties of milk alternatives (Huis in 't Veld, 2023)

2.4 Quooker market analysis

The Quooker user

To define the target audience for the design, we will first analyze the general Quooker user. In chapter 3, we'll dive into a more detailed analysis of Quooker coffee and milk users. This initial analysis takes a holistic view of Quooker's user base, forming a foundation for the subsequent research stages.

Countries where Quooker is active

Quooker is expanding its business throughout Europe and into select regions outside Europe, such as the United Arab Emirates, Hong Kong, and Israel, see Figure 11. The company is experiencing rapid growth and has ambitions to enter additional markets. This expansion is particularly relevant to the design process, as Quooker does not plan to sell its coffee system independently of its existing systems. Consequently, the likelihood of selling a Quooker milk foamer without a Quooker system is extremely low, if it is even considered a viable option.

Even within the countries where Quooker currently operates, there is significant variation in milk consumption preferences. As Quooker pursues its ambition to expand into more markets, it becomes increasingly important to develop a milk foaming system that is versatile and adaptable to diverse preferences and cultural expectations.

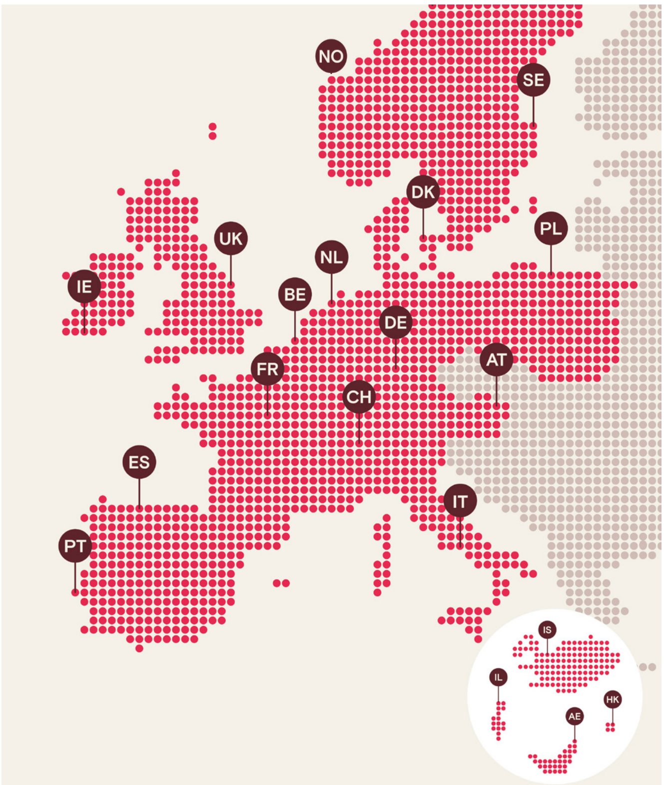


Figure 11: Countries where Quookers are sold (Quooker, 2025.-a)

Consumer analysis

Quooker's customer base comprises three primary groups according to Y. Elemans (personal communication, November 19, 2024), Part of Quookers marketing devision:

DINKs (Dual Income, No Kids): Couples where both partners earn an income and have no children. This demographic often has higher disposable income and values convenience and efficiency in household appliances (Kagan, 2023). **Why they would want a Quooker:** The Quooker tap offers instant boiling water, aligning with their preference for time-saving and multifunctional kitchen solutions.

YUPs (Young Urban Professionals): Young professionals living in urban areas, typically well-educated and career-focused, who appreciate modern and high-quality home appliances (Halton, 2024). **Why they would want a Quooker:** The sleek design and advanced functionality of the Quooker tap appeal to their desire for stylish and efficient kitchen equipment.

Empty Nesters: Individuals or couples whose children have moved out, often leading to a focus on home improvement and personal convenience (Bougea et al., 2020). **Why they would want a Quooker:** The Quooker tap simplifies kitchen tasks, providing ease of use and enhancing the cooking experience, which is beneficial as they adapt to a new lifestyle phase.

PESTLE

A PESTLE analysis examines Political, Economic, Social, Technological, Legal, and Environmental factors to understand the external environment influencing a company's operations (Yusop, 2018). This is crucial for designing new products, as it helps align development strategies with market trends, regulatory requirements, and consumer expectations, ensuring both relevance and long-term success. In Figure 12, you can see the most important trends per category.

This PESTLE analysis highlights several external trends that directly impact the design direction of the milk frother. Growing demand for **plant-based milk alternatives**, increasing consumer focus on **sustainability**, and the rising **popularity of multifunctional kitchen appliances** all support the need for a solution that is both future-proof and adaptable. As a result, the milk frother must be designed to handle a variety of milk types, integrate cleanly into existing kitchen setups, and comply with evolving food and product safety regulations. These trends reinforce the importance of compatibility, convenience, and compliance in the final design.

Political

Trade arrangement

- Compliance with food safety and manufacturing standards across countries.
- Impact of import regulations, tariffs, and trade policies on production costs

Economic

Supply & demand

- Fluctuating raw material costs, especially stainless steel, influencing production costs.
- Growing market demand for luxury kitchen products due to higher disposable incomes. (mordorintelligence, 2024)

Sociological

Changing habits

- Increasing consumer preference for multi-functional, space-saving appliances.
- Rising health consciousness, with opportunities in plant-based milk alternatives. (NielsenIQ, 2024)

Technological

Market leaders

- Dominance in boiling water tap technology with continued innovation opportunities.
- Potential for smart kitchen integration with connected systems for enhanced convenience. (Tuohy, 2024)

Legal

Compliance

- Compliance with global safety and food-contact material standards (e.g., CE marking).
- Need for intellectual property protection (patents, trademarks) for new features.

Environmental

Better products

- Focus on sustainability through reduced plastic waste (e.g., sparkling water feature).
- Energy efficiency as a key selling point compared to traditional kettles.

Figure 12: PESTLE analysis of the kitchen appliance industry, identifying key external factors influencing product development across six domains: Political, Economic, Sociological, Technological, Legal, and Environmental.

Criteria: The milk foamer should be compatible with milk alternatives, as this is a growing trend and is likely to become increasingly important in the future.

Brand Pyramid

To understand Quooker as a brand, we can use Keller's brand equity pyramid (Beverland, 2021). In this framework, equity is not viewed in financial terms but as the perceived value people find in the brand. The pyramid helps analyze the brand's public image by assuming a relationship between brand awareness and brand equity, see Figure 13 for the pyramid. At the base of the pyramid is basic awareness, often called brand recognition, which assesses if people understand the category or purpose the brand fulfills. As we move higher up the pyramid, we evaluate the emotional connection people have with the brand. Understanding the entire pyramid, especially how the brand resonates with its customers, is essential. Only then can a milk frother be created that aligns with customers' perception of Quooker and leverages the personal relationship people have with the brand. Note: Quooker does not have a coffee product

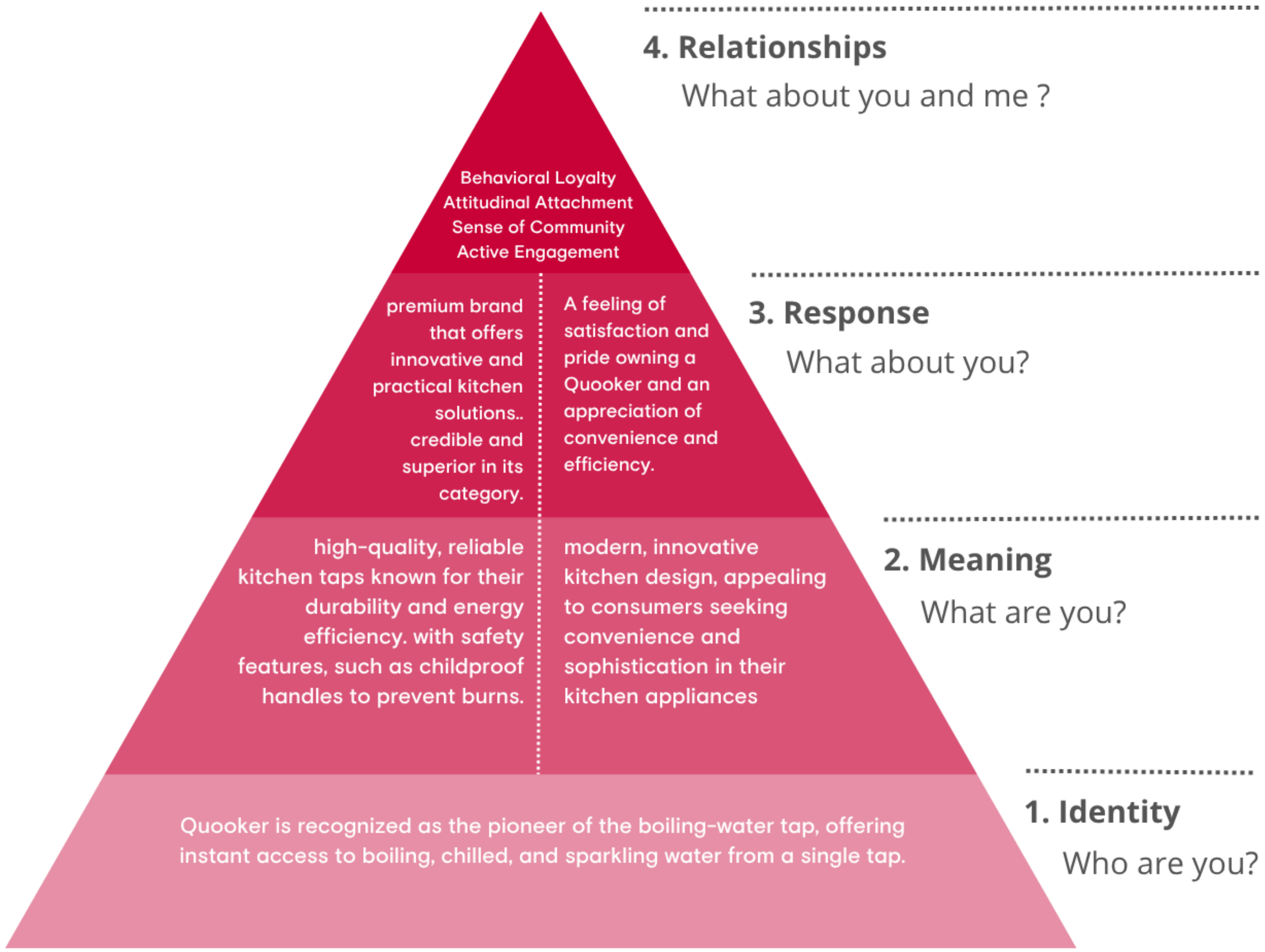


Figure 13: Kellers brand pyramid filled in for Quooker

on the market yet, this is why the Keller's brand pyramid is filled in with the consumers perception of the current product portfolio.

With Keller's brand equity pyramid filled in, we've gained insight into the relationship people have with the Quooker brand. Let's look further into this:

- **Behavioral Loyalty:** Many customers become repeat buyers and recommend Quooker to others, reflecting strong brand loyalty. This suggests that if Quooker introduced a coffee and milk frothing solution, existing users would likely consider purchasing it. Therefore, part of this research focuses on identifying the specific needs of Quooker coffee drinkers, rather than general coffee consumers.
- **Attitudinal Attachment:** Users form an emotional connection with the brand, appreciating its contribution to an enhanced kitchen experience. Quooker has become a symbol of luxury, often associated with groups like young urban professionals (YUPs) (Bowker & Bowker, 2024).
- **Sense of Community:** Quooker has cultivated a user community where experiences and tips are shared, fostering a sense of belonging among owners. On various websites, users share tutorials and tips, and Quooker supports this by publishing repair guides and prioritizing service (Quooker, 2025b). This sense of community could be extended to include a milk frother, enhancing its value.
- **Active Engagement:** Customers engage actively with Quooker through social media, events, and by staying informed about product updates and innovations (such as on Instagram @quooker). This offers a valuable opportunity for the coffee project to engage users with barista workshops and related events, building on Quooker's established brand loyalty.

Quooker brand DNA

It is important to understand the Brand DNA of Quooker to increase the alignment with its core values and make sure the product is consistent with the brand's identity (Aaker, 2010). For Quooker (see Figure 14), whose DNA emphasizes convenience, quality, and innovation, something the milk foamer should also meet to satisfy the needs of Quooker users. Research by Keller (2001) shows that products that reflect the brand's identity are more likely to be perceived as authentic, increasing customer satisfaction and loyalty. Designing a frother that will resonate with Quooker's Brand DNA will increase the emotional connection and thus reinforce Quooker's brand identity.

Brand DNA Quooker

Purpose
To make everyday kitchen tasks faster, safer, and more convenient, while supporting sustainability and enhancing the quality of life at home.

Personality
Innovative, premium, reliable, and user-centric.

Positioning
For quality-conscious and forward-thinking homeowners, Quooker offers multi-functional, high-quality taps that deliver boiling, chilled, and sparkling water instantly. By combining convenience, safety, and energy efficiency, Quooker elevates the kitchen experience, fitting seamlessly into modern, sustainable lifestyles.

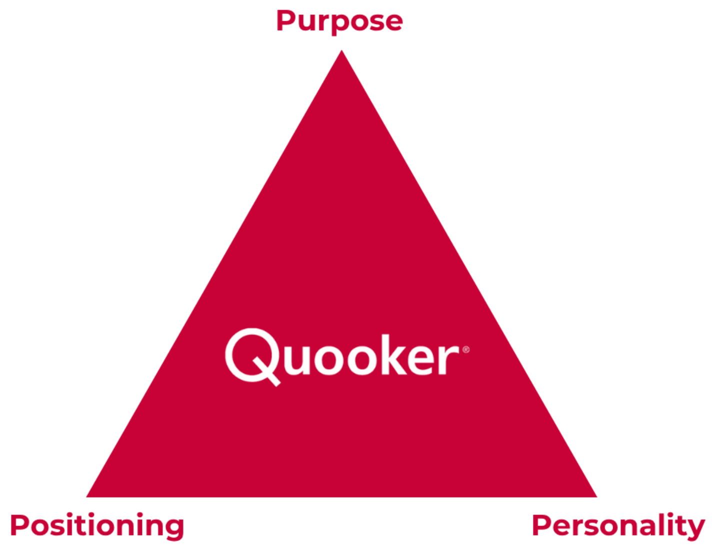


Figure 14: Quooker's brand DNA

Design Insight: To align with Quooker's current brand DNA. The milk foamer should make the milk foaming process faster, safer, and more convenient.

Quooker's 'Clean counter' Philosophy

Within Quooker's design team, the clean-counter philosophy is a key aspect and arguably a significant factor in the company's success. A major selling point of Quooker's products is their aesthetics, which make them popular among kitchen designers. This is largely due to the fact that Quooker eliminates the need for bulky kitchen appliances, such as water boilers and sparkling water machines, to be placed in view. New products, such as the Coffee Tap and milk foamer, should also align with this philosophy to resonate with Quooker's clients.

Criteria: For the milk foamer to fit into Quooker's Brand DNA, it should align with its clean-counter philosophy.

2.5 Preliminary market assessment

To estimate the production volume of the milk foamer, projected sales figures for the Quooker Coffee Tap were used as a foundation (see Appendix 7 – Sales Projections and Assumptions). Since both systems rely on the same Quooker base unit, their adoption is closely linked. The analysis in the appendix revealed two key insights. First, the Coffee Tap is most often purchased during kitchen renovations, when consumers are already investing in high-end appliances. Second, this moment of renovation also represents the ideal opportunity to offer add-ons like a milk foamer, as customers are more willing to commit to additional features during this decision-making phase. According to calculation in Appendix 7, annual sales are expected to grow from 1,026 units in 2027 to 19,764 by 2030. This confirms that early batch sizes will be modest, supporting a low-volume, scalable production strategy.

2.6 Competition assessment

When analyzing the competition, most consumer options can be plotted on a 2-axis graph. For this analysis, we use two key factors: quality of the foam and ease of use, see Figure 16. In this context, ease of use serves as an umbrella term encompassing how simple the device is to operate, how easy it is to clean, and how long the process takes.

While there are many competitors on the market, we focused on a few significant ones. For example, battery-powered whisks are widely available, with hundreds of brands offering essentially the same motorized whisk (see Figure 15). However, apart from variations in design and price, there is little differentiation, except for the NanoFoamer, which uses a specialized whisk head to achieve higher-quality foam.

The "red zone" in Figure 15 represents the optimal positioning for a Quooker milk frothing solution, where high ease of use is prioritized alongside acceptable foam quality. This positioning aligns with Quooker's brand identity, which emphasizes minimal effort, intuitive use, and seamless kitchen integration. Among the various methods assessed, three stand out for their balance between performance and usability: motorized jugs with a whisk, Venturi systems, and automatic steam wands.

The same process was applied to another two-axis comparison (see Figure 17), in which the speed of the process was plotted against the cleaning effort. The emphasis on cleaning effort in Figure 17 reflects the growing consumer expectation for low-maintenance kitchen products. In the premium segment, ease of cleaning is increasingly considered a core feature, particularly for devices used daily. Solutions that minimize hands-on cleaning or are dishwasher-safe are therefore more likely to meet user expectations and avoid becoming a barrier to use.

Speed also emerged as a key purchasing motivation. However, it is important to note that overall speed depends on whether the system requires supervision or operates fully automatically. For example, the Aeroccino takes about 90 seconds to froth and heat milk automatically, freeing the user to do something else in the meantime. In contrast, handheld whisks can take roughly the same amount of time but require additional tasks, such as manually heating the milk and holding the device while frothing.

Finally, ease of cleaning can be improved if the device is dishwasher-safe, like the newer Aeroccino models and the LatteGo system.

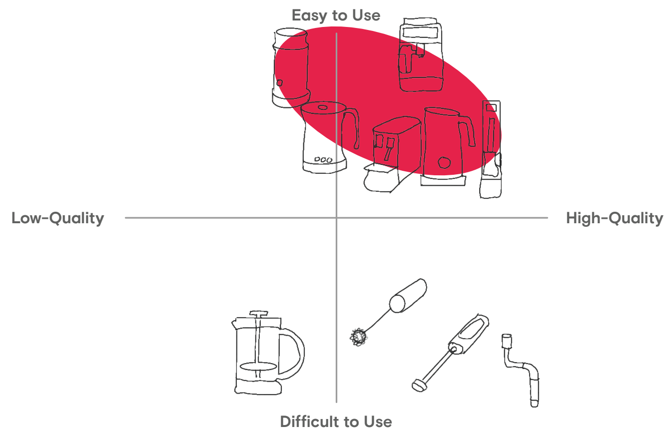


Figure 16: Existing solutions mapped on a grid, with the red area indicating area of interest.

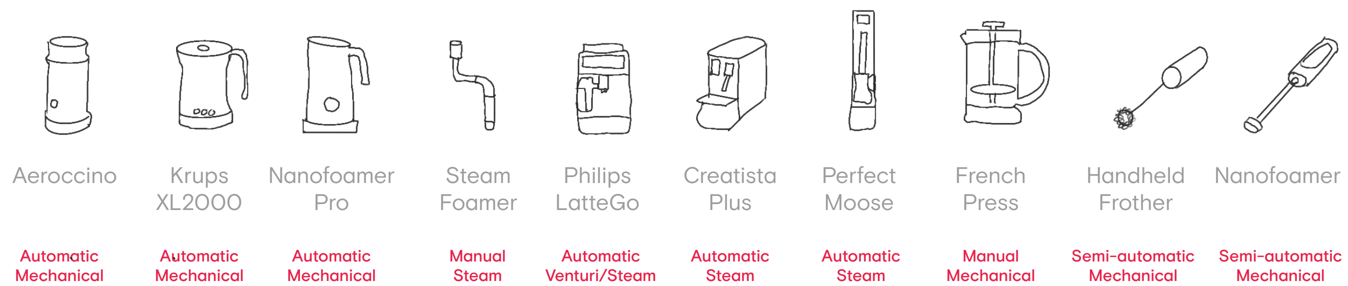


Figure 15: Overview of Popular Milk Frothing Devices Categorized by Operation Type and Price.

Next, this process was repeated using a two-axis comparison of cost versus consistency, see Figure 18. Here, devices such as steam wands and handheld whisks scored lower on consistency because they require a certain level of skill to achieve reliably good results. In contrast, fully automatic options tended to score higher in consistency, although their prices can vary significantly.

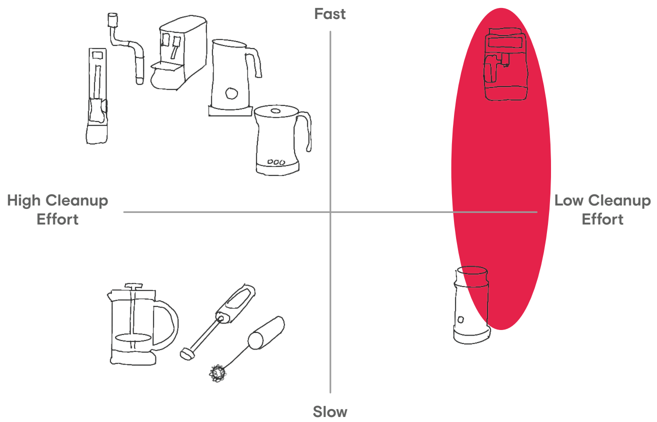


Figure 17: Existing solutions plotted on a grid, effort compared to speed, with the red area indicating area of interest.

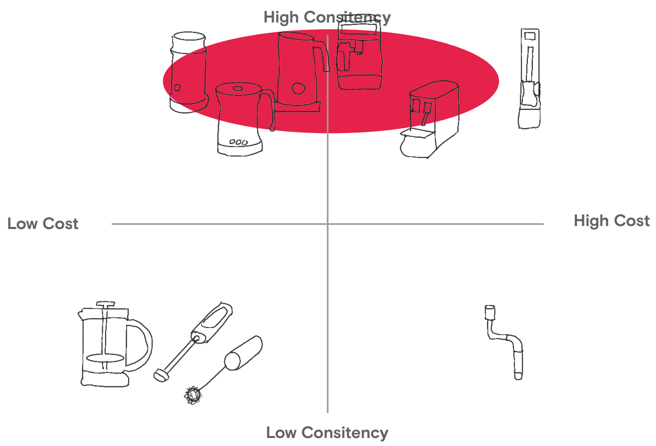


Figure 18: Existing solutions plotted on a grid, consitency compared to cost, with the red area indicating area of interest.

2.7 Preliminary technical assessment

This subchapter explores existing milk foaming systems, including the Aeroccino, LatteGo, and NanoFoamer, to understand their technical approaches and user value. It also includes a focused patent analysis to ensure the proposed design does not infringe on existing intellectual property. The findings were validated with input from Quooker's patent expert.

LatteGo

The LatteGo is an example of a Venturi system, see Figure 19. A Venturi system uses the Venturi effect to draw milk from a reservoir. This version, developed by Philips, allows for efficient cleaning by splitting the LatteGo system into two dishwasher-safe parts. This method enables the milk to be steamed while maintaining automation and ease of cleaning. The internal workings of the machine are similar to standard coffee machines, see Figure 20. A pump draws water from a reservoir and heats it. Multiple solenoid valves manage the flow, directing the water either to the brewing chamber or the milk steamer.

This method could potentially be adapted to the Quooker system, as the Quooker tap already has the capability to heat water to steam. This would mean that the entire control system could be placed under the counter. The advantage of this approach is that it would be extremely efficient and cost-effective. However, the downside is the need for close integration with the Quooker Coffee Tap, as this system would require more complex interfaces compared to other solutions


Figure 19: The two pieces of the LatteGo System

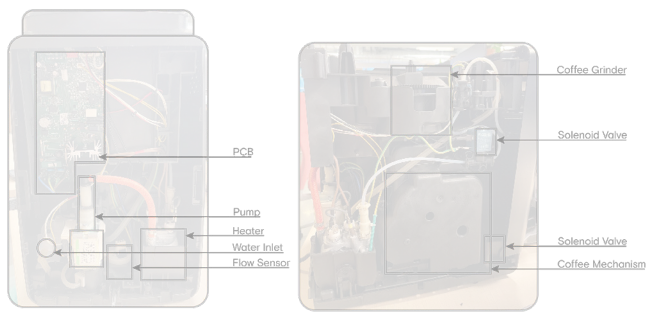


Figure 20: Technical assessment of Philips coffee machine

Patents of the LatteGo

An early patent analysis, conducted in consultation with Quooker and outlined in Appendix 8, suggests that there would be sufficient freedom to operate when exploring design directions similar to existing Venturi-based systems. The review identified several opportunities to circumvent key patents, making this approach a viable option for further development

Temperature mesurement of Philips LatteGo

Temperature is key when foaming milk. Earlier in our research, we established that 70°C is the maximum temperature for foaming milk, as exceeding this threshold can negatively impact the taste. The temperature of the LatteGo was measured, and the milk is foamed at 75°C (see Figure 21). This is relatively high and could have a negative effect on the quality. However, since the milk is foamed in small portions for a very short time, this may mitigate the negative impact. The coffee with the milk has a temperature of 58.3°C, which is ideal for consumption (see Figure 22).


Figure 21: Temperature of LatteGo during foaming


Figure 22: Temperature of coffee from the LatteGo system

Aeroccino

With dozens of different versions, the choice of the Aeroccino is due to its high popularity. The Aeroccino is a milk jug with a built-in motor and heating element, see Figure 23. With the click of a button, it can produce either heated milk with foam or cold foam for iced coffees.

The Aeroccino 2 offers no other customizations except the ability to switch out the spinning whisk for a second version. The whisk spins inside the jug using a magnetic transmission, allowing easy cleaning. The PCB, motor, and heating element are all housed in the bulky base of the jug, and the device is powered via a water kettle-style power transmission system.

Newer versions, such as the Aeroccino 4, are dishwasher-safe. However, it's important to note that the dishwasher-safe jug still contains the motor, PCB, and heating element, which require excellent waterproofing. The Aeroccino 4 also includes customization options for setting the temperature.

In my opinion, the foam quality of the Aeroccino is not great, as it tends to be very stiff. However, reviews and user tests are overwhelmingly positive, as ease of use and automation outweigh the foam quality for most users. The Aeroccino does not have overheating protection. Newer versions include this feature, as it is essential for safety.

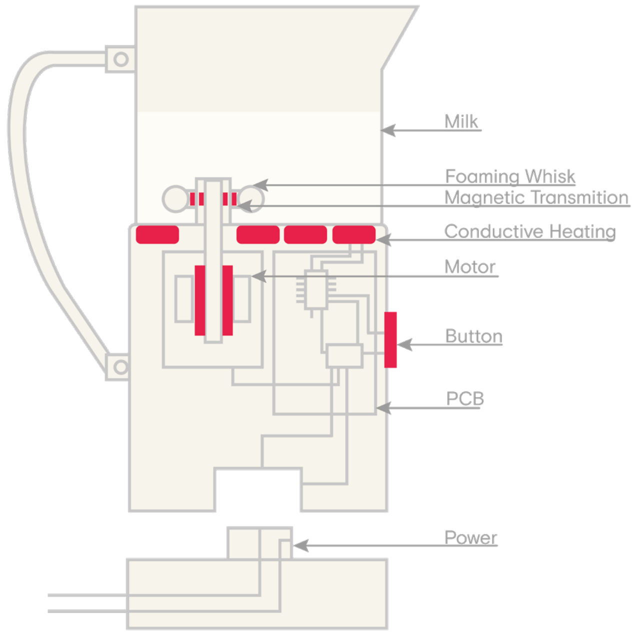


Figure 23: Technical assessment of the Aeroccino 2, showing all components

Criteria: The system must include an overheating sensor and a liquid detection sensor to detect whether the system is empty. When steam is used, it's crucial to detect whether there is a proper connection, as steam must not flow freely.

NanoFoamer

The Nanofoamer is a method developed by the brand Subminimal, which produces electric handheld foamers and electric countertop foamers. This method claims to produce barista-level foam consisting of smaller foam bubbles compared to traditional handheld electric devices, hence the name Nanofoamer. The concept works through a propeller-type attachment that forces the milk through a steel mesh.

To test this concept and understand its functionality, a version was created by modifying the attachment of the Aeroccino to mimic the Nanofoamer, see Figure 24. After ten iterations, a device was developed that is perfectly tuned to the Aeroccino and successfully replicates the Nanofoamer concept.

After testing, the foam indeed appeared denser. However, the lack of control in the Aeroccino 2 caused the milk to be foamed for too long, resulting in overly stiff foam. The next step would involve adding controllability to a spinning tabletop foamer, allowing precise adjustment of the foaming duration to achieve optimal results.

Figure 24: Own prototype version of the Nanofoamer principle, with the goal of understanding and repeating the principle.

2.8 What is considered good milk foam

Analyzing milk foam and judging what constitutes good milk foam is very complex. It is usually done through a combination of expert judgment and instrumental analysis. Key attributes include foam stability, volume, microfoam texture, mouthfeel, and visual appearance. Sensory evaluations often focus on aspects such as creaminess and uniformity of the foam, which contribute to the overall quality of milk-based coffee beverages like cappuccinos and lattes (Al-Attabi et al., 2021). Foam stability, the ability of the foam to maintain its structure over time, is particularly important in consumer perception and can be assessed by measuring foam collapse rate or liquid drainage (Huppertz, 2010). Microfoam, defined by its small, uniform bubbles, is considered ideal for creating a smooth mouthfeel and aesthetic latte art; its presence is typically verified visually and through microscopy or bubble size distribution analysis (Janssen et al., 2016).

At Quooker, several members of the coffee team possess extensive knowledge of milk foam, having completed multiple barista trainings. Their expertise has been invaluable throughout this project, and I have primarily relied on their judgment to evaluate the quality of the foam produced during prototyping. In addition, by testing with a variety of colleagues and users, particularly within the Automation Seeker segment, I have developed a stronger sense of what constitutes "good enough" foam for this specific target group. I also attempted to assess foam structure more objectively by examining samples under a microscope. However, this proved challenging, as the consistency of the foam had already changed by the time the sample was transferred. Taste testing was similarly restricted due to safety concerns, since the prototypes were constructed using non-food-safe materials such as sanded polycarbonate. As a result, most evaluations focused on visual, structural, and procedural aspects of the foam rather than direct consumption.

2.9 Why does Quooker needs a milk Frother?

Within Quooker, there is ongoing discussion about whether the initial launch product of the Coffee Tap should include a milk foamer or if this feature should be implemented in future editions. The original decision by management was to exclude the milk foamer from the launch product to reduce the complexity of the project, as this is a new product category for the company. However, I disagree. I must acknowledge that I have a bias, but here are the reasons why Quooker should implement a milk foamer at launch or ensure the product is backward compatible.

Firstly, nearly 50 percent of people mention that they sometimes drink a coffee recipe that includes milk (Van Maarschalkerweerd & Van Teeffelen, 2024). A coffee machine is usually a shared product within a family or household, increasing the likelihood that at least one person drinks coffee with milk. Additionally, Quooker's target groups, YUPs (young urban professionals) and DINKs (dual income, no kids), have a higher percentage of milk and milk alternative drinkers (from own research 4.1 – 4.4). The demand for milk-based coffee is also higher within Quooker's targeted product category. Espresso lovers, who are less likely to add milk to their coffee, tend to use higher-quality machines, while black coffee drinkers usually prefer filter coffee. Next, Quooker's clean-counter philosophy implies that the Coffee Tap eliminates the need for a large coffee machine with a built-in milk foamer on the countertop. This makes the idea of purchasing a separate milk foamer, such as the Aeroccino, counterintuitive, see Figure 25. The Coffee Tap will be an expensive product, a centerpiece in the kitchen that symbolizes design, efficiency, and luxury. It should not be accompanied by a wired, standalone milk foamer that highlights the Coffee Tap's shortcomings. Lastly, Quooker aims to build trust in its brand. Convincing customers to drill a second hole into their brand-new kitchen counter requires them to believe that the product is not just another fast-moving electronic device but a long-term fixture at the heart of their kitchen. Quooker has gradually gained consumer trust through decades of quality and service. Releasing an incomplete product with the promise that a milk solution "might" come later could diminish this trust. Consumers may suspect that a future version will have a different hole diameter or improved features, leading them to delay their purchase or opt out altogether.

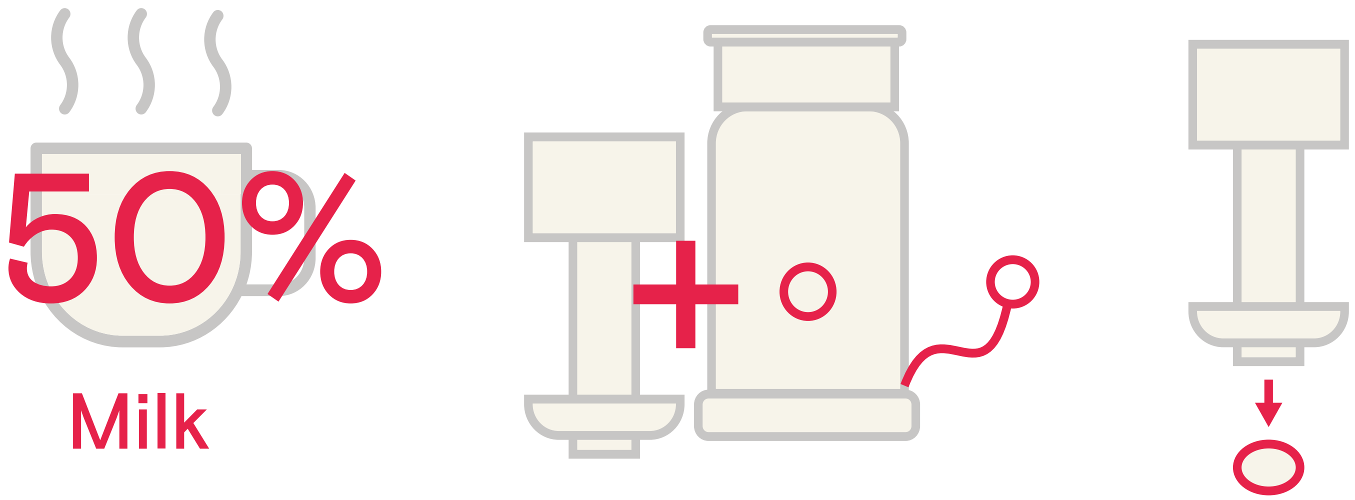


Figure 25: Why does Quooker need a milk frother

3 User centered research (Phase 1)

3.1 User-centered research methods

Before designing a milk foamer for Quooker, it is essential to understand the target audience for the Quooker coffee system, including their needs and pain points. This research concludes the first diverging phase of the triple diamond model, labeled as Phase 1 in Figure 6. This part of the research is guided by the following research questions (the steps correspond to the research steps, explained later on):

- **RQ1: (step 1) What segmentation of the Quooker customer base should the milk foamer target?**
- **RQ2: (step 2) What emotions do participants associate with their coffee-making habits, and how do these emotions differ based on their routines?**
- **RQ3: (step 2) What are the typical times at which participants make coffee, and how do these times vary across different user segments?**
- **RQ 4: (step 3) What are the underlying habits and unarticulated needs of participants regarding coffee-making and milk foaming?**
- **RQ 5: (step 3) What key factors influence people's coffee-drinking experiences and routines?**
- **RQ 6: (step 4) How do participants perceive and evaluate different coffee milk foaming methods in terms of usability, performance, and overall experience?**

To answer the research questions, a user research plan was developed, consisting of 5 steps, as shown in Figure 26. This approach combines both quantitative and qualitative methods, selected and adapted to fit the needs of this project. As Creswell (2014) explains, mixed methods research allows for a deeper understanding of users than quantitative methods alone, while still capturing insights from a broader user base than traditional qualitative research would typically allow. This was particularly important for this project, which aims to understand a diverse customer base while also uncovering **deep behavioral patterns, routines, and expectations.**

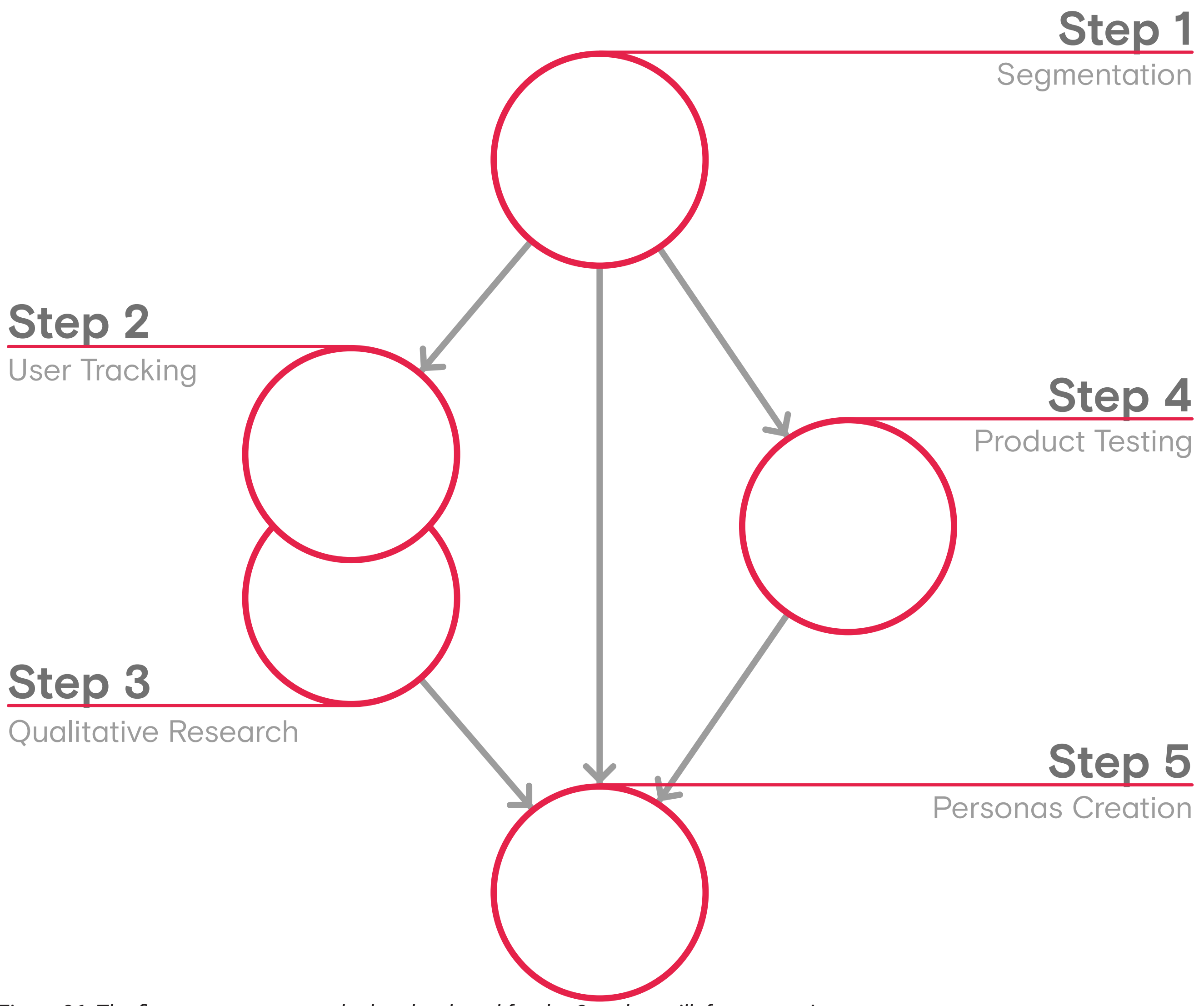


Figure 26: The five-step user research plan developed for the Quooker milk foamer project.

The process is also informed by Schweitzer's (2013) perspective on customer involvement in design. He emphasizes the value of including users early in the fuzzy front-end of development to better align solutions with real needs and reduce the uncertainty of market acceptance. The five-step plan reflects this approach and builds in multiple opportunities for users to express and reflect on their own experiences.

Step 1: User Segmentation and Surveys
The first step draws from Ottum's (2012) market analytics methodology, which emphasizes the importance of starting with the question: Who are my customers? To answer this, a quantitative survey was conducted among current Quooker users, focused on their coffee consumption routines, milk usage, expectations of quality versus speed, and general product attitudes. The goal was to identify **clear user segments** that differ in motivations and behavior. Segmenting the user base not only helped to focus later research stages but also reduced the risk of designing a product that is too generic to resonate with anyone meaningfully.

Step 2: User Tracking for Behavioral Insights
In Step 2, the goal was to observe how users engage with their current coffee routines in real-life settings over time. Participants were given a physical card system, where they categorized each coffee-making moment into one of five emotional states. This method was inspired by Wenemark et al. (2011), who applied **Self-Determination Theory** to stimulate user participation, and by Kouprie & Visser (2009), who emphasized **empathetic design** and observing users in context. The tracking cards allowed participants to reflect on their routines while producing structured, emotion-laden data — offering insight into when, how, and why coffee moments felt satisfying or frustrating.

Step 3: Qualitative Interviews Based on Survey and Tracking Data
Step 3 built directly on Step 2 and was designed to **deepen the understanding** of user routines, expectations, and unspoken needs. Importantly, **data from Step 2 served as the stimulus** for these interviews, allowing participants to reflect on their own behavior patterns, preferences, and emotions. This structure is based on Sanders and Stappers' (2019) **Path of Expression** framework, which explains that users often struggle to articulate future desires or evaluate hypothetical solutions. Instead, by reflecting on real past experiences, users are better able to uncover **latent needs** and imagine new possibilities. Combining Steps 2 and 3 in this way enabled participants to move from passive data subjects to active **co-interpreters** of their experiences, strengthening the depth and validity of the qualitative data.

Step 4: Product Feedback Through Testing
Step 4 introduced a new group of participants who tested three different existing milk frothing devices. These devices were selected based on insights from earlier steps and represented different market categories. The goal of this step was to **evaluate real-world preferences and pain points**. Participants were encouraged to speak aloud during use, describing their expectations, frustrations, and product evaluations in real time. This helped identify which product attributes (e.g., cleaning difficulty, feedback clarity, foam quality) were most valued or problematic in actual use. The results of this step served as a reality check for earlier hypotheses and clarified which directions held the most promise.

Step 5: Data Synthesis and Persona Development
In the final step, data from all previous steps were synthesized to build **design tools** such as personas and insight visualizations. Inspired by the work of Grudin et al. (n.d.), who emphasize the value of personas in communicating complex user needs, this step translated abstract findings into tangible reference points. The personas developed here represent the archetypal Quooker coffee user and describe their emotional, functional, and contextual expectations from a milk frother. These tools guided the design process and served to communicate research findings to stakeholders, ensuring the design remained aligned with user needs throughout development.

Participants of Multi-Method User Research

Figure 27, visualizes the participant flow throughout the five-step mixed methods research process. It shows how individuals were recruited, segmented, and distributed across each phase of the study, distinguishing between **quantitative**, **qualitative**, and **synthesis** steps. The diagram also clarifies that some participants contributed directly to specific steps, while others informed later phases indirectly.

The research began with a **predefined customer base**: potential Quooker customers. These were identified in Chapter 2.4 as individuals fitting within three core demographics: **YUPs, DINKs**, and **empty nesters**. This group was chosen because the Quooker Coffee Tap — and by extension the milk frother — will not be sold as a standalone product. Given the cost and required hardware integration, only those interested in or already owning a Quooker tap are considered relevant target users.

To gather data from this group, I distributed a **quantitative survey** in two forms. The first version was shared internally within Quooker (**N = 137,** With N standing for the number of participants.), due to confidentiality concerns around revealing coffee-related developments to the outside world. However, to ensure that the research also reflected users outside of Quooker, I created a second, anonymized version of the survey (**N = 24**). This version removed all Quooker branding and instead asked participants about their current kitchen appliances, including whether they had an instant boiling water tap. It also included a self-segmentation question, allowing participants to identify themselves as belonging to one of the five user segments defined later in the study. While this introduces some risk of misclassification, most respondents aligned accurately, and both survey groups produced consistent results.

From the combined survey data, I developed **five user segments**, described in Step 1 of the research. These segments became the foundation for further recruitment. Participants for **Steps 2 and 3** were selected from these segments — with most coming from **Segment 1 (Automation Seekers)**, the largest group. Due to privacy restrictions, it was not possible to directly recontact survey participants. Instead, a new set of participants was recruited, who were asked to **self-identify into one of the five segments**. For this reason, the connection between survey data and later qualitative steps is represented as a **dotted line** in the diagram.

Steps 2 and 3 shared the same participants, as these steps were designed to complement each other. Step 2 involved emotional tracking using card-based data collection, while Step 3 used this data as a stimulus for in-depth interviews. This combination allowed participants to reflect on their own routines and emotional experiences, which provided a richer understanding of user needs and behavior.

For **Step 4**, which involved product testing with physical milk frothers, I recruited a **different group of participants**. This was necessary because testing took place at **Quooker headquarters**, and it was not feasible to transport the coffee tap system to users' homes. Despite the new sample, I maintained a similar distribution across the user segments, with a focus again on Segment 1.

Finally, **Step 5** involved the synthesis of all data collected across the previous steps. This included survey responses, emotional tracking data, interview insights, and product feedback. Based on this comprehensive dataset, I developed personas and design insights that guided the ideation and embodiment phases of the project.

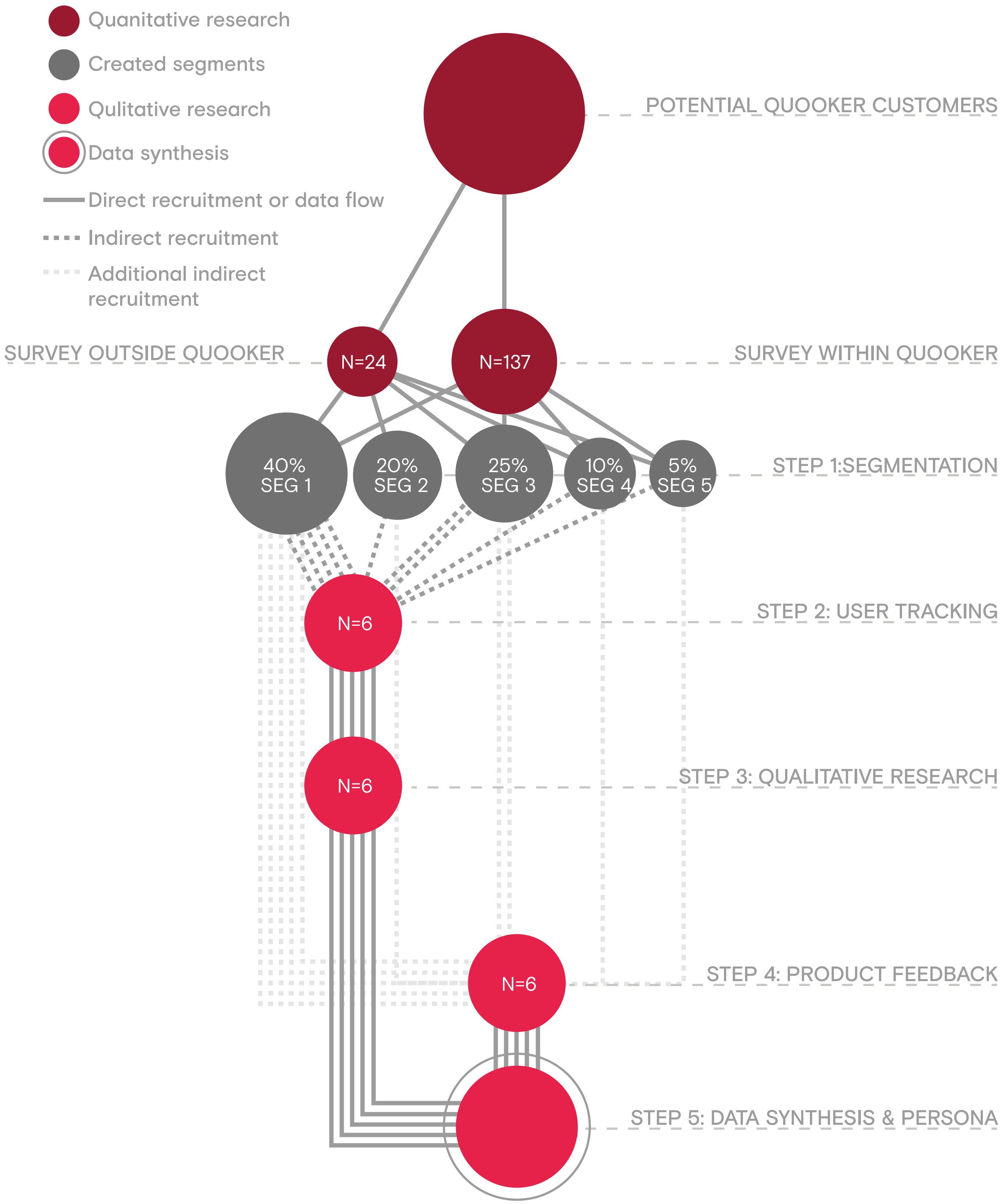


Figure 27: Participant recruitment and distribution across the five-step mixed methods research

3.2 Step 1: User Segmentation and Survey findings

Preliminary Survey Findings

To fully understand the user segmentation of Quooker coffee drinkers, data must be gathered regarding their preferences. While we already know who the typical Quooker user is, the focus now shifts to analyzing their coffee drinking habits and attitudes. The first question to address is: what type of coffee do they currently drink? For example, if most Quooker users drink high-end coffee from expensive espresso machines, they are unlikely to settle for a lower quality standard. However, if their preference leans toward capsules or fully automatic machines, efficiency is likely prioritized over quality.

This question has already been addressed in a master's thesis by Huis in 't Veld (2023). Their survey, with a sample size of N=147, concludes that most Quooker users currently use fully automatic machines, with capsule machines as a close second, see Figure 28 . All other options scored significantly lower. Based on this research, it can be cautiously inferred that Quooker coffee drinkers prioritize efficiency over quality. The hypothesis will be further investigated.

Additionally, it is notable that both fully automatic and capsule machines are relatively expensive in terms of operational (OPEX) and capital (CAPEX) expenditures compared to other options. This suggests that cost is less of a concern for Quooker customers, which aligns with the premium nature of the brand.

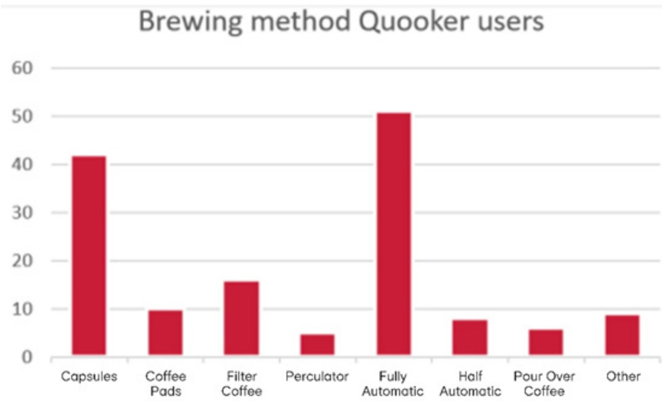


Figure 28: Results of a survey on what type of brewing method Quooker users currently use. (Huis in 't Veld, 2023)

Creating Segmentation

The first step to creating a segementation is to understand the customer, Kraemer (1987) suggests 300 to over 1,000 participants should complete the survey to understand the market segmentation. This however is beyond the scope and time of this graduation project. The survey was sent to all Dutch Quooker employees. Unfortunately, due to the confidentiality of the project, it was not possible to distribute the survey to many individuals outside the organization. However, the R&D department assured me that the company's employee base provides a reasonable representation of the typical Quooker coffee user. This is because the survey was distributed across all departments and service providers, helping to minimize bias that could arise from relying solely on the R&D department. The survey was filled in by 137 respondents.

This part of the research will answer the following research questions:

RQ1: What segmentation of the Quooker customer base should the milk foamer target?

Quooker market segmentation based on N=137

The process of transforming the survey data into market segmentation involved several steps. First, the data was reviewed to identify recurring themes and create segment labels. This process included analyzing specific questions, such as the type of coffee machine respondents use. For example, capsule coffee machines (40.7%) and fully automatic machines (18.5%) were grouped under the "Automation Seekers" segment, while semi-automatic espresso machines (7.4%) were classified under "High-end Coffee Enthusiasts." This thematic analysis was applied to all survey questions, resulting in the identification of five segments. This aligns with Ottum's (2012) theory on market segmentation, which states that the ideal number of segments falls between four and eight.

Next, the segments were quantified. Each question was analyzed to calculate the percentage of respondents fitting into each segment. For instance, 55% of respondents indicated they prefer to spend less than 30 seconds foaming their milk, aligning them with "Automation Seekers." Similarly, 14% of respondents who purchase their coffee from specialty stores were categorized as "High-end Coffee Enthusiasts." However, it is important to acknowledge potential biases in this process. Some questions may overlap between segments or not align perfectly with a single category. For example, the 55% who prefer quick milk foaming could also include individuals from other segments, such as "High-end Coffee Enthusiasts" who only drink espresso.

This analysis ultimately resulted in the creation of the five market segments presented in Figure 29. From this analysis, the following segments were created. Each segment has key characteristics, behaviors, and provides specific marketing insights.

Segment 1: Automation Seekers (40%)
- Characteristics: Prioritize speed, ease of use, and minimal rituals.
- Key Behaviors: Heavy reliance on capsule or fully automatic coffee machines.

Strategic insight: Highlight automation, one-touch features, and convenience.

Segment 2: High-end Coffee Enthusiasts (25%)
- Characteristics: Valuing premium quality and customization.
- Key Behaviors: Preference for semi-automatic machines and specialty coffee.

Strategic insight: Emphasize quality, customizability, and design.

Segment 3: Casual Coffee Drinkers (20%)
- Characteristics: Neutral on rituals, prioritize convenience and affordability.
- Key Behaviors: Purchase coffee from grocery stores, prefer simple setups.

Strategic insight: Highlight simplicity and bundled offers.

Segment 4: Sustainability-Conscious (10%)
- Characteristics: Strong focus on eco-friendly options and practices.
- Key Behaviors: Reusable pods, sustainable coffee sources.

Strategic insight: Promote recyclability, energy efficiency, and sustainability.

Segment 5: Price-Conscious Buyers (5%)
- Characteristics: Focus on affordability over advanced features.
- Key Behaviors: Purchase budget options, prefer cost-effective machines.

Strategic insight: Highlight reliability, discounts, and affordability.

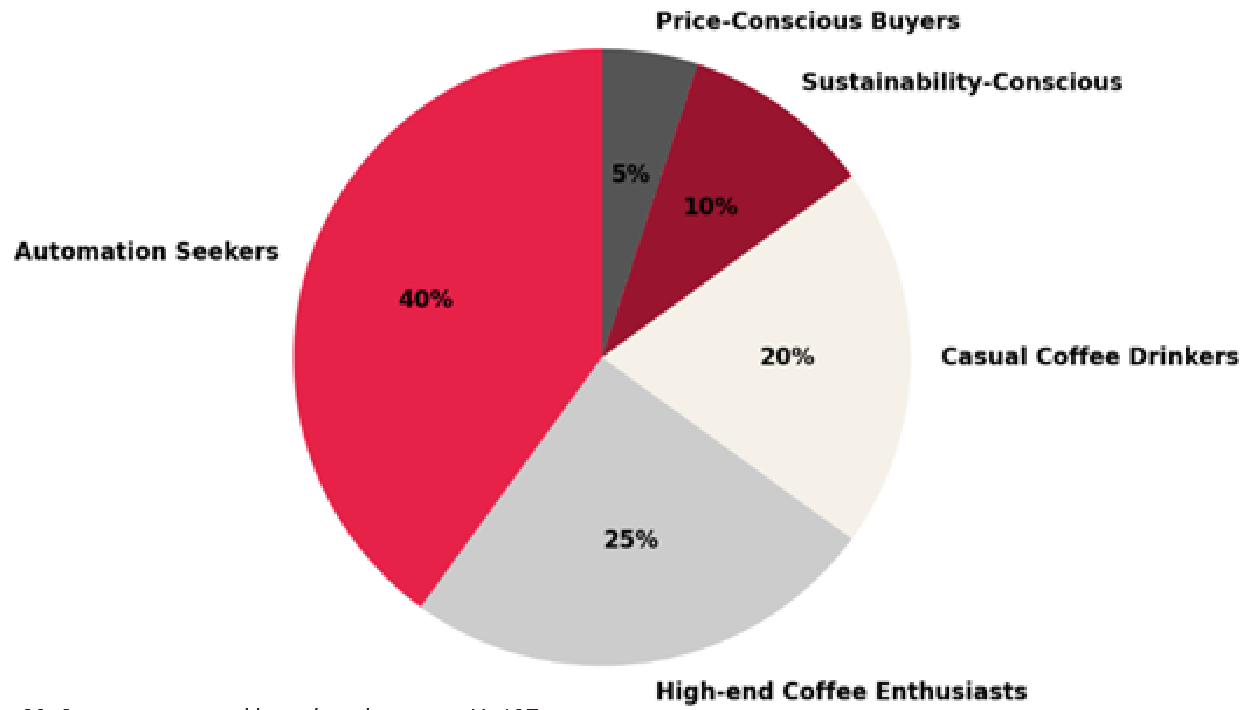


Figure 29: Segments created based on the survey N=137

Conclusion step 1

The survey facilitated the creation of five distinct segments. For the upcoming research, the primary focus will be on the largest segment, the **Automation Seekers.** This focus is not only due to the size of this segment but also based on the hypothesis that this group is the most likely to purchase a Quooker Coffee Tap with a milk frother. This assumption stems from the fact that the capsule-based system proposed by Quooker closely resembles the devices Automation Seekers currently use, both in terms of convenience and coffee quality — making the transition to the Quooker ecosystem a natural fit. In contrast, it is hypothesized that High-end Coffee Enthusiasts are more inclined to invest in premium espresso machines and maintain their established coffee-making rituals, which they may be reluctant to change. However, this remains a hypothesis, and the High-end Coffee Enthusiasts segment and other segments will also be included in the research, though it will not be the primary focus.

The second survey received fewer responses than the first, primarily due to Quooker's restriction against sharing the survey in group chats or posting it online, out of concern for confidentiality. Despite the lower response rate, the results showed no notable differences between the first and second surveys.

3.3 Step 2: User tracking for behavioral insights

This step investigates the coffee-drinking habits of Quooker coffee drinkers, with a primary focus on the previously identified user segment, the Automation Seekers, while also incorporating a small number of participants from other segments. The objective is to track the times at which participants consume coffee and the emotions they experience during these moments. This data will serve as stimuli for step 3, which involves qualitative research conducted by co-analyzing the results of this step with the participants. The data collection methods are informed by Self-Determination Theory, aiming to enhance participant engagement and motivation throughout the study.

Uncovering people's habits and needs is essential for successful product development and can be leveraged across the entire business activity (Patnaik & Becker, 1999). Especially when it comes to coffee, people have certain habits. Understanding these habits will be key when developing a milk foamer, as customers may be reluctant to change them. Habits are often associated with negative connotations, such as addictions or bad habits (Verplanken & Orbell, 2021). However, when it comes to making coffee, these habits can also be seen in a positive light, better described as rituals. The goal of this research step is to uncover these habits or rituals and enable participants to reflect on their routines.

Research by Wenemark et al. (2011) supports the use of Self-Determination Theory to enhance participant engagement. This theory highlights intrinsic motivation as a key factor in research participation, suggesting that activities that provide opportunities for self-reflection or enjoyment are more likely to maintain participant involvement. To apply this theory, I incorporated its concepts into the research. By making the activity enjoyable and including interesting coffee facts, participants were more likely to engage with and complete the research.

Aim of the Study

The aim of this study is to collect data on the times and emotions linked to the moments when people prepare coffee. The research is designed to enable participants to reflect on their habits and provide stimuli for the qualitative research in the next step of the research plan. This step seeks to answer the following research questions:

RQ2: What emotions do participants associate with their coffee-making habits, and how do these emotions differ based on their routines?

RQ3: What are the typical times at which participants make coffee, and how do these times vary across different user segments?

Method

To gather behavioral data, a low-tech, participant-friendly approach was chosen to minimize the effort required from participants. Each participant received a box divided into five compartments, with each compartment representing a specific emotion (see Figure 30). These emotions were selected based on prior discussions about morning routines and their emotional associations.

Figure 30: Emotion-based card sorting activity used to gather user insights on coffee habits

Participants were also provided with cards to record key details about their coffee habits, including the time of preparation, type of coffee, and preparation method. To make the process more engaging, the cards featured coffee-related facts on the reverse side, designed to add an enjoyable and informative element. The boxes included a window, allowing participants to visualize which emotion they most frequently associated with their coffee-making habits. This leverages the Self-Determination Theory to enhance participant engagement.

Participants were instructed to log their coffee habits using the card system for a duration of seven days. This timeframe was selected to ensure sufficient data collection while minimizing the risk of participant fatigue.

Method

Participants for this study were primarily sourced from my personal network, with 4/6 belonging to the Automation Seekers segment and the remaining participant being a High-end coffee enthusiast. Due to the anonymous nature of the survey conducted in Step 1, it was neither possible nor ethical to recruit participants directly from the survey while respecting their privacy.

To ensure participants were accurately categorized, recruitment involved asking individuals to self-identify as belonging to one of the five user segments defined in Step 1. Descriptions of the segments from the initial research were provided to assist participants in selecting the category that best aligned with

Table 2: Participants of study step 2

ID	Segment	Coffee frequency	Coffee preference	Age range
P1	Automation seeker	Daily	Cappuccino	55-64
P2	High-end	Daily	Cappuccino	55-64
P3	Automation seeker	Daily	Cappuccino	65+
P4	Automation seeker	Every other day	Latte	25–34
P5	Automation seeker	Daily	Cappuccino	65+
P6	Automation seeker	Daily	Latte	25–34

their coffee-drinking habits and preferences. The recruited participants are summarized in Table 2. Recruitment continued until the point of data saturation was achieved, ensuring the sample size was sufficient to provide comprehensive insights.

Table 2 shows the segmentation of the participants. The first two participants were used for the pilot study, but their results were also integrated into the final analysis. Age is presented in ranges to minimize the risk of participant identification. The age groups also corresponded to the original target groups identified as Quooker users: YUPs and DINKs are usually between 25 and 34, while empty nesters are typically over 55. Coffee preference is included, as participants who prefer milk-free coffee would provide fewer valuable insights for the qualitative research phase. Additionally, coffee frequency is important; participants who drink coffee at home only once a month would make the self-reflection aspect less relevant, as the research would take too long. It is also important to note that participants were asked to conduct this research at home, which introduces a potential bias, as they needed to have several days where they worked from home. This may have influenced their routines, as coffee consumption at home can differ from behavior at the workplace. On working days, participants might experience more time pressure in the morning, making speed and ease of use more critical factors. Additionally, coffee moments at work often serve a social function — offering a chance to interact with colleagues — which may not be reflected in a home environment. The same participants will be used for Step 3.

Pilot step 2

To validate the proposed data collection method, a pilot study was conducted prior to the full-scale rollout. In this context, a pilot is understood as a t**est run of the research setup**, aimed at evaluating its effectiveness and identifying areas for improvement before wider implementation. The pilot offered early insights into user behavior, confirmed the motivational value of the printed coffee facts, and identified design improvements—such as increasing the card thickness to enhance visual clarity. A detailed account of the pilot, including setup, participant context, and outcomes, is provided in Appendix 5 – Pilot research Step 2.

Conclusion step 2

This research step successfully uncovered when and why participants prepare coffee, revealing both emotional and behavioral patterns that shape their routines. Most participants associate coffee-making with the emotions Happy and Stressed, highlighting its dual role as both a comforting ritual and a functional necessity (as seen in Figure 31). Morning and early afternoon emerged as the most common preparation times, with little variation across user segments, especially among Automation Seekers, who followed predictable, efficiency-driven routines.

Beyond offering valuable insights, these findings are especially important as input for the next research step. Step 3 will build upon this foundation by engaging participants in qualitative conversations, using the data they logged to explore their motivations and rituals in more depth. This co-analysis approach promises to yield richer, more personal insights that will directly inform the design of a user-centered milk foamer. In Figure 32, you can see the system in use.

Figure 31: One of the boxes a participant filled, note that the emotion happy and stressed is filled the most.

Figure 32: Emotion card system in use with participant 2.

3.4 Step 3: Qualitative Interviews Based on Survey and Tracking Data

This qualitative study builds upon the cards collected research in Step 2, using the cards as stimuli to structure and guide the interviews. By re-engaging the same participants from the prior phase, the research allows for a deeper exploration of their behaviors, habits, and preferences related to coffee-making. The primary objective of this step is to identify underlying habits and latent needs in the coffee preparation process, with the goal of generating insights for the development of a milk foaming solution.

RQ 4: What are the underlying habits and unarticulated needs of participants regarding coffee-making and milk foaming?

RQ 5: What key factors influence people's coffee-drinking experiences and routines?

Method

The process begins by collaboratively organizing the cards with the participants. The goal of this exercise is to cluster the cards by time and day while preserving the emotional categories previously identified. Conducting this activity together allows participants to reflect more thoroughly on their habits and provides them with time to engage meaningfully with the research. In contrast to traditional design, co-analyzing the data with the participants gives the eventual users of the product the role of "experts of their experience." This aligns with the theory of Sanders and Stappers (2019), which highlights the value of user research. Once the cards are clustered, participants are asked to explore their routines and behaviors related to coffee preparation.

The research method also draws on the literature of participant validation, which emphasizes a more person-centered approach by allowing participants to actively shape the study in collaboration with the researcher (Ravitch & Carl, 2015). This is achieved by evaluating and sorting the cards together with the participants, as well as verifying the accuracy of the transcripts with them. These steps are implemented as validity measures to establish the credibility of the research (Lincoln & Guba, 1985).

The discussions focus on themes that emerge from the clustering activity. For instance, if all morning-related cards are placed in the "stressed" category and indicate an average coffee preparation time of six minutes compared to two minutes in the afternoon, this could reveal a latent need for a more efficient coffee-making system in the morning. Alternatively, it might highlight a specific pain point, such as the time it takes for a coffee machine to warm up in the morning.

Since the questions will depend on the clusters formed during the activity, a standardized interview guide cannot be prepared in advance. This flexible approach ensures that the interviews remain participant-driven and responsive to the themes uncovered. Additionally, during the clustering process, participants will be asked follow-up questions about milk foaming preferences. The use of the cards as stimuli is expected to enhance their ability to recall details about their routines and preferences, resulting in richer and more accurate insights.

Pilot of step 3

To verify the effectiveness of the interview method, a pilot was conducted using participants from Step 2 (see Figure 33). Although this session is referred to as a pilot, it is **officially considered part of the actual study**, as the results were used in the analysis. No major adaptations were required that would render the collected data unusable. The session confirmed that the card-sorting activity naturally initiated meaningful conversations, revealing emotional patterns and preparation-related frustrations without relying on pre-scripted questions. A full description of the session setup, transcription process, and key learnings is available in Appendix 6 – Pilot research Step 3.

Figure 33: Sorting the cards during the Pilot

Data analysis and processing

After the interview in which the conversation was recorded, the study was transcribed. This was achieved through the automatic transcription function built into Word, with the addition of manually transcribing the recordings to ensure the audio was transcribed correctly and due to the fact that double transcription can help prevent bias (Mujtaba et al., 2024). During the transcription of the interview, the first step in anonymization was achieved by removing names and personal information. Next, the transcriptions were uploaded onto the desktop version of ATLAS.ti, where the transcripts were coded. Some sections of the transcripts were additionally coded by a peer researcher and compared with the main codes. This was done to identify if there was a large difference in coding. This should eliminate some bias and be a basic form of investigator triangulation (Ravitch & Carl, 2015), although ideally, all codes should have been reviewed by multiple researchers. It is important to note that the peer researchers did not have insights into personal data of the participants.

For the thematic analysis, research by Graneheim and Lundman (2004) was used as a guideline. First, the codes were exported from ATLAS.ti to Miro, where they were color-coded based on the segment the participant belonged to (see Figure 34). The yellow codes correspond to the automation seekers, while the red codes represent the high-end coffee enthusiasts. Next, the codes were categorized into subcategories, which were then grouped into overarching categories.

Results

Thematic analysis of the interview transcripts led to the identification of several key themes (Figure 34): Efficiency, Coffee as a Tool, High-Quality Coffee, Easy Cleaning, Bean Preference, Control, and Ritual/Hobby . These themes capture both articulated behaviors and latent needs related to coffee and milk preparation.

The **Efficiency** theme was dominant, particularly among Automation Seekers. Participants often expressed frustration with slow heating times and the time required to manually foam milk. Phrases such as “duurt te lang” (takes too long) and “gemak boven kwaliteit” (convenience over quality) reflect this preference. One participant noted that if a machine foams automatically, it may be allowed to take longer, suggesting a trade-off between effort and time.

Coffee as a Tool emerged among participants who primarily consume coffee for its functional properties. These users typically drank coffee only in the morning and often opted for simple or instant options. Emotional attachment was limited, and preferences leaned toward utility and speed.

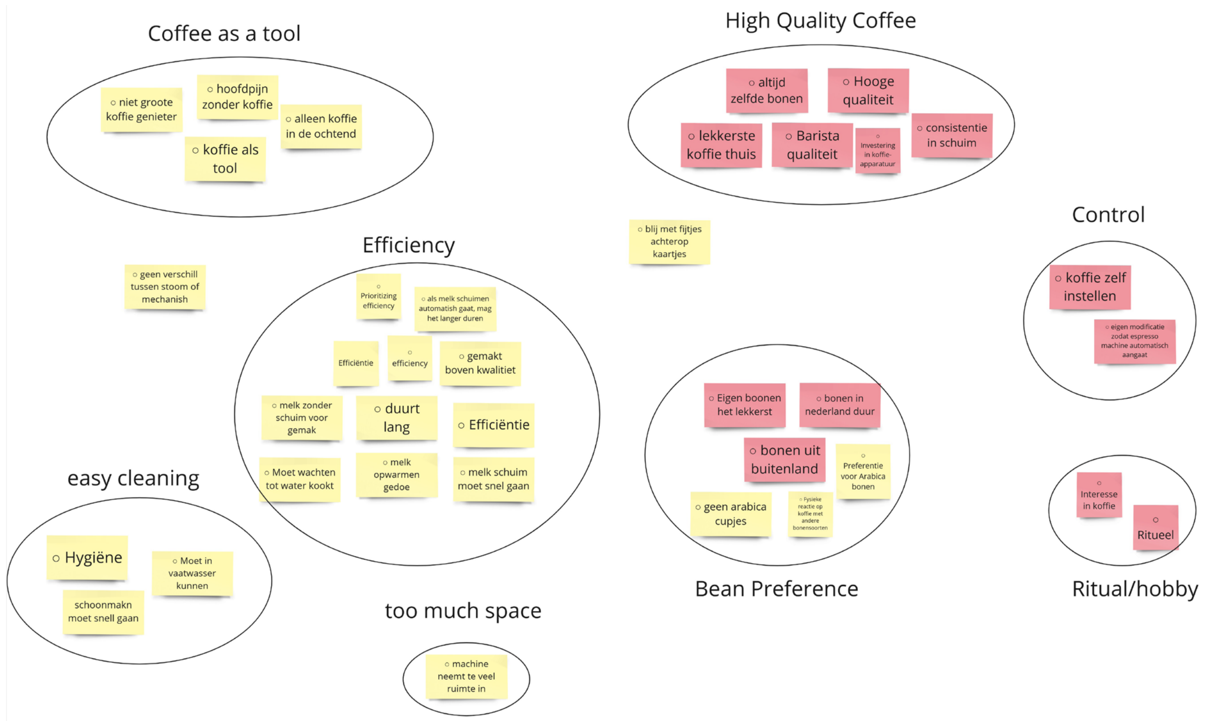


Figure 34: The emotion card system in use with Participant 2.

The **High-Quality Coffee** theme was more prominent among High-End Coffee Enthusiasts. Terms such as “Barista kwaliteit” (barista quality), “altijd dezelfde bonen” (always same beans), and “consistente schuim” (consistent foam) illustrated a strong emphasis on premium experience and control over the brewing process.

Easy Cleaning was mentioned frequently as a barrier to milk foaming. Participants desired solutions that could be cleaned quickly or placed in the dishwasher. The perceived maintenance effort was a major factor influencing whether or not users chose to foam milk.

Bean Preference was mentioned across both segments, although High-End Coffee Enthusiasts expressed more specific preferences, often importing beans. Several participants emphasized the lack of suitable arabica capsules and the high cost of quality beans in the Netherlands.

Control and **Ritual/Hobby** appeared more often in the High-End segment, highlighting the importance of being able to customize settings and the pleasure derived from the preparation process itself.

Discussion and Conclusion

The results of this step reveal a nuanced spectrum of coffee preparation behaviors shaped by both **practical constraints and personal values**. For **Automation Seekers,** coffee-making is primarily functional, with a strong emphasis on **efficiency, speed, and low maintenance.** Their reluctance to foam milk often stemmed from the time and effort required to clean milk-related devices. For these users, an ideal solution would minimize manual interaction and integrate smoothly into their morning routine without adding friction.

In contrast, **High-End Coffee Enthusiasts** are driven by **quality, flavor, and a ritualistic appreciation** for coffee-making. They value **control, consistency,** and often see preparation as part of the overall experience. While more tolerant of added complexity — such as longer preparation or cleaning time — even this group identified cleaning as a common pain point, particularly when it broke the flow of their established habits.

In answering **Research Question 4 (RQ4)** — What are the unspoken needs and routines related to milk foaming among Quooker coffee users? — this study uncovered several key insights. First, participants across both segments share a desire for a **milk foamer that fits effortlessly into their established routines,** with minimal disruption or maintenance. Second, latent needs were uncovered around **cleanability, automation, and integration with existing appliances**. These needs often go unvoiced but strongly influence adoption and satisfaction. For Automation Seekers, the unspoken ideal is a nearly invisible, single-touch system. For Enthusiasts, it’s a device that complements their ritual without compromising performance.

Regarding **Research Question 5 (RQ5)** — How are coffee and milk-related routines shaped by emotional, practical, and identity-based factors? — the results highlight a complex interplay of drivers. Emotional states like morning stress, practical concerns such as time pressure or cleanup effort, and identity-driven values (e.g., feeling like a coffee connoisseur) all influence how and when users engage with coffee and milk. These drivers vary not only between user segments, but also **across different times of day and use contexts.**

A key strength of this research step was the use of the **emotion card system** as a participatory co-analysis tool. This approach allowed participants to reflect on their real routines, compare emotional states over time, and express nuanced frustrations and desires. It supports Sanders and Stappers’ (2019) argument that treating participants as **experts of their own experience** yields deeper and more meaningful insights for design.

In summary, this step successfully addressed both RQ4 and RQ5. It uncovered **latent needs,** emotional undercurrents, and usage habits that span across user segments, providing a strong foundation for the next stages of design. The results suggest that the ideal solution must balance **convenience, foam quality, and hygiene,** while respecting each user group’s emotional relationship to coffee and the role it plays in their daily lives.

Design Insight: For Automation Seekers, the product should require **minimal interaction**, ideally working with a single touch or automatically.

Design Insight: Morning stress was a recurring theme, so the experience should feel **reliable, intuitive, and non-disruptive.**

3.5 Step 4: Product Feedback

The objective is to explore how users experience three different milk foaming methods, focusing on their preferences, pain points, and perceived value. Note that we are not yet comparing specific milk foaming devices within a single category; instead, we are testing different methods, see Figure 35. While there are certainly differences between individual devices, at this stage of the research, my aim is to gain a holistic overview of what is available on the market. This approach will help me understand user perceptions and prioritize their needs. Additionally, this step will clarify the trade-offs between the different methods.

The goal of this step is to use perceptual mapping and needs ranking to identify which elements of the milk foaming process are pain points for our user segment. We already have an understanding of who our users are, their habits, and their needs based on previous qualitative research. However, these product tests will provide insights into user perceptions of competitors and milk foaming methods.

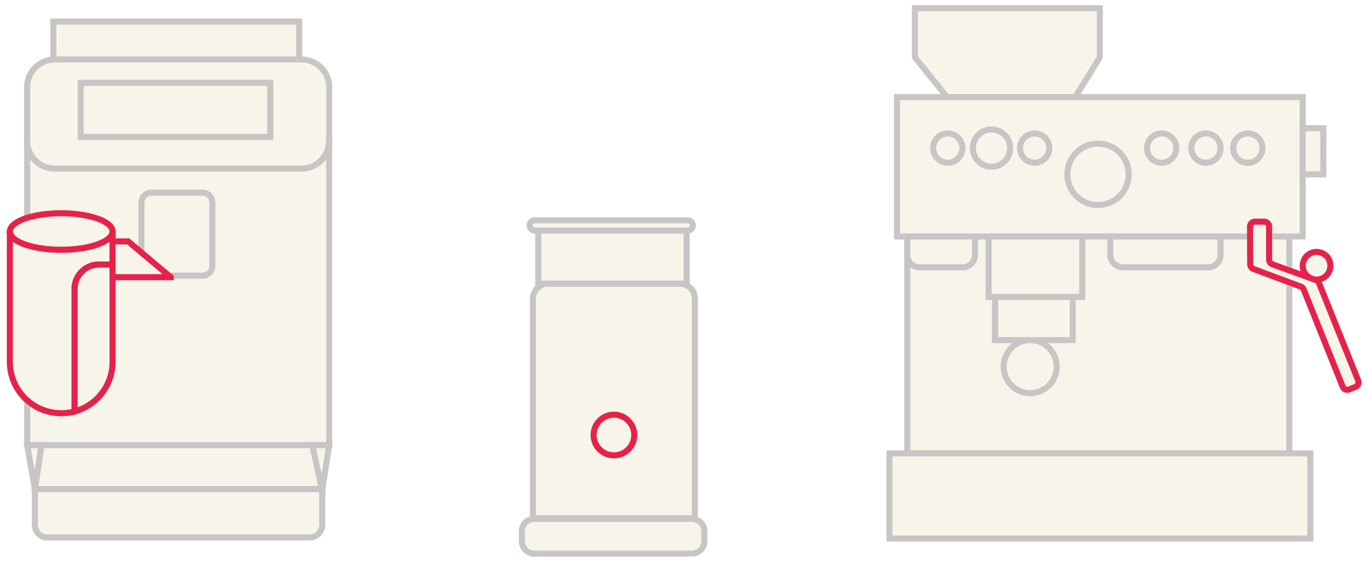
RQ 6: How do participants perceive and evaluate different coffee milk foaming methods in terms of usability, performance, and overall experience?

Method

The research was conducted qualitatively at Quooker's coffee lab. Upon arrival, participants completed an informed consent form and were given a short explanation of the research goals and procedure. They were then introduced to **three different milk frothing methods,** which they used to foam full cow's milk and barista oat milk in a randomized order. Each machine was briefly explained beforehand.

During the foaming process, participants were encouraged to **think aloud,** sharing their thoughts, reactions, and frustrations in real time. These sessions were recorded using a TU Delft laptop, capturing the audio of the conversations. In addition to the recordings, participants were asked to **rank the machines on a scale from 1 to 5** across a set of criteria, including **usability, learning curve, foam quality, and cleaning effort.**

Although quantitative rankings were collected, the **most valuable data emerged from the natural conversations and spontaneous comments** participants made while using the machines. Unlike in Step 3, where thematic coding was applied, the analysis in this step focused on listening back to the recordings and extracting direct quotes and key takeaways. These were then used to form the results, supported by patterns observed across participants in their preferences and verbalized experiences.



LatteGo Aeroccino Steam Wand

Figure 35: Different selected milk foaming methods From left to right: an automatic milk frother integrated into a fully automatic coffee machine, a stand-alone capsule-based milk frother, and a manual steam wand attached to a high-end espresso machine. These devices were selected to represent a broad spectrum of current market solutions — varying in level of automation, control, and user involvement — to probe different user experiences and preferences.

Participants

As stated in Figure 27, the participants for this research step differ from those in Steps 2 and 3, although they also fit into the segmentation created in Step 1. In Table 3, the participants are listed and labeled as NP (New Participants) to avoid confusion with the previous tables.

Results Venturi (LatteGo) System

Participants were asked to make a coffee using the LatteGo system. They were instructed to fill the system, make a cappuccino, and then place the components in a dishwasher. The following points summarize the main results of the test (The subtitles used in this section, were defined based on recurring themes identified while listening back to the interview recordings):

Quality
Participants mentioned that they were happy with the quality of the LatteGo. NP1 said: "This is just how I like my coffee." NP2 commented: "Wow, look, it steams!" NP3 added: "I really like the quality. It's not as foamy as the Aeroccino, but I like the proportion of steam and milk."

Ease of use
Participants were most enthusiastic about the ease of use. They appreciated that the milk foam went directly into the glass and that they could place the device into the dishwasher. They also liked that they could do other tasks while making their cappuccino. NP3 said: "Putting it in the dishwasher is really a game changer."

Table 3: Participants of research step 4

ID	Segment	Coffee frequency	Age range
NP1	Automation seeker	Daily	25-34
NP2	Automation seeker	Daily	18-24
NP3	Automation seeker	every other day	25-34
NP4	Automation seeker	Daily	55-64
NP5	High-end	Daily	55-64
NP6	High-end	Daily	24-35

Results Aeroccino

Quality
Participants were very positive about the quality of the Aeroccino. This is quite surprising, as the quality of the milk foam is considered subpar by the coffee specialists on the Quooker coffee team. They argue that the foam is too stiff and that the ratio between foam and milk is not ideal. However, the participants did not share this opinion. NP3 said: "This is exactly how I like my milk foam – nice and fluffy, just like a marshmallow." Similarly, NP1 remarked: "The milk foam has a nice texture."

This aligns with the hypothesis that automation seekers do not value quality as highly and may not recognize what good milk foam should be like.

Participants were less satisfied with the results when using plant-based milks in the Aeroccino. NP3 commented: "I only drink plant-based milk, so I would not use this device. Even if I drank cow's milk, I would still want to be able to make coffee for guests." However, NP6 said: "the foam looks like whipped cream, not how milk foam should be"

Time
When participants used the Aeroccino, they mentioned that it takes a relatively long time for the milk to foam and heat up. However, they also noted that because they do not have to actively attend to the device, the longer duration did not matter much. When asked how long it would be acceptable to wait for the milk, most people stated that two minutes was their maximum, but they preferred it not to take longer than the Aeroccino, which takes about 90 second.

Criteria: Foam production and heating should not take longer than 90 seconds.

Sound
One of the participants (NP3) mentioned that they liked how silent the Aeroccino is. They noted that a version from a different manufacturer produced more noise, reaching a sound level they found annoying.

Criteria: The foaming solution should be quiet (exact amount TBD)

Results Steam wand

The participants were all asked to foam milk using the steam wand. This steam wand is part of the lab setup at Quooker and is of barista quality. The participants received a brief instruction on how to steam the milk. In Figure 36, you can see one of the participants pouring the milk into a coffee. All participants were also asked to clean the device afterward to simulate a realistic procedure. The subtitles used in this section, such as Ease of use and Learning curve & safety, were defined **based on recurring themes identified while listening back to the interview recordings.** The following where the main insights:


Figure 36: Participant using the Steam wand

Ease of use
Participants mentioned that they do not like having to hold the milk jug and manually foam the milk. They feel that this process takes too much time and prefer the operation of the Aeroccino or LatteGo, as these devices allow them to do other tasks while the milk is being frothed. NP2 remarked: "I don't mind if the Aeroccino takes longer, at least I can do something else in the meantime." Participants also disliked the need to use both hands. NP3 said: "I don't like that I have to feel the temperature with my other hand."

Learning curve & safety
During the steam wand test, participants mentioned that they did not know how to use a steam wand. The willingness to learn and the prior knowledge available varied among participants. A few participants mentioned that using steam intimidated them and that they would need to take lessons to understand the process. Most participants mentioned that they thought the steam wand was too complex. NP3 said: "I think the steam is scary, especially since I have kids – I wouldn't want something like this in my kitchen."

Criteria: Minimal learning process should be needed to operate the milkfoamer.

Criteria: The system must include safety mechanisms for overheating and dry operation and no steam should leak.

Discussion and Conclusion

This study aimed to investigate how users perceive and evaluate three milk foaming methods — an automated steam-based system (LatteGo), an induction-based device (Aeroccino), and a professional-style steam wand — in terms of usability, performance, and overall experience. The findings offer clear insights into the preferences, priorities, and limitations of a target user segment, particularly Automation Seekers, who **value effortless integration into their routine, minimal interaction, and low-maintenance design** above professional control or foam perfection.

A consistent theme throughout the test sessions was a strong preference for convenience and ease of use. Participants consistently rated hands-free operation, asynchronous functionality, and minimal cleaning effort as highly desirable. The LatteGo was praised for its direct milk-to-cup system and dishwasher-safe components, while the Aeroccino stood out for allowing multitasking, even though its total cycle time was perceived as longer. These devices met the core expectations of Automation Seekers, who favor solutions that do not interrupt their workflow or require active supervision.

In contrast, the steam wand, although producing high-quality foam, was perceived as too demanding. Participants cited the need for active attention, two-handed operation, and a steep learning curve as major drawbacks. This aligns with literature suggesting that perceived ease of use is a primary factor in technology adoption (Davis, 1989).

Interestingly, while Quooker's internal coffee experts consider the Aeroccino's foam quality inferior, users expressed satisfaction with its results, highlighting a clear gap between technical performance and perceived value. This supports Norman's (2013) argument that user perception and emotional satisfaction often outweigh technical superiority in product adoption.

Safety and confidence also emerged as important factors. Several participants found the manual steam wand intimidating or unsafe, especially in households with children. One participant explicitly stated they would not want such a system in their kitchen due to open steam exposure. These responses indicate that household milk foaming solutions must prioritize safety, integrating features such as overheat protection, steam containment, and intuitive controls that minimize risk.

Another notable insight concerns time perception. Although the Aeroccino had a longer operational time than the steam wand, participants preferred its asynchronous operation because it allowed them to perform other tasks. This shows that minimizing user involvement is often more valuable than reducing total task time — a key insight when designing for busy, efficiency-focused users.

In summary, the comparative evaluation of milk foaming methods revealed a clear preference among users — and particularly among Automation Seekers — for solutions that prioritize automation, safety, and ease of integration over manual control or barista-level foam. These findings yield the following design implications for the Quooker milk frother:

- **Ease of use and asynchronous operation** are critical, especially for Automation Seekers who expect intuitive, hands-free interaction.
- **Perceived quality** often diverges from expert definitions; user satisfaction should guide design choices more than technical benchmarks.
- **Low-effort cleaning** and compatibility with kitchen workflows (e.g., dishwasher-safe components) are essential.
- **Safety concerns** must be proactively addressed when working with steam or heat.
- **Minimal learning curve** should be expected — the product must feel plug-and-play from the first use.

These findings strongly support the design direction toward an automated, user-friendly system with built-in safety and cleaning simplicity. A future research step could explore **device-specific preferences** within the most promising foaming category once a technical direction has been selected.

3.6 Step 5 Data Synthesis and Persona Development

In this final step, we will analyze the data collected in the previous steps. The goal is to gain a comprehensive understanding of the Quooker coffee drinker, establishing a solid foundation for the design process.

Quality vs Efficiency

When designing a milk foaming solution that aligns with the Quooker coffee drinking experience, it is essential to first define what this experience entails. In this two-dimensional axis, I have plotted Quick Coffee vs. Ritual against Quality, Figure 37. The Efficiency vs. Ritual axis is primarily informed by user research conducted by Quooker (Insight company, 2022), where this dimension was also used, as well as insights from the qualitative research in step 3. The Quality axis is derived from both questionnaires and qualitative research findings.

It is important to note that this plot includes a mix of coffee brands, coffee machines, and preparation methods. This is because some brands transcend their methods, such as Nespresso, which operates as a capsule provider, machine manufacturer, and, most importantly, a brand with a specific user expectation and identity.

This matrix, shown in Figure 37, was constructed by combining insights from both the **quantitative survey and the qualitative interviews**. Specifically, the final survey question asked participants to rank the expected quality of various coffee brands and systems, including Quooker. These quantitative results were enriched with qualitative input from Step 3, where participants shared personal routines and values related to coffee. One High-End Coffee Enthusiast, for example, described their preference for using a traditional espresso machine, emphasizing the ritualistic process of grinding beans and distributing them precisely in the puck — highlighting how preparation itself becomes part of the experience.

The horizontal axis represents perceived coffee quality, ranging from low to high, while the vertical axis maps how ritualistic the coffee preparation is, from quick and automatic to slow and hands-on. For instance, Nespresso is placed in the bottom-right quadrant, as it offers consistent high-quality coffee with minimal effort. Senseo appears in the bottom-left quadrant, as it is likely perceived as lower quality, partly due to its porous packaging, which allows air exposure and leads to faster degradation of the coffee. Jura scores high on both axes due to its premium fully automatic systems. Meanwhile, brands such as Douwe Egberts (D.E.) and Starbucks fall lower in perceived quality and closer to the convenience-oriented end of the spectrum.

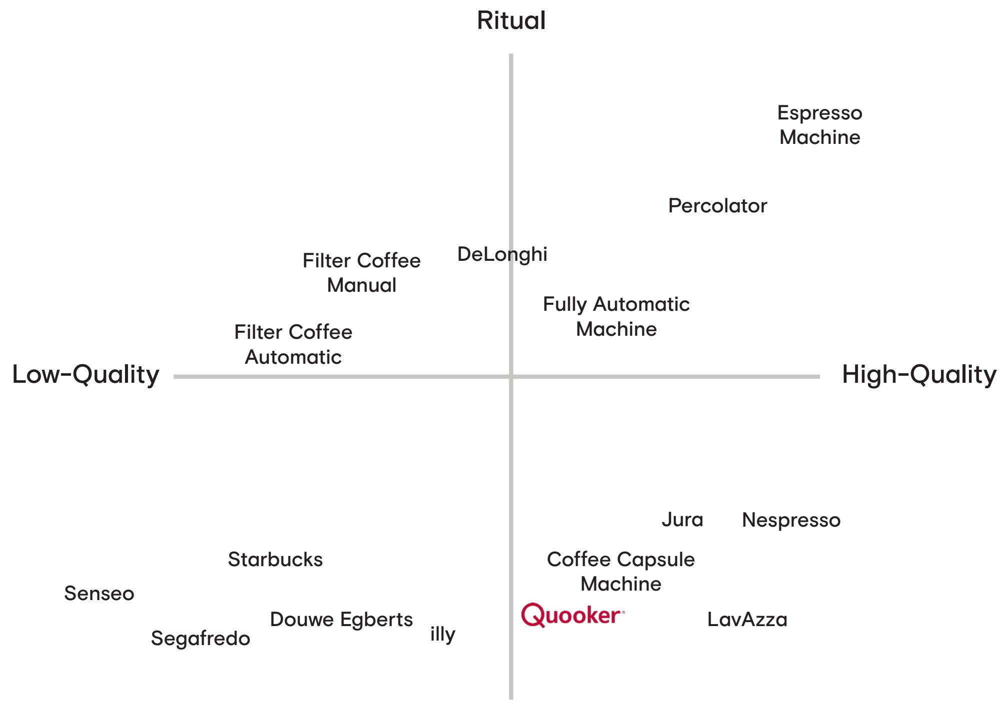


Figure 37: Matrix comparing quick coffee versus ritual, plotted against perceived quality.

Analysis of Quooker's Positioning

- **Low vs High-Quality Axis:** Quooker scores above average in perceived quality. This is largely because the brand is associated with high-quality products. However, Quooker has no prior experience with coffee, which influences its perceived expertise in this area. It is important to highlight that the data includes a significant number of Quooker employees, due to the confidentiality of this project. This likely affects the perceived quality of the product.
- **Efficiency vs Ritual Axis:** Quooker is placed in the Quick Coffee segment . This aligns with the brand's philosophy of instant hot water and is reflected in its customer perception, where efficiency is often highlighted. Quooker's decision to incorporate a capsule/pod mechanism into its coffee system further supports this positioning and meets customer expectations for quick and convenient coffee preparation.

Design Insight: Based on this analysis, efficiency is a key attribute to prioritize when designing a milk foamer. While quality remains important, the milk foaming solution must align with Quooker's identity as a brand that emphasizes speed and convenience. This ensures that the product integrates seamlessly into the Quooker coffee experience and meets the expectations of its target audience.

Persona

The next step is to create a persona. This persona was created by analyzing the previous steps in combination with existing literature and frameworks. By using existing frameworks, it is possible to transform the data gathered into a solid base on which the design process can build upon.

The persona creation leaned on the principles described by Cooper (2004), where personas serve as a representation of user archetypes. Following this method, the insights from the survey, which included preferences and demographic data, were analyzed to identify shared patterns. Such as prioritizing efficiency, minimal effort, and aesthetic appeal, formed the foundation for Sophie's goals and needs. Additionally, the product testing phase (Step 4) contributed to behavioral insights, particularly around user interaction with existing coffee-making solutions. The triangulation of data sources ensures that the persona reflects an understanding of the user behavior rather than isolated assumptions.

One key framework used when creating the persona was the "Needs Empathy Map," as outlined by Krüger et al. (2022). The framework systematically organizes user insights into observable behaviors, emotions, and psychological needs. The tool made it possible to map Sophie's actions, thoughts, and feelings alongside identifying unmet needs. The method also became relevant when structuring insights from Step 2 (the coffee cards) and Step 3 (the qualitative research), which asked participants to express their emotional responses while making coffee and tried to uncover their habits. The emotional cues, together with the qualitative research, enabled the articulation of Sophie's pain points and preferences.

Drawing on Desmet and Fokkinga's (2020) typology of fundamental needs, Sophie's needs for convenience, quality, and minimal effort were emphasized. This psychological aspect helped create the persona by linking her functional requirements with her emotional drivers, such as her requirement of wanting a solution that can go into the dishwasher, which is derived from her emotional driver of her frustration of having to spend more time cleaning the house before and after a long day of work. The "Persona with Needs" method, as highlighted by Krüger et al., guided this process by mapping all the different emotional responses on a Miro map. Once multiple of these maps were filled in, themes within these emotional responses were made, leading to the emotions of Sophie.

Finally, the persona's perception of Quooker was bundled from the qualitative research in combination with contextual data gathered during the research phase. Concluding, this persona gives a good overview of who the product should be designed for. The Persona is visible in Figure 38: Sophie Vermeer, the result of the persona creation.

Figure 38: Sophie Vermeer, the result of the persona creation.

Risk of personas

Many design experts regard personas as a valuable tool for engaging stakeholders and guiding design decisions. However, some argue for more abstract alternatives, such as user profiles or archetypes, due to several risks. Grudin et al. (n.d.) highlight that personas may be reused without fresh research, applied inconsistently across departments, and overused at the expense of other user-centric methods.

Despite these concerns, a persona was chosen for this project because it effectively synthesizes user research into a relatable and actionable representation. It helps communicate key insights across disciplines and keeps the user perspective central throughout the design process. While alternatives were considered, the persona was supplemented with other user research methods to ensure a well-rounded understanding and avoid oversimplification.

3.7 Conclusion

This chapter concludes the first diverging phase of the Triple Diamond model, aimed at understanding the Quooker coffee user and uncovering key design insights for a future milk foamer. By using a five-step, mixed-methods research approach, I was able to answer all six research questions through the process of segmentation, behavioral tracking, interviews, product testing, and data synthesis.

RQ1 was answered in Step 1 by segmenting the Quooker customer base using survey data. This revealed five clear user groups, with Automation Seekers identified as the most promising segment for the initial product design due to their strong alignment with Quooker's efficiency-focused values.

RQ2 and RQ3 were addressed in Step 2 by tracking participants' coffee routines through emotional card-sorting. This revealed when users prepare coffee, how they feel during those moments, and what role coffee plays in their daily rhythm — from a comforting ritual to a functional necessity.

RQ4 and RQ5 were explored in depth during Step 3, where qualitative interviews uncovered underlying habits and latent needs related to coffee and milk preparation. The participant-led co-analysis method brought to light both practical barriers (e.g., cleaning effort) and emotional drivers (e.g., morning stress, desire for control), offering rich input for user-centered design.

RQ6 was answered in Step 4 by conducting hands-on testing of three different milk foaming systems. This comparative evaluation clarified what participants value most in a milk foamer: asynchronous operation, low maintenance, intuitive use, and a safe, plug-and-play experience — especially for Automation Seekers.

All of these insights were synthesized in Step 5 into a **persona**, Sophie Vermeer, representing the core target user. The persona draws together demographic data, emotional patterns, behavioral insights, and brand perception to provide a human-centered foundation for design. It reflects not only what Sophie does and wants, but also why — linking her functional requirements to deeper psychological needs.

This persona now serves as a bridge between user research and product development. It ensures that the resulting milk foaming solution will resonate with real users, not just technically perform. As such, the research phase not only answered the initial questions but also transformed them into actionable insights for design.

4 Sharp, early, and fact-based product definition (Phase 2)

Before beginning the design process, it is essential to define a clear direction, scope, and set of criteria to guide development. This chapter outlines the future vision, design scope, target market, and program of criteria that together form the foundation for the concept development phase.

4.1 Future vision

Before the design process starts, it is crucial to know what the future vision is. This allows the design process to have a destination on the horizon. The future vision is expressed as a desired direction and will provide a strategic reference point. Whether it is to guide the design, make strategic choices, or motivate a design team or stakeholders, a good future vision is the cornerstone. To establish a good future vision, the theory of the IDE course design roadmapping will be used together with the theory of the book Design Roadmapping by Simonse (2018). For this project, the following future vision has been created:

We imagine a future where crafting the perfect cup of coffee at home is effortless, joyful, and sustainable. A world where a milk foamer empowers people to elevate their coffee-drinking experience to barista quality at the touch of a button. All this, while being hassle-free and seamlessly integrating into the modern kitchen. Together, we are redefining the future of coffee rituals.

This vision embodies the four aspects highlighted by Simonse (2018) that define a good future vision. Firstly, the future vision should be **clear**. This is why relatable words such as "effortless" and "barista quality" were chosen, concepts that resonate with everyone's experiences. Next, a future vision should incorporate **value drivers**. This means that a future vision highlights benefits and addresses user needs and dilemmas. During the 5-step user research process, the needs and pain points of our customer segments were identified. These, and Quooker's philosophy, were incorporated into the future vision through terms like "seamless ", "integrating into the kitchen" and "the touch of a button". The desire for drinking good coffee without the need for effort was also integrated, creating a sense of **magnetism** for the reader. The future vision is formulated in a way that motivates stakeholders, particularly with the final statement.

The last aspect of a good future vision is the **artifact**. This is typically achieved through renders or, in the automotive industry, with concept cars. For us, this will be done through renders and prototypes, which will eventually be incorporated into the roadmap.

4.2 Design scope

The goal of this thesis, and thus the design scope, is to analyze the needs of Quooker's Coffee Tap users and create a suitable milk foamer. The objective is to design a solution that fulfills customer needs while aligning with the Coffee Tap and remaining viable for Quooker. This does not necessarily mean developing a novel method for creating milk foam. While this may be an exciting design challenge, it is unlikely to benefit the consumer, Quooker, or the environment. The solution should be prototyped and serve as a proof of concept for Quooker.

4.2 Design scope

From the research conducted in this thesis, we have defined our target customer. It is essential to keep this customer in mind throughout the design process. To ensure this, the key characteristics of the target customer are summarized below.

While the target customer represents the primary user we are designing for, the product may also appeal to individuals outside of this group. The target customer is a Quooker owner or someone considering purchasing a Quooker, typically falling into the YUP (Young Urban Professional), DINK (Dual Income, No Kids), or Empty Nester demographic. This person is often in the process of buying a new kitchen and belongs to the automation seeker segment, someone who desires a quick coffee with foamed milk while minimizing effort.

This customer values consistency and does not require extensive control over their milk foam. They prioritize ease of cleaning and expect the device to align with Quooker's clean-counter philosophy. The product should have a luxurious look and feel, complementing other Quooker products, yet the customer may not have a deep understanding of milk foam quality. Additionally, the solution must be compatible with milk alternatives, ensuring versatility in usage.

4.4 Program of criteria's

Before the design process begins, the list of requirements is drafted. These requirements are based on research conducted on the design problem. It is important to note that some criteria are directly derived from research presented in this thesis. For example, requirement M1, which states that the system must require minimal cleaning or be dishwasher safe, is supported by research findings. Other requirements, such as the criteria that the device should not consume more than 2300 watts, are industry standards and do not require separate justification within this thesis. These requirements, however, are referenced with appropriate sources.

Additionally, note the wording used for the requirements: Must, Should, and Could. To achieve a "Good" design, all Must requirements must be fulfilled. The Should requirements should be met whenever possible, while the Could requirements are considered desirable but not essential. The requirements are also categorized into subcategories, as shown in Figure 39. The six subcategories were not based on an existing framework but were developed by me after reviewing and clustering the full list of design criteria found in Appendix 15. This approach allowed for grouping recurring themes and aligning them with the needs and preferences uncovered during user research. Additionally, structuring the criteria this way made it easier to apply a weighted criteria method for idea evaluation, as it would not have been feasible to assess each concept against an overly long list of individual criteria.

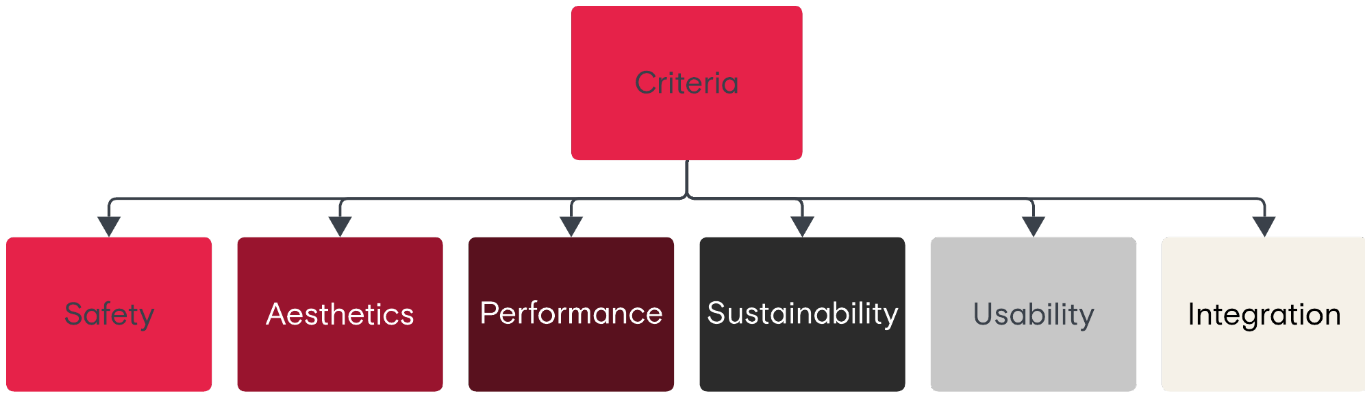


Figure 39: Subcategories Criteria's

Must Criteria

#	Requirement	Subcategory & Source	Importance	How/Why	Quantification or Rationale	Quantified Value
M1	The system must require minimal cleaning or be dishwasher safe.	Usability (4.3, results)	Must	Users prioritize convenience and hygiene. Dishwasher-safe parts simplify cleaning.	Components should be dishwasher-safe or require cleaning in under 30 seconds.	30 seconds
M2	The system must fit into Quooker's clean and minimalist design language.	Aesthetic Integration (2.3, Quooker's design philosophy)	Must	Quooker's brand identity focuses on sleek, clutter-free designs.	Dimensions should match Quooker's product line and maintain minimal visible components.	-
M3	The system must handle standard milk volumes for household use.	Performance (2.2, Milk in coffee)	Must	Ensures suitability for typical use cases, like making coffee for one to four people.	Should foam 100-250 mL of milk in one cycle.	100-250 mL
M4	The system must include safety mechanisms for overheating and dry operation.	Safety (5.3, Aeroccino)	Must	Ensures user safety and device longevity.	Include thermal cut-off or sensors for liquid detection or connection hall sensors	-
M5	The system must not exceed the maximum allowable power draw for typical kitchen sockets.	Safety (Personal conversation within Quooker)	Must	Prevents circuit overloads and aligns with household electrical standards.	Maximum power draw should be under 2300 watts.	2300 watts
M6	The system must support multiple foaming cycles back-to-back without overheating.	Performance (4.4, maximum number of coffees consumed)	Must	Prevents downtime for households preparing multiple drinks.	Allow at least 5 consecutive cycles without thermal shutdown.	5 cycles
M7	The system must be operable by users aged 14 and older without prior training.	Usability (4.4, results)	Must	Ensures intuitive use, reducing the learning curve and making the system accessible without prior experience.	Achieving successful operation within 30 seconds of first use. (when having used Coffee Tap previously)	30 seconds
M8	The system must not spill more than 25ml of liquid during operation.	Integration (2.2, Quooker's Coffee Solution)	Must	The drip tray of the Quooker Coffee Tap is small, and excessive spillage could lead to mess and inconvenience for the user.	Volume of drip tray	≤ 25ml
M9	The system should produce foam in a quick and efficient manner.	Performance (4.4, results)	Must	Ensures user satisfaction by aligning with the need for a fast, modern kitchen experience.	Foam production and heating should not take longer than 90 seconds.	90 seconds

Should Criteria

#	Requirement	Subcategory & Source	Importance	How/Why	Quantification or Rationale	Quantified Value
S1	The system should operate quietly to match Quooker's premium standards.	Performance (4.4, results)	Should	Quiet operation improves the user experience and aligns with Quooker's high-end appeal.	Noise level should not exceed 50 dB during operation.	50 dB
S2	The system should integrate with the existing Coffee Tap without requiring an additional hole in the countertop	Integration (2.2, Quooker's Coffee Solution)	Should	Maintains Quooker's clean-counter philosophy and simplifies installation by avoiding modifications to the kitchen setup.	Only 1 extra hole should be required for the entire coffee system	1 hole

Could Criteria

#	Requirement	Subcategory & Source	Importance	How/Why	Quantification or Rationale	Quantified Value
C1	The system could be made of recyclable materials.	Sustainability	Could	Aligns with modern sustainability standards and user expectations.	Use at least 50% recyclable materials in construction.	50% recyclable
C2	The system could offer manual adjustments for advanced users.	Usability	Could	Adds value for users who enjoy fine-tuning temperature or foam density.	Option to adjust temperature (0-75°C) or foam density with a secondary interface.	0-75°C

5 Iterative, spiral development – build, test, feedback, and revise (Phase 3)

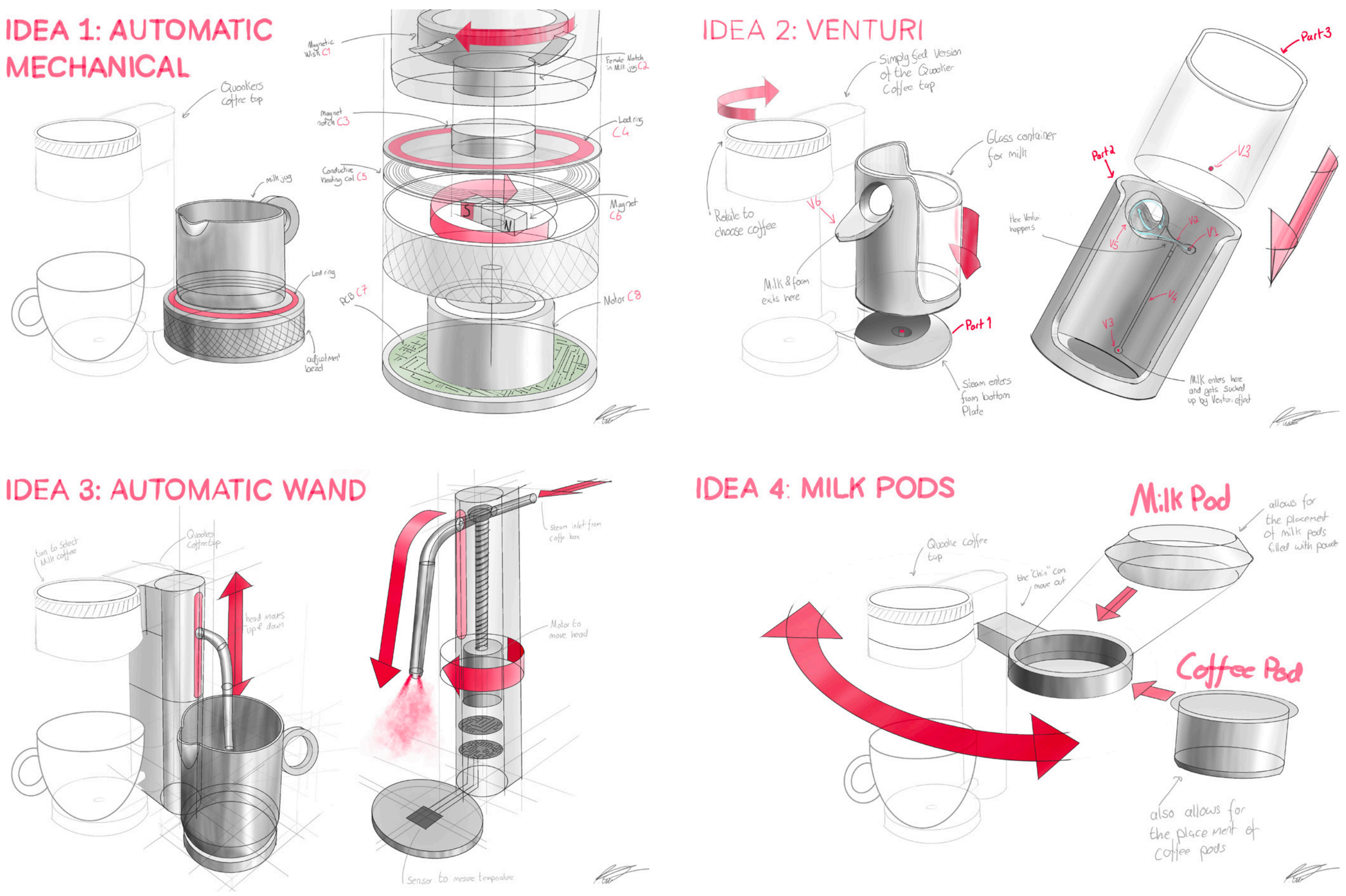
Now, the first part of phase 4 has begun. This phase involves generating various ideas that are built upon the customer research conducted in the previous phases. Since we now have a clear understanding of our customers and their desires, we can develop concepts that align with their expectations. To achieve this, we apply different methods presented in the Delft Design Guide (Van Boeijen et al., 2014). These methods encourage us to think outside the box and combine different existing solutions.

A variety of ideation techniques were used to explore the design space and stimulate creative thinking. These methods helped generate a diverse set of early ideas, which laid the groundwork for the development of eight distinct concept directions. A detailed overview of the ideation process and the methods applied can be found in Appendix 9.

5.1 Ideation Overview

During the ideation phase, eight diverse concept directions were generated to explore how milk foaming could be seamlessly integrated into the Quooker ecosystem. These concepts represent a wide range of technological approaches, from mechanical foaming to steam-based systems and even capsule or ultrasonic-based solutions. The goal of this phase was to think broadly before narrowing down.

An overview of the eight initial concepts is presented in Figure 40. Detailed descriptions, illustrations, and the rationale behind each idea are provided in Appendix 10 – The 8 Ideas.



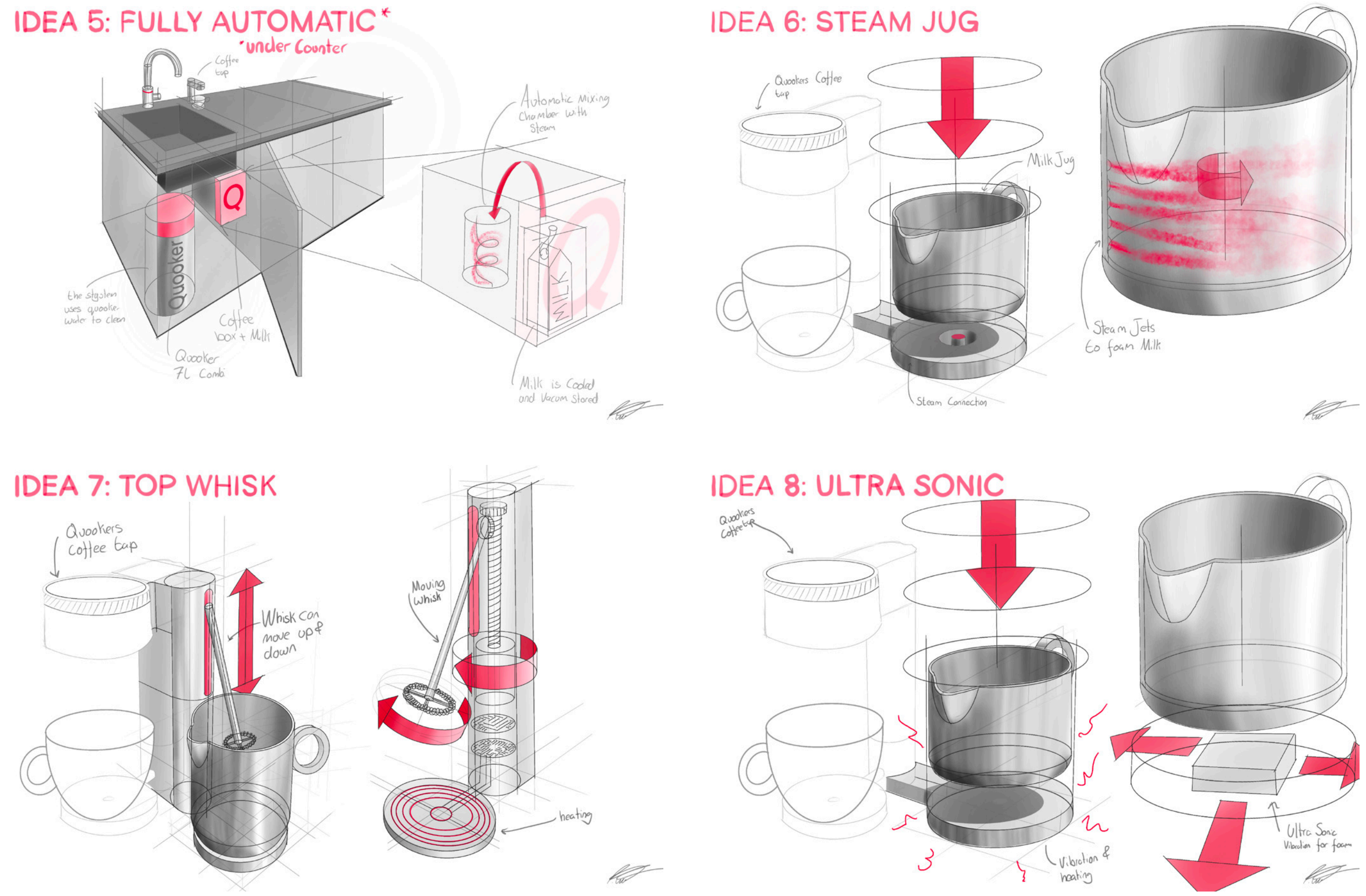


Figure 40: A visual summary of the eight ideas generated during early ideation. For a full breakdown of each concept, refer to Appendix 10.

5.2 The 3 most promising concepts

The three most promising ideas were generated, just like the other 5 ideas, using methods such as, the morphological chart, see Figure 41.

To determine which concepts had the most potential, eight ideas were evaluated using a Harris Profile method (Van Boeijen et al., 2014), which compared them across key criteria such as usability, performance, and integration. While a full overview of this comparison is included Appendix 11, the analysis ultimately led to the selection of three promising concepts that best align with user needs, Quooker's design philosophy, and technical feasibility. These concepts are presented and discussed in detail below.

Explained: Idea 1 The Automatic Mechanical System

Idea 1 is called the Automatic Mechanical System. While the name is not particularly catchy yet, it effectively describes the product category and functionality. The system uses a motor with a magnetic drive to spin a disk inside a milk jug. As the disk rotates to create foam, an inductive system heats the bottom of the milk jug, warming the milk simultaneously. This design builds upon and iterates existing market solutions, featuring a detachable, dishwasher-safe milk jug placed on a base. Inside the jug, a spinning disk foams the milk at a nanofoam level (see C1 in Figure 42), achieved through a turbine mechanism that forces the milk through a fine steel mesh. The disk spins within the jug and is powered magnetically (C6), ensuring easy cleaning with no direct motor contact with the milk.

A magnet is placed inside a notch (C3) that extends from the base. This notch fits into a cutout inside the milk jug (C2), where the spinning disk is positioned. This alignment ensures that the spinning magnet and the disk interact through a magnetic field, transmitting power without physical contact.

Compared to competitor products, the detachable jug eliminates the need for waterproofing electronics, making it dishwasher-safe and easy to clean. The compact base houses all electronics and is designed to integrate seamlessly with the Quooker Coffee Tap, avoiding the need for an additional hole in the kitchen countertop. Inside the base, an inductive heating coil (C5) provides over 500 watts of power, heating up to 150 ml of milk, sufficient for most coffee recipes, in under a minute. A powerful DC motor (C8) inside the base drives the magnetic spinning mechanism. The system is managed by a motor driver and microcontroller (C7), which also controls the inductive heating coil. A current converter transforms 230V into the appropriate levels for the system's components.

Interaction with the device follows the intuitive design philosophy of Quooker taps. A textured control ring allows users to set the milk temperature, adjustable from 0 to 75°C, making it suitable for both iced coffees and warm drinks. An LED ring (C4) displays the selected temperature, which is confirmed and stored for future use by pressing the ring. After selecting the temperature, the LED changes from red to white, signaling the user to set the foaming duration (0 to 120 seconds). Longer foaming times create stiffer foam. For added convenience, pressing the button twice quickly selects the previously used settings, while holding the ring activates the default settings. This ensures flexibility for both advanced users who prefer customization and those who want a simple, hassle-free experience.

Advantages

- The system is fully backward compatible. The Coffee Tap could be placed on an adapter that allows a 230V cable to exit the tap stem and power the device. The device can be clicked onto the tap, creating a cohesive product.
- While the system consists of multiple parts, the technology itself is relatively simple.
- The detachable jug is easy to clean and dishwasher-safe.
- The system can be sold as a standalone product.
- Being separately controllable from the Coffee Tap allows full control over the foaming process.
- Milk and coffee can be prepared simultaneously.
- The system supports the foaming of cold beverages.

Disadvantages

- The system is bulky on the countertop.
- Using mechanical foam production instead of steam does not follow a logical narrative.
- The components are expensive and have a high environmental impact.
- The additional heater increases power consumption and places extra strain on power breakers.
- The system may not feel like a fully integrated product with the Coffee Tap, potentially lacking synergy.
- Inductive heating could be complex to implement.
- The quality of the milk foam may not be optimal.
- The product might not be compelling enough compared to alternatives like the Aeroccino.

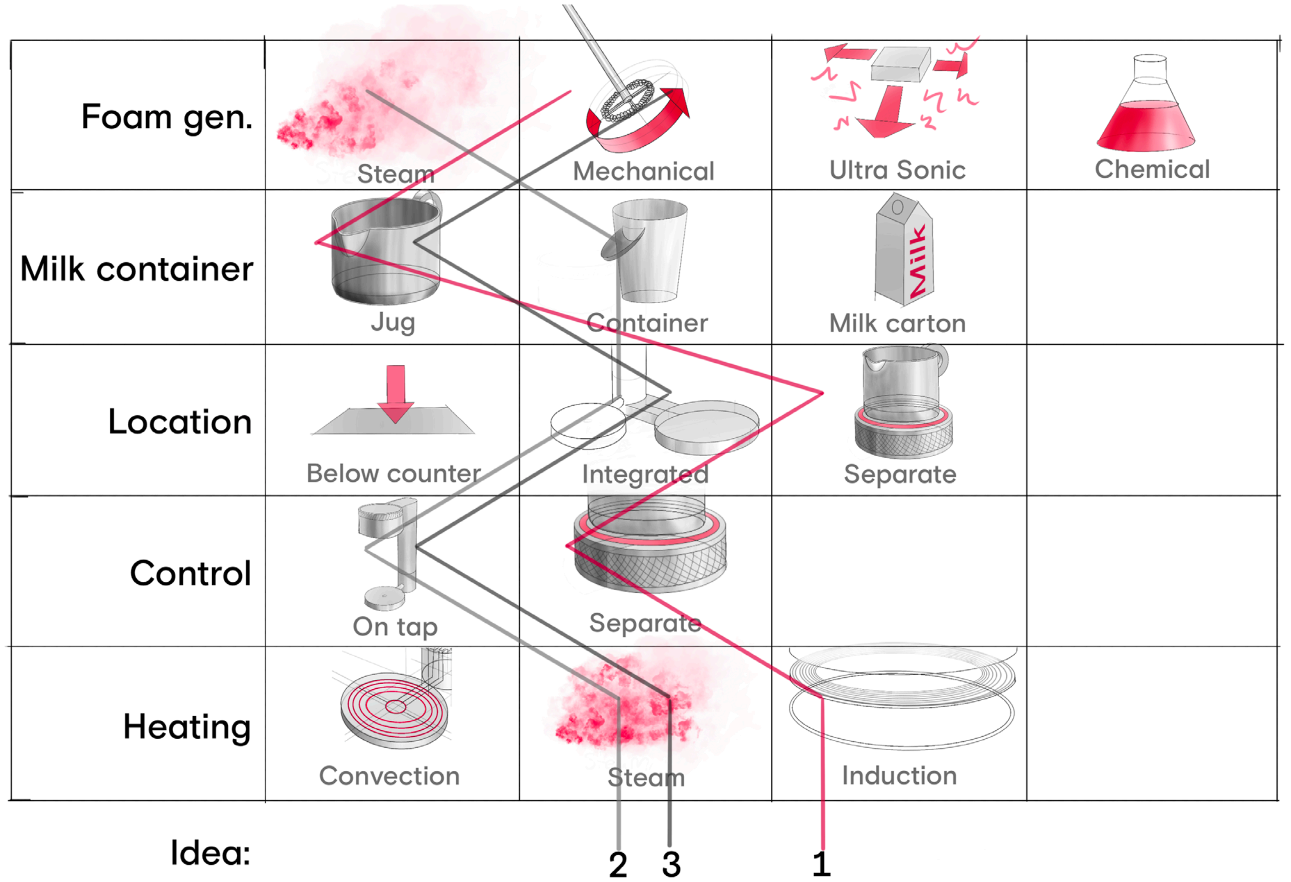


Figure 41: The morphological chart filled in for the 3 most promising concepts.

In the render shown in Figure 43, you can see how this design would appear in real life alongside the Quooker Coffee Tap. The exploded view in Figure 44 illustrates that all the necessary components for this system are contained within the device itself.

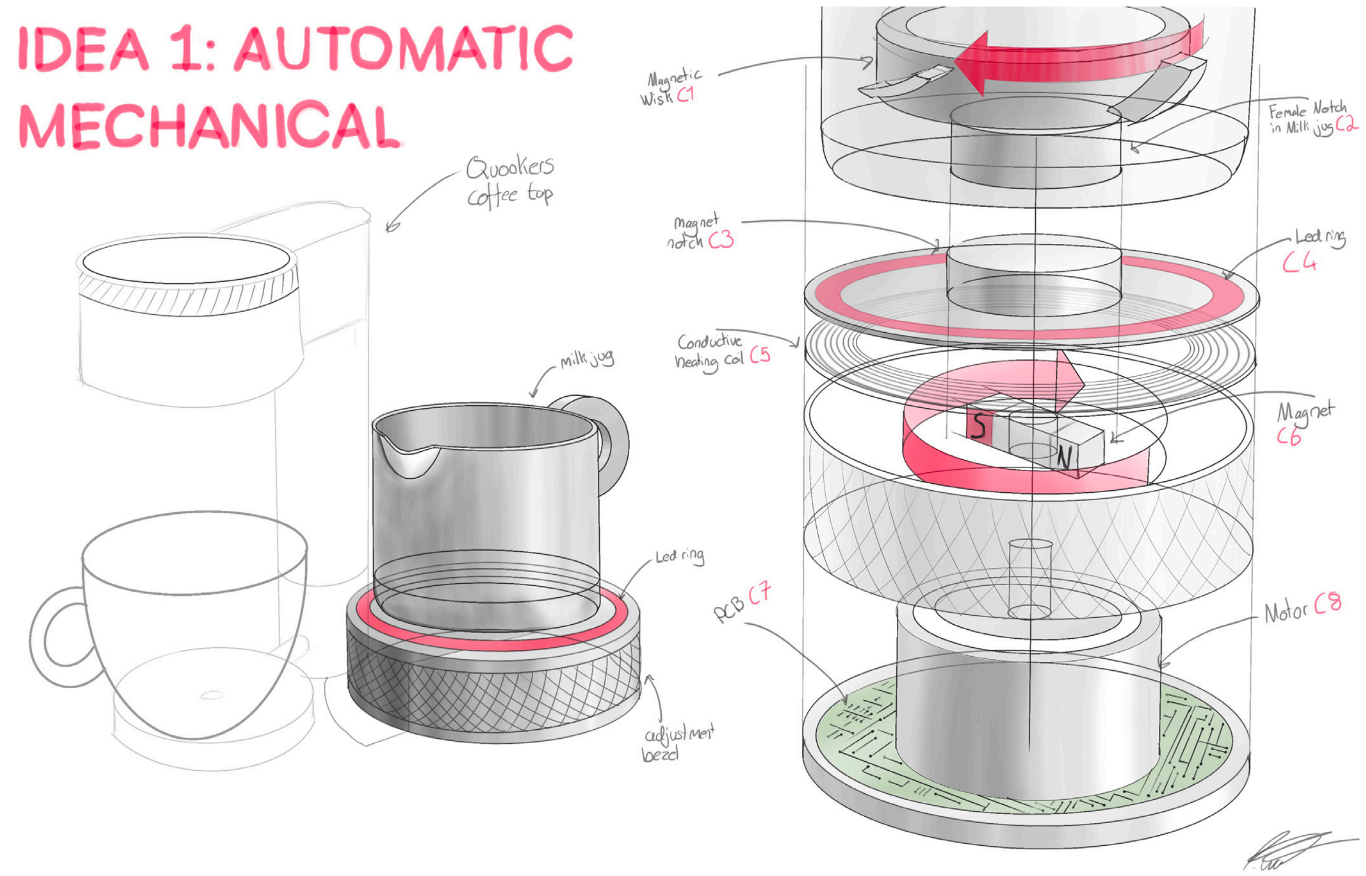


Figure 42: Drawing of Idea 1: Automatic mechanical


Figure 43: Rendered concept of Idea 1, featuring an integrated milk container with a ring interface and illuminated LED feedback for user interaction.


Figure 44: Exploded view of Idea 1, revealing the internal components including the LED ring interface, electronics, motor, and integrated milk container.

Explained: Idea 2 The Venturi Concept

The second concept, for now called the Venturi Concept, uses steam to draw milk from a container (see Figure 45 for a drawing of concept 2). It is based on the Venturi principle, a physics phenomenon that will be explained in detail in the Appendix 12 – The Venturi Principle explained. For now, it is important to understand that a stream of steam creates suction, pulling milk through a channel where it is subsequently steamed and frothed in a chamber.

This concept is similar to the LatteGo system from Philips but has been modified and optimized to better suit Quooker users. It integrates with the existing backend of the Quooker Coffee Tap, meaning the solution requires minimal additional components. Since it utilizes the pump and heater already installed under the countertop, it is a highly efficient and cost-effective approach.

The system consists of three main parts. The first part is the stand, designed with a visual language similar to the drip tray. This round base connects to the Coffee Tap and could, in theory, be installed as an add-on, ensuring backward compatibility. Through this base, a steam tube links to the Coffee Box located under the counter. The base also serves as the connection point for the two remaining parts. This connection could be achieved using strong magnets that are capable of countering the steam pressure while ensuring a secure seal or through other snap-fit mechanisms. Making the base detachable from the upper parts allows for the milk-contacting components to be placed in the dishwasher for easy cleaning.

The second and third parts form the Venturi system and are held together using magnets or another sturdy mechanism. These two halves split the Venturi system in half, making all surfaces that come into contact with milk directly accessible for cleaning. The design ensures they can be easily washed or placed into the dishwasher.

The outer shell of the Venturi system, or Part 2, is the section that connects to the base. Here, steam flows through the structure and exits into the Venturi tube (marked as V1 in Figure 45). The steam then passes through the Venturi channel (V2), where it creates suction, pulling milk from Part 3 through an intake hole (V3) and up the milk channel (V4). Inside the mixing chamber (V5), the steam and milk are combined and frothed before flowing directly into the user's coffee cup (V6).

Part 3 serves as the milk reservoir and acts as the outer wall of the system. It is crucial that Parts 2 and 3 form an airtight and watertight seal to ensure the system functions properly. The entire system is operated using the existing interactions on the Quooker Coffee Tap, ensuring a seamless user experience without requiring additional controls.

Advantages

- The system uses the existing Coffee Tap infrastructure, meaning it remains simple and requires minimal additional parts.
- This simplicity makes it a cost-effective solution.
- Using steam as the heating and foaming method is intuitive for customers, as Quooker is already associated with boiling water.
- No skill is required to achieve high-quality milk foam, as the milk and foam flow directly into the coffee cup without any extra steps.
- The system is easy to clean, as all milk-contacting components can be placed in the dishwasher.
- The design aligns with Quooker's clean counter philosophy, keeping most parts hidden under the counter while utilizing the existing Coffee Tap hardware.
- The use of steam ensures high foam quality and allows for foaming alternative milks.

Disadvantages

- The system is similar to Philips' LatteGo, which is patented. While Quooker's patent experts confirm there is freedom to operate, designing a solution that circumvents existing patents while improving upon the LatteGo system will be a challenge.
- While the milk foam quality is good, refining it to an excellent standard may prove difficult, if not impossible.
- Although the system is semi-backward compatible, it requires certain decisions to be made by the Coffee Tap team. For this concept to be viable, the team would need to select a more expensive heater capable of producing steam, integrate an additional valve into the Coffee Box, and modify the tap interactions to support the new milk foaming function. While these adjustments are relatively simple and cost-effective, they require significant confidence in the system before moving forward.

This concept is illustrated in Figure 46. Note that the Coffee Tap shown is a simplified representation of the final design. For this system to function, steam must be generated, as explained in the Appendix 11 - Steam Generation.

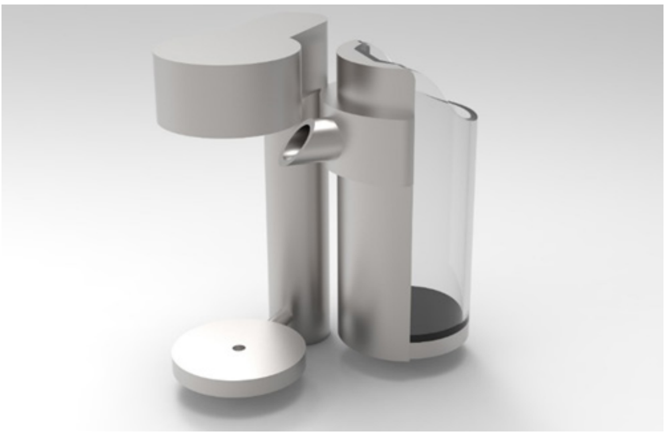


Figure 46: Rendered concept of Idea 2.

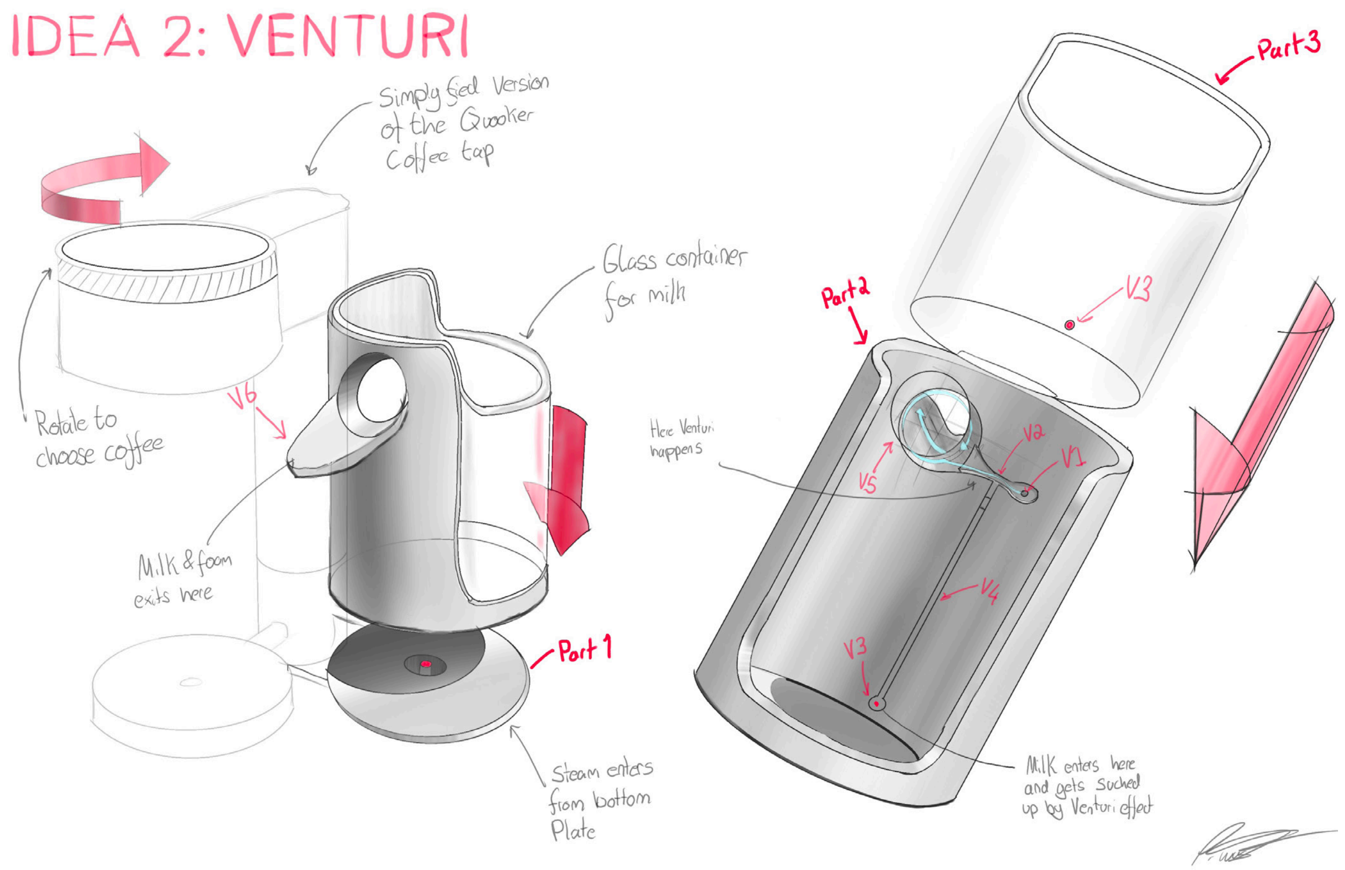


Figure 45: Drawing of Concept 2: Venturi

Explained: Idea 3 Automatic wand

The third concept (see Figure 47) builds upon the traditional method baristas use to steam milk, but fully automates the process. This is achieved by integrating a sensor in the base that measures the milk's temperature in real time. The steam wand is powered by steam generated in the Coffee Box, and its nozzle can move up and down automatically using a spinning motor or stepper motor. Like Idea 2, this system is controlled via the Coffee Tap, ensuring a seamless user experience.

This concept provides a premium feel, as it closely mimics the way professional baristas prepare milk foam. Additionally, since the system uses steam to heat the milk, it is highly compatible with alternative milk options.

Advantages

- The system delivers a professional experience, as it replicates the milk foaming process used by baristas.
- Thanks to the use of steam, it is well-suited for alternative milks.
- It utilizes the steam production of the Coffee Box, making it a logical and efficient solution.
- Because it operates with a milk jug, users can refine the foam by spinning or tapping the jug to remove larger bubbles, allowing for post-optimization of the milk texture.
- The system can handle larger portions of milk, making it more versatile for different serving sizes.

Disadvantages

- While the milk jug can be placed in the dishwasher, the steam wand must be cleaned manually, a step often overlooked, leading to potential bacteria buildup.
- The system relies on multiple electronic components, increasing the risk of failure points.
- A mechanism needs to be developed to position the jug under the steam wand, requiring either a pivoting arm or a system that moves the wand up and down completely.
- Maintaining consistently high-quality milk foam is challenging. Proper foaming requires the steam wand to remain at the milk's top surface, producing the characteristic sizzling sound, which this system may struggle to achieve.
- Finally, this system may not align well with consumer expectations. People prioritize consistency and ease of cleaning, both of which are weaknesses of this design.

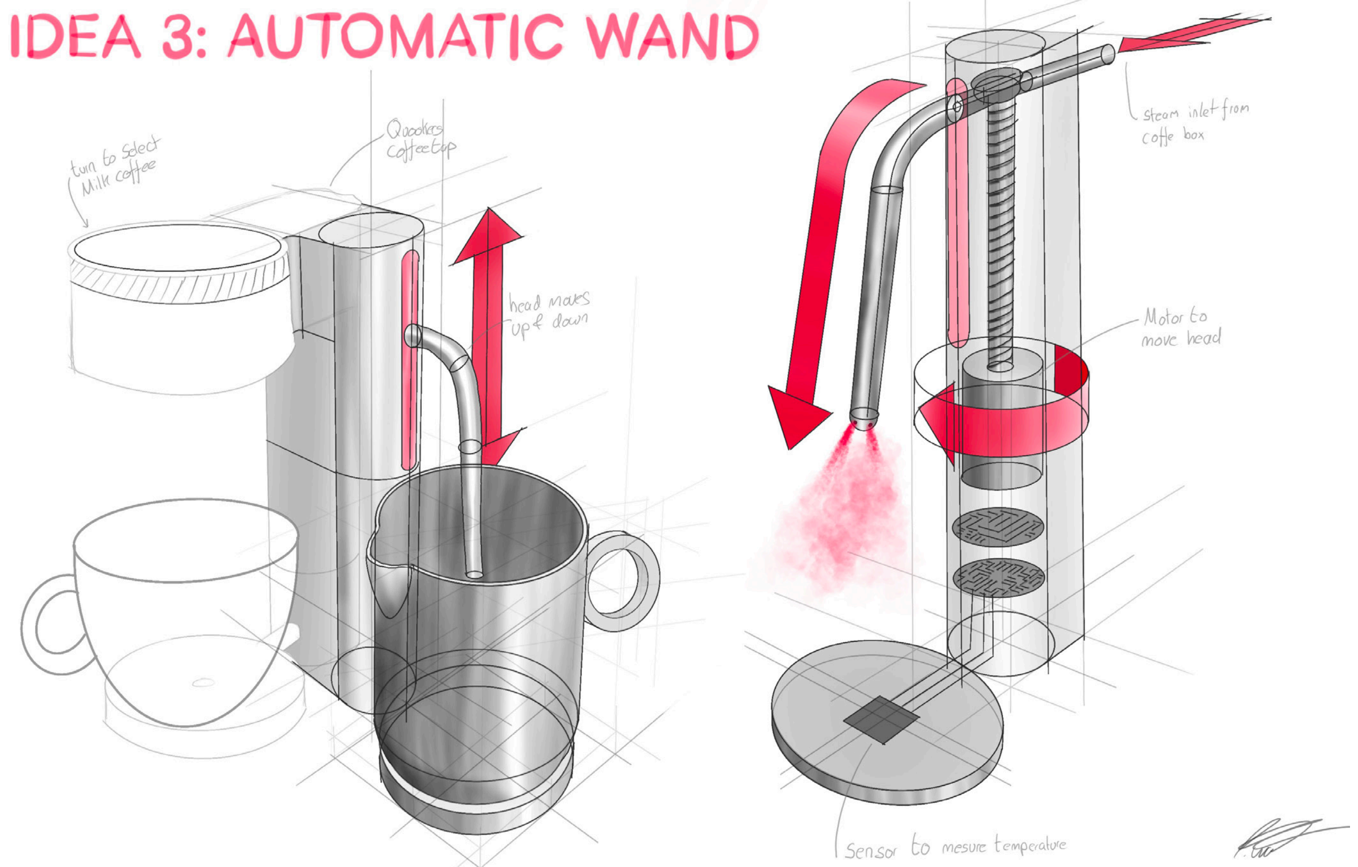


Figure 47: drawing of Idea 3: automatic wand

5.3 Choosing a concept

To make a choice between the top three concepts, a weighted criteria method (Van Boeijen et al., 2014) has been used (see Table 4). It is important to note that the actual design process is much more fluid than the table suggests. There are multiple reasons for choosing a concept beyond simply weighting criteria. This was also the case for this choice; however, this method is ideal for translating a complex decision into a simplified overview and serves as an effective tool for communicating the choice to the reader.

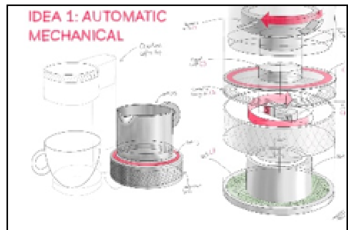
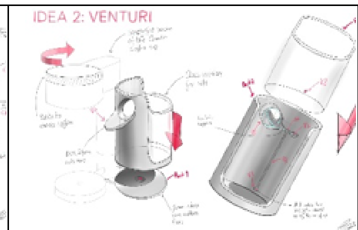
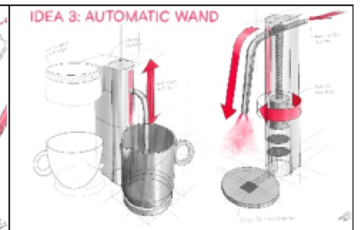
The method works by assigning weights to the criteria and subcategories on a scale from 1 to 100. In this case, subcategories are used because there are too many individual criteria. The weighting has been applied according to the needs ranked by the users, as expressed in Chapter 2 of the research. It is important to mention that while translating these ranked needs, I, as the designer, have also incorporated my own interpretation.

A good example of this is the criteria of safety and sustainability. These factors score very low in the weighted criteria, while in real life, they might be among the most important ones. This was already explained in the Harris profile, but I want to emphasize it again. The reason for assigning a lower weight is that these two criteria can still be addressed later in the design process.

For instance, the Venturi system uses steam, but by simply adding a Hall sensor that detects whether the Venturi is connected, the system can be made just as safe as any other. In the sustainability criterion, the main focus was on the number of parts required. However, since we are still in the concept phase, it is uncertain what materials will be used. The Venturi system may need fewer materials, but since it uses steam, it might require a less sustainable material compared to a mechanical system. Decisions like these will become clearer once we enter the embodiment phase, and therefore, they are weighted less at this stage.

Notably, Concept 2 scores the highest in the weighted criteria method. This is due to a few distinct advantages. The first major advantage is in usability. This is because the device can be placed in the dishwasher, and the milk foam is dispensed directly into the user's cup. Next, Concept 2 scores high in integration. This is because the device would use the same backend as the Coffee Tap, is backward compatible, and has a low profile. In terms of sustainability, it also scores quite well because it requires only a few parts and minimal or no electronics.

Table 4: Results of the weighted criteria method.

		 Concept 1: Automatic Mechanical		 Concept 2: Venturi		 Concept 3: Automatic wand	
	Weight	Score	Total	Score	Total	Score	Total
Usability	30	8	240	9	270	5	150
Performance	20	6	120	8	160	9	180
Integration	20	5	100	9	180	6	120
Aesthetics	15	6	90	7	105	6	90
Sustainability	7.5	4	30	8	60	6	45
Safety	7.5	8	60	6	45	4	30
Total	100		640		820		615

5.4 Explanation of the venturi system

A Venturi system operates on the principles of fluid dynamics, specifically Bernoulli's principle, which describes the inverse relationship between the velocity and pressure of a fluid in motion. When a fluid passes through a constricted section of a pipe—the Venturi throat—its velocity increases while its static pressure decreases. This localized drop in pressure can create a suction effect, enabling the drawing in of a secondary fluid or gas through a side channel. This effect is commonly used in applications such as carburetors, aspirators, and foam generation systems, where one fluid is used to entrain another without the need for additional mechanical components.

Application in the Quooker Venturi System
In the Quooker milk foaming solution, the Venturi principle is applied to enable the passive mixing of milk, air, and steam without active pumping. The system is composed of six key functional points, see Figure 48:

- **Point 1:** Steam enters the system from the Coffee Box through an inlet channel.
- **Point 2:** As the steam flows into a narrower section—the Venturi throat—its velocity increases, leading to a pressure drop.
- **Point 3:** This pressure drop creates a suction effect that draws milk up from an adjacent milk container via a dedicated inlet.
- **Point 4:** Simultaneously, a small calibrated air inlet allows ambient air to enter. This step is critical for foam formation, as the presence of air enables the creation of microbubbles when mixed with milk and steam.
- **Point 5:** The steam, milk, and air converge in a mixing chamber. Here, their interactions generate turbulence, initiating the foaming process.
- **Point 6**: A strategically designed ramp at the exit of the chamber introduces just the right amount of rotational turbulence, enhancing steam penetration and foam texture before the foamed milk is dispensed.

This integration of the Venturi mechanism allows the Quooker system to create high-quality milk foam using minimal components and no moving parts, ensuring hygiene, reliability, and compatibility with the existing infrastructure.

Figure 48: Exposed view of the Venturi-based milk foaming system with the seal and milk container removed.

5.5 Iteration on concept 2

A detailed overview of the custom steam testing setup is provided in Appendix 12. This appendix is crucial for understanding the technical testing process behind the prototypes. The setup replicates the core functionalities of the envisioned Quooker system while allowing precise control over every operational parameter.

Terminology iteration models

In this subchapter and the following chapter, I will introduce some key terminology. In Subchapter 7.4, I present the iterations of the lab setup for the Venturi system. These prototypes and development steps are referred to as, for example, "Venturi V1," as shown in Figure 49.

In Chapter 8, this process will be extended to include embodiment, introducing additional complexity. The insights from Subchapter 7.4, which serve as proofs of concept, will be integrated into a model that functions as the final product is intended to. This model is referred to as the integration model, as shown in Figure 49. In this model, components such as a milk reservoir and sealing mechanisms will be added.

Simultaneously, the Venturi lab setup will be optimized to produce higher-quality milk foam and to better align with the embodiment model. These iterative improvements are referred to as optimization steps.

Following this, a production model will be developed. Also referred to as the design model, this version will visually resemble the final product intended for consumers. As it is not optimized for prototyping, it will exist only as rendered images and, due to confidentiality, will be partially included in the embargoed appendix.

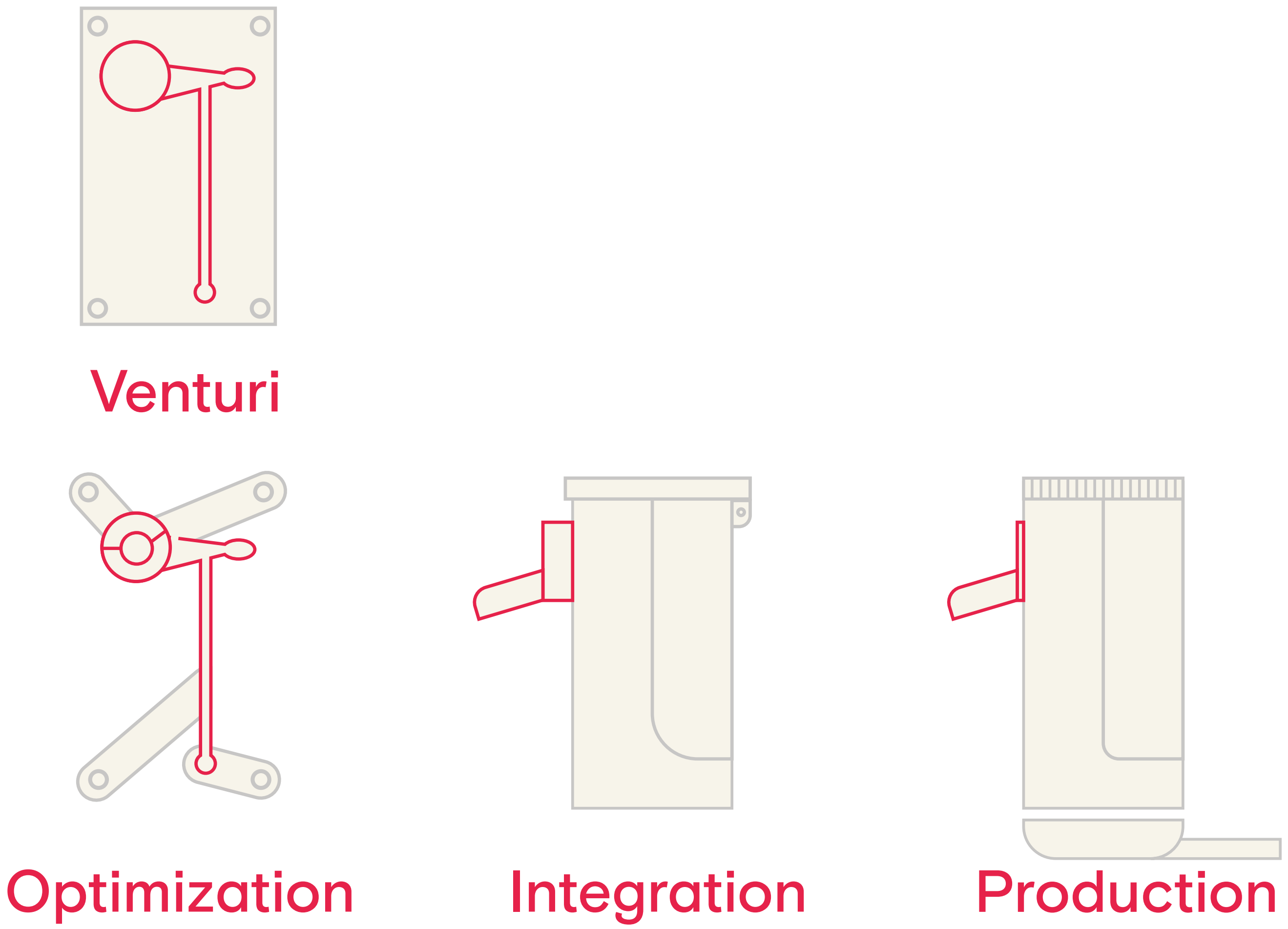


Figure 49: Overview of the iterative development process of the milk foamer system, progressing from basic Venturi principle testing to optimization, integration of components, and a final production-ready design.

Iterations Venturi model

Before the chosen concept could be embodied into a working design, an in-depth technical exploration of the Venturi system was required. Although the concept was promising in theory and aligned with Quooker's design values, practical implementation brought forward many unknowns, especially regarding steam behavior, milk-air interaction, and material constraints. Therefore, a structured, iterative process was initiated to test the Venturi principle in practice, assess its viability, and gradually refine the system to reach proof-of-concept quality. The full iteration trajectory and technical testing are detailed in Appendix 13 – Iteration on the Venturi system.

The process began with the creation of a 1:1 scale model, non-functional but essential for assessing proportions and alignment with the Coffee Tap in a physical kitchen setup. From there, the focus shifted to engineering experimentation, starting with simplified prototypes of the Venturi system that could be tested using a steam lab setup. These iterations aimed to replicate the key functional elements of market examples like the LatteGo system, while ensuring future compatibility with Quooker's under-counter hardware and clean-counter philosophy.

Rapid iteration was made possible through 3D printing. While PLA and PC (polycarbonate) are not ideal in terms of food safety or heat resistance, they allowed for fast turnaround and cost-effective testing of complex geometries. Early iterations (Venturi V1–V3) focused on validating the basic suction effect created by the steam flow, revealing that even basic configurations could draw milk successfully (see Figure 50 as an example). However, challenges emerged quickly: PLA deformed under steam heat, the mixing chamber designs were suboptimal, and air intake was insufficient for effective foam generation.

Through successive versions (V4–V6), key insights emerged. Foam quality was strongly influenced by the presence and placement of an air inlet, and turbulence in the mixing chamber was essential to achieve the desired microfoam. Material limitations, print resolution, and sealing between components were also critical. Tests revealed that even small changes in nozzle diameter (0.4 mm vs. 0.6 mm) could dramatically affect fit and foam output.

More advanced iterations (V7–V9) refined the seal design, reoriented the steam and air channels, and introduced a second Venturi-style air inlet for improved integration. Ultimately, Venturi V9 succeeded in producing stable and high-quality milk foam, meeting the expectations of non-expert testers and demonstrating the technical feasibility of this solution. These results validated the concept as a viable basis for the final product and provided a clear path forward for integration into a fully functional prototype.

This iteration phase not only proved the Venturi mechanism's effectiveness but also confirmed that it could be implemented with limited component complexity, dishwasher compatibility, and strong alignment with Quooker's clean aesthetic. The learnings gained, from steam dynamics to manufacturing tolerances, formed the technical foundation for the next step: embodiment design.

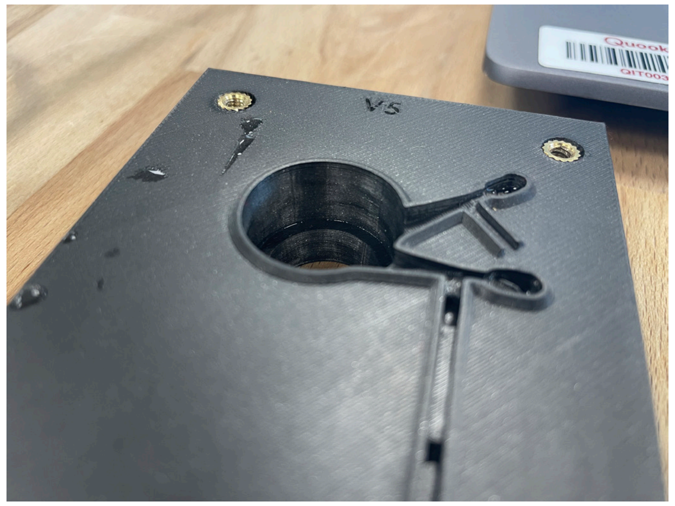


Figure 50: Example of a venturi iteration model

6 Embodiment Design (Phase 4)

After proving the technical viability of the Venturi system in earlier iterations, the next step was to integrate this mechanism into a complete product prototype. This phase marked the transition into the third diamond of the Triple Diamond methodology, Embodiment, where the focus shifted from isolated functionality to full-system integration. The goal was to transform the lab-validated Venturi setup into a compact, user-friendly, and manufacturable milk foaming unit compatible with Quooker's design language and backend hardware. The full process and associated iterations are documented in Appendix 14.

The embodiment process began with Integration V1 (see Figure 51 for an example),, which used the final Venturi design (V9) and aimed to establish a functional form factor and sealing mechanism. Although the model was not made of final materials and was oversized, it served as an effective physical reference for stakeholders and enabled early testing of the click-and-seal system.

In parallel, a series of optimization prototypes were developed to further refine foam quality and internal flow behavior. Early successes revealed the importance of chamber geometry, air turbulence, and surface finishing, most notably through sanding printed parts to reduce internal friction. A significant breakthrough occurred during Optimization V2, where the Venturi produced higher-quality foam than the commercial LatteGo system, while maintaining a compact orientation suitable for integration.

Subsequent integration steps focused on reducing the product's physical footprint, aligning it visually with the Coffee Tap, and maintaining performance. Integration V2 succeeded in downsizing the system to a 155 ml milk volume while matching the diameter of the Coffee Tap, improving both functional and aesthetic compatibility.

The final integration version, Integration V3, incorporated all learnings from previous rounds. This version featured a redesigned seal system, polycarbonate printing for heat resistance, and precise geometry adjustments to support a dishwasher-safe, detachable milk container. Though initial tests revealed some leakage, applying additional clamping force resolved the issue and resulted in high-quality, consistent milk foam. This final embodiment validated that the Venturi system could be scaled into a practical, user-centric product while respecting Quooker's clean-counter philosophy and usability standards.

Together, these embodiment iterations confirmed that the Venturi system could deliver on performance, compactness, and user experience. These outcomes laid the groundwork for the upcoming design phase, in which form, interface, and brand alignment will be refined for product readiness.

Figure 51: An example of a integration model

6.1 Design of the Final Venturi System

In this chapter, we will discuss the translation of the integration model into the design model. This design model represents how the final product should look. While my ambition is to keep the design model and the working prototype (integration model) as closely aligned as possible, this is not fully achievable, nor is it necessarily desirable.

The prototype has reached a stage where it fulfills its purpose as a proof of concept. As such, it is optimized for 3D printing and other prototyping manufacturing methods. However, this differs significantly from how the final product will be produced.

An example of this is the sealing. When a seal is 3D printed, it is much rougher than when injection molded. To compensate for this and achieve a leak-free prototype, increased clamping power may be required. This, however, could be undesirable for the final injection molded design.

Therefore, the design model should be seen as a conceptual representation of the final product. While it does take manufacturability into account to some extent, it remains at a very conceptual level. It should be regarded as an inspiration for what the final product could be, rather than as a definitive blueprint. Developing a product that is fully manufacturable would require more time than is feasible within the scope of this graduation project.

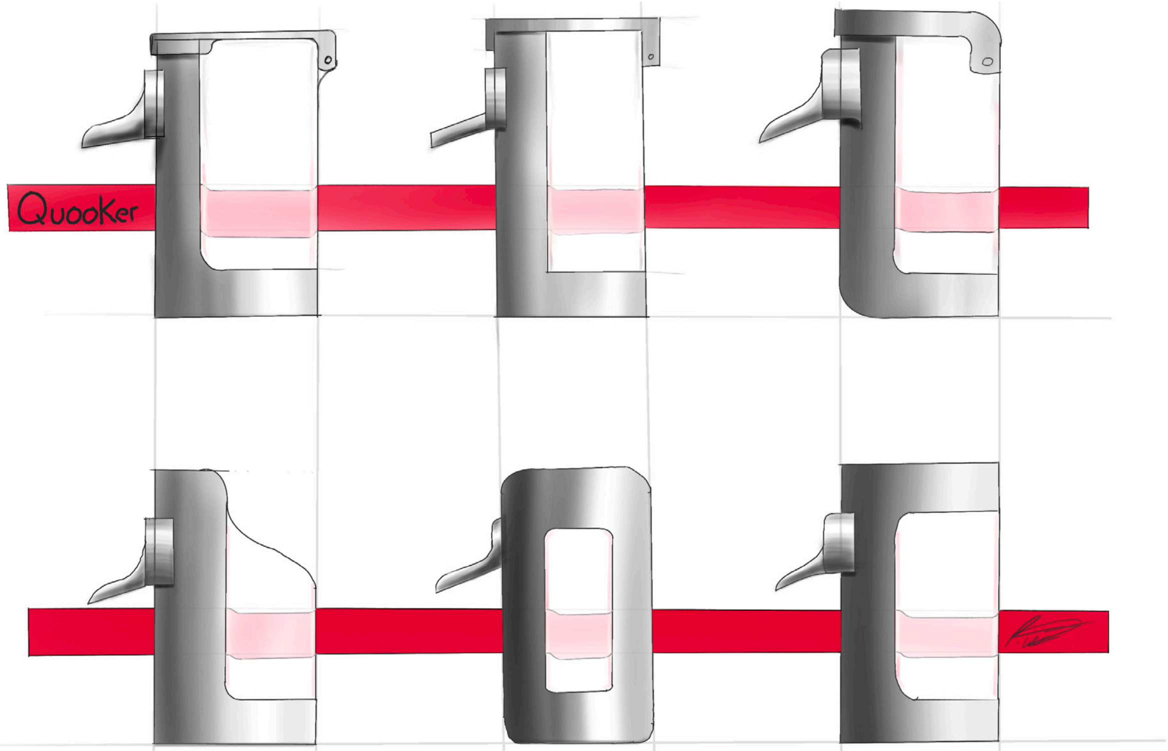


Figure 52: Design alternatives to the current integration prototype

Exploring different designs

The first steps involve translating the current functional properties, such as the venturi milk inlet needing to reach the bottom and the two-part design, into a form that is visually more appealing. A few ideas can be seen in Figure 52.

To enhance the synergy between the milk foamer and the existing Coffee Tap, and to refine the design of the venturi system, I consulted with the designer of the Coffee Tap. This aligns with the ambition to leverage in-house expertise and to make effective use of Quooker's available resources.

During this collaborative session, we reviewed the design in direct comparison to the Coffee Tap. This led to the formulation of several proposed design adjustments intended to create a more cohesive and visually integrated product. The proposed changes are as follows:

- Reduce the diameter of the venturi system. The current version shares the same dimensions as the Coffee Tap, which makes the milk foamer too visually dominant.
- Maintain the cylindrical shape and avoid enlarging the lid beyond the device's diameter.
- Integrate the drip tray with the milk foamer to visually unify both components.
- Apply consistent detailing by matching the venturi system's rounding to that of the Coffee Tap: a 5 mm radius at the bottom and a sharp 90-degree edge at the top.
- Align the appearance of the lid with the design language of the Coffee Tap.
- Relocate the hinge to the interior to create a cleaner exterior.
- Mirror the device so that the larger chamber is positioned at the rear, reducing its visual impact.
- Sharpen the outlet edges to replace
- the current soft rounding, resulting in a more defined and precise appearance.

In the design drawings used throughout this thesis, a mockup version of the Coffee Tap has been applied. However, this is no longer suitable when designing a milk foamer that requires a strong design correlation with the Coffee Tap. Due to the NDA agreement with Quooker, the final design cannot be fully shown in this report. As a result, the mockup version will continue to be used alongside the new design, which may appear inconsistent. The actual design can be found in Appendix 16 [EMBARGO] – Design of the Venturi System. Figure 53, shows a version of the Quooker coffee tap that uses a modified design of the original Quooker coffee tap.

Figure 53: The final design with a edited version of the Quooker coffee tap

7 Strategy & implementation (Phase 5)

With a validated concept in place, this phase focuses on exploring how the milk foamer can be positioned, integrated, and refined within Quooker's broader strategy. The chapter outlines an initial strategic roadmap for implementation, discusses the technical and functional integration with the Coffee Tap, and presents opportunities for customization to accommodate different user types. It concludes with a critical evaluation of the prototype's performance and maturity.

7.1 Strategic Roadmap

In Figure 54, a strategic roadmap illustrates the implementation of the Venturi system. The timeline of the roadmap is aligned with Quooker's planning for the Coffee Tap rollout. It outlines the necessary steps to realize the future vision for this product. Additionally, the roadmap highlights relevant trends and the value this product offers to users.

A strategic roadmap is primarily intended to convince stakeholders of a project's potential. Therefore, this version is designed to be displayed at Quooker to inform and persuade colleagues and management of the project's value. The roadmap also aligns with the stage-gate system, which is not discussed in depth in this thesis but has been used extensively within Quooker.

7.2 Quooker integration

A detailed description of the interaction between the milk foamer and the Quooker Coffee Tap is provided in Appendix 16 [EMBARGO?] – Interaction Design and Integration with the Coffee Tap. This appendix explains how the milk foamer connects physically and functionally to the coffee system, including safety features, user flow, and assembly logic. It also describes how feedback from a heuristic evaluation with Quooker's interaction expert led to important refinements in the interface.

Due to NDA restrictions, not all information can be disclosed, particularly the interaction design of the Coffee Tap itself. However, the appendix fully details the user interaction with the milk foamer and how it integrates with the system through a modular, backward-compatible connection.

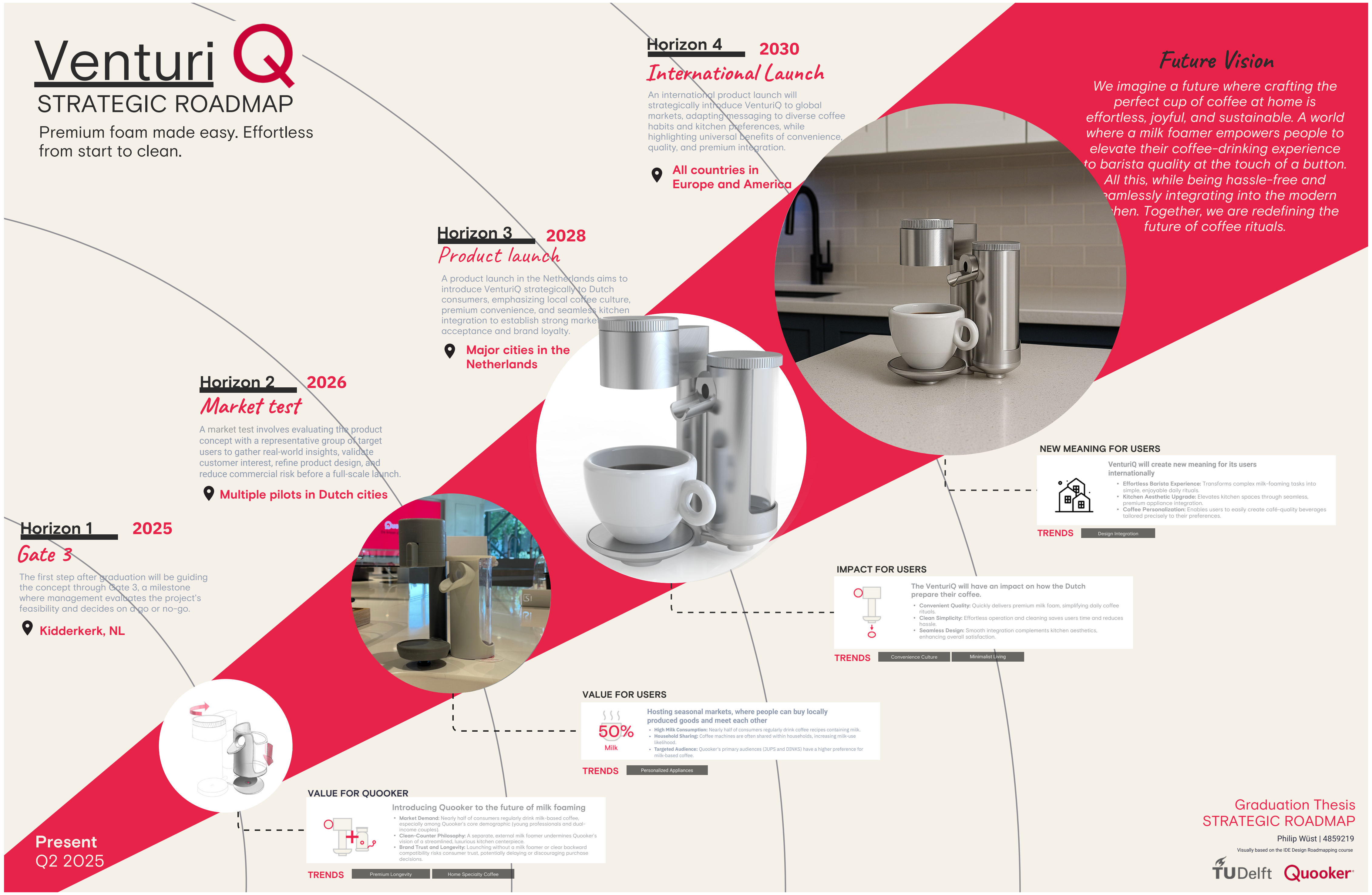


Figure 52: Strategic Roadmap of the Venturi system: A phased development plan from prototype to international launch, outlining key milestones, user value, and envisioned impact on the future of home coffee rituals.

7.3 Milk alternatives customization

As we are designing for the Automation Seekers segment, it is important that the product remains simple and effective. Previous research has shown that this group doesn't necessarily want customization, and they actively avoid screens, settings, or gauges. That's why the product is designed with an extremely simple interface (see Figure 55).

When a user wants to make, for example, a cappuccino, they simply twist the knob on the Coffee Tap to select "Milk" and press the button to confirm. This setting is optimized for full-fat cow's milk but will also produce decent milk foam with most milk alternatives. However, to achieve optimal results, the temperature and flow rate should be adjusted. This level of complexity, however, is too much to ask from most Automation Seekers.

Automation seekers with optimization need

That said, there is a notable subgroup within this segment that is open to taking a few extra steps to optimize their experience. For these users, we introduce the Quooker App, a project aligned with Quooker's broader ambition to integrate IoT into the Coffee Tap (see Figure 56). The challenge here is to design an interface that doesn't scare off users with graphs and overwhelming settings.

There are downsides to the trend of adding IoT to products that don't require it, such as increased resource and power consumption, as well as greater vulnerability to cyber-attacks. However, since Quooker is adding it to the Coffee Tap anyway, which will share the same Coffee Box as the milk foamer, I might as well take advantage of this opportunity. users to scan their (alternative) milk carton. A computer vision model will recognize the brand and version. Once the user confirms that this is their preferred milk, the app will automatically adapt the values to optimize the settings for that milk type.

Pro users

Then there is a final user group: the Pro Users. This group stretches the boundaries of the Automation Seekers, you could even argue that they're already high-end coffee enthusiasts. Own observations at coffee expos has shown that this group is growing.

A brand that resonates with these users is Sage, which offers fully automatic machines with a barista-like feel. Even Nespresso has entered this space with their Creatista line. These products give Automation Seekers a sense of control and the ability to tweak features within a predefined range.

In our context, we call them Pro Users. While they still prefer capsule coffee over traditional espresso (which keeps them in the Automation Seeker category), they want to push the boundaries of what their machine can do. We will accommodate them by introducing the concept of "brand ambassadors." These users can tweak the milk settings and share them with the community. The community can then vote on the optimal settings, and if enough users agree, these settings can become the new baseline for that specific milk alternative (see Figure 57). This also helps users achieve the highest form of brand loyalty, as discussed in the Brand Pyramid in Chapter 2.3.

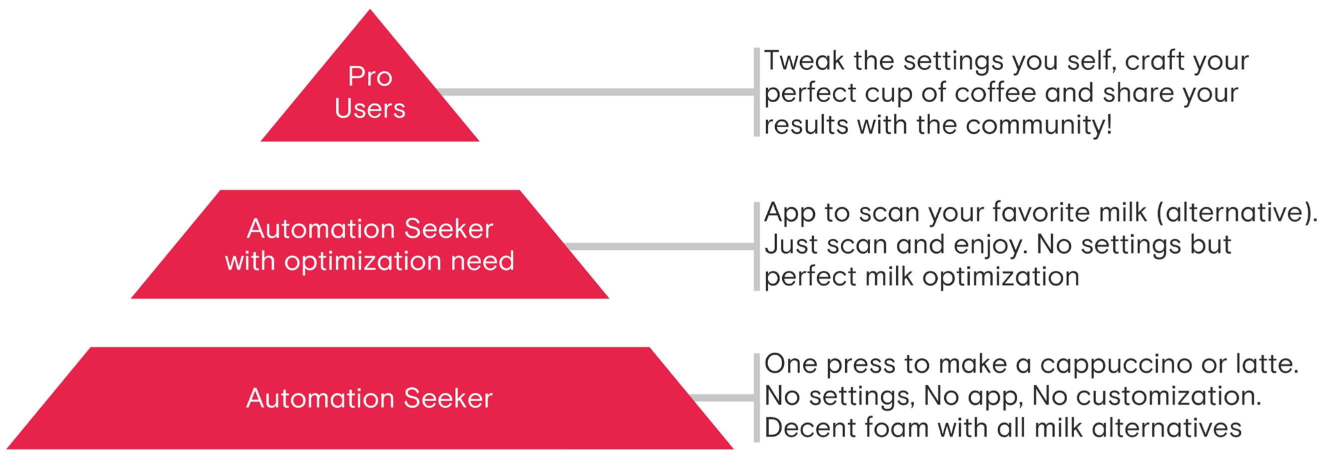


Figure 55: Needs Pyramid, milk customization

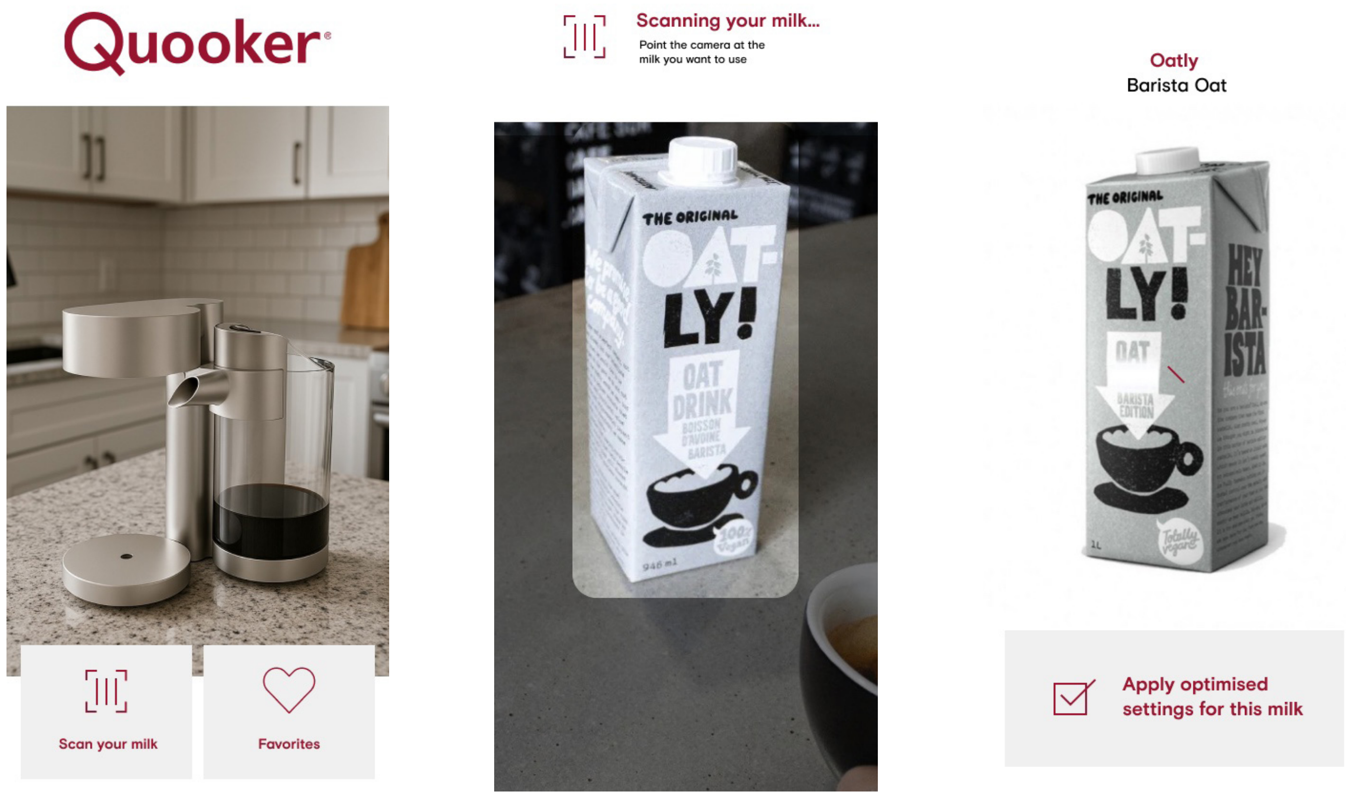


Figure 56: concept of how the app could look like. (image: Oatly)

It fosters a sense of community among users. This example illustrates how it might look in practice, but a detailed implementation falls outside the scope of this project. This approach also minimizes the effort required by Quooker to define settings for every new milk alternative product.

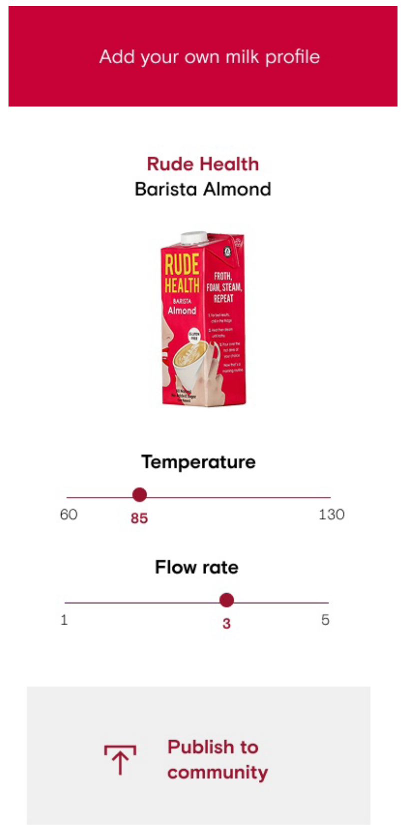


Figure 57: How the Pro user feature could look like. (image: Rude Health)

7.4 Evaluation

This subchapter reflects on how well the developed concept meets the defined objectives, combining a critical evaluation of the original design criteria with early-stage validation and technology readiness assessment. The goal is to understand how far the concept has come and what is still needed for future development. This section begins with a structured evaluation of the design criteria established earlier in the report.

Design Criteria Evaluation

To assess whether the final concept fulfills its intended objectives, each main criterion from the report has been reviewed individually. The evaluation considers both quantitative and qualitative findings, including design reviews, technical testing, and user-focused considerations. The following table summarizes the evaluation:

Code	Criterion	Fulfilled?	Justification
M1	Must be dishwasher safe	✅ Yes	The product splits at the right location to expose all milk-contact surfaces and is made from dishwasher-safe materials.
M2	Must align with Quooker design language	✅ Yes	Verified in collaboration with the designer of the Coffee Tap; shows strong visual and functional synergy. See *Appendix 15*
M3	Must handle 150 ml of milk	✅ Yes	The current prototype holds 155 ml, suitable for any milk recipe.
M4	Must be safe to operate	✅ Yes	Safety is ensured via a Hall sensor (detects locking) and a pressure sensor (detects steam drop when empty).
M5	Must not exceed 2300W power draw	✅ Yes	Utilizes components from Quooker's Coffee Box with built-in power limitations.
M6	Must withstand multiple cycles without overheating	✅ Yes	Prototype handled over 10 cycles successfully; more extensive testing was needed in final stages.
M7	Must be easy to use	✅ Yes	Interaction is intuitive, especially for users familiar with the Coffee Tap. See Appendix 14 for details.
M8	Must avoid spillage	⚠️ Partial	No spillage occurs under normal use. However, if no cup is placed, milk may be dispensed externally.
M9	Must heat and foam milk within 90 seconds	✅ Yes	The full cycle completes in 40 seconds and operates automatically.
S1	Should be quiet (under 50 dB)	⚠️ Partial	Currently measures ~60 dB, but expected to drop below 50 dB in final version using a gear pump and enclosed housing.
S2	Should integrate with the Coffee Tap	✅ Yes	A bridge component allows seamless integration without requiring additional countertop holes; backward compatibility is supported.
C1	Could be recyclable (≥50%)	✅ Yes	Designed with recyclable plastics and metals. Weak points are engineered for better material separation during shredding.
C2	Could serve different user types	✅ Yes	Layered design accommodates both automation seekers and power users, as discussed in Chapter

Discussion

The concept successfully meets the vast majority of its core functional, safety, and usability requirements. Must-level criteria (M1–M9) are all either fully satisfied or show only minor limitations in very specific edge cases (e.g., missing cup detection for M8). The sound level and recyclability goals (S1, C1) are close to being achieved, with reasonable expectations for full compliance in future iterations.

Importantly, collaboration with Quooker designers has ensured that visual alignment and brand integration (M2, S2) have been achieved, and thoughtful interaction design (M7) aligns well with the Automation Seeker segment. Safety, performance, and power considerations have also been addressed through hardware constraints and system safeguards.

Small validation user test

To gain early insights into user perception of foam quality and process expectations, a short informal test was conducted with six colleagues. Of these, five identified as Automation Seekers, and one as a High-End Coffee Enthusiast, representing two key personas from the user research. The goal of this test was to gather quick, experience-based feedback on both the foam quality and the foaming process as presented with the latest prototype. Because the prototype used in the test was made from polycarbonate (PC), it was not safe for food contact, and participants were therefore only asked to observe and visually assess the milk foam, not taste it.

All five Automation Seekers expressed high satisfaction with the foam quality and the automated nature of the process. They noted that the system appeared effortless and aligned well with their preferences for ease and speed. The single High-End Coffee Enthusiast participant initially raised concerns about the foam's texture retention and milk-coffee integration, but after repeating the demonstration into a glass jug (which allowed clearer observation of the foam structure over time), they were satisfied with its stability and fineness.

In addition, two participants directly compared the foam quality to that of the Philips LatteGo and Nespresso Aeroccino. Both stated that the foam from the Venturi-based prototype appeared superior in terms of texture and microfoam structure. However, it should be noted that this comparison was not blind or highly controlled, and subjective bias may have influenced their feedback. Cleaning and usability were not tested directly in this session but were briefly discussed. Participants responded positively to the idea of a dishwasher-safe, detachable milk container, stating that this would reduce perceived effort and increase convenience.

These early impressions suggest that the concept aligns well with user expectations, particularly those of the Automation Seeker persona and supports the initial assumptions made during the criteria definition phase. Nonetheless, more rigorous and food-safe testing will be required to validate these impressions in a realistic use context.

Technology Readiness Assessment (TRL)

To assess the maturity of the current milk foaming prototype, the Technology Readiness Level (TRL) framework has been used. This system, commonly employed in innovation and engineering environments (e.g., by NASA), defines nine levels of technological development, from theoretical principles (TRL 1) to full commercial deployment (TRL 9) (RVO, 2022).

The current prototype is estimated to be at TRL 5: "Technology validated in a relevant environment." This level is supported by the following facts:

- The prototype is fully functional in a lab environment, where it consistently produces high-quality milk foam using a steam and Venturi mechanism.
- It has been successfully integrated with Quooker's backend system, including steam generation and pump control. While this integration revealed that further tuning is required (as the system is currently optimized for a plunger pump), it also opens opportunities for enhancement, such as quieter operation and controlled pump shut-off to reduce splashing.
- The design utilizes polycarbonate (PC), a food-safe material, although it is known to degrade under high temperatures. Moreover, the prototype was sanded after printing, meaning fine plastic particles remain on the surface, making the current version unsafe for actual consumption. A production-safe version is underway.
- In terms of durability, the system has withstood over ten consecutive cycles without overheating or component failure, though long-term reliability and stress testing have not yet been performed.
- Safety-wise, no critical hazards were observed, and built-in overheating protection has only activated occasionally. However, no formal safety certification tests have yet been conducted.

While the prototype creates the illusion of a near-final product, and is even being prepared for basic usability testing, it is important to stress that this version is a proof of concept, not a production-ready unit. Reaching TRL 6–7 will require significant R&D investment to address aspects such as:

- Food-grade certified materials and surface finishes
- Tolerance optimization for injection molding
- Full system integration with Quooker's internal software and control logic
- CE certification and hygiene testing
- Design-for-manufacture refinements

This TRL assessment confirms that the concept has passed the critical feasibility threshold and demonstrates strong potential for scaling, but must now transition from a working lab prototype to a refined, manufacturable product.

8 Conclusion

This thesis set out to address a clear gap in Quooker's product ecosystem: the absence of a milk foaming solution to accompany its upcoming Coffee Tap. Guided by the principles of user-centered design and grounded in both strategic and technical constraints, this project culminated in the development of the Venturi system — a compact, integrated milk foamer that aligns with Quooker's clean-counter philosophy and user expectations.

The solution was approached through three key perspectives — **Human, Strategic, and Technological** — ensuring the design was desirable, viable, and feasible. Each perspective shaped the process from concept to prototype. Human-centered research revealed the everyday routines, habits, and frustrations of Quooker's customers, highlighting the demand for automation, hygiene, and seamless operation. Strategically, the system was designed to integrate invisibly into the kitchen landscape and align with the aesthetic and functional expectations of target demographics such as YUPs and DINKs. Technologically, the solution capitalized on Quooker's existing Coffee Box infrastructure and used steam-powered Venturi dynamics to foam milk efficiently, all while maintaining safety, cleanability, and manufacturability.

To ensure the design responded to real needs, a five-step mixed-method user research was conducted. This research answered six core questions, ranging from user segmentation and behavioral habits to emotional drivers and product preferences. Ultimately, the insights were synthesized into a detailed persona, serving as a touchstone for design decisions and stakeholder communication.

The Venturi system (see Figure 58) stands as a concrete response to the central design challenge: to create a milk foamer that fits seamlessly within Quooker's brand and user ecosystem. It proves that meaningful innovation can emerge when deep user insights, strategic thinking, and engineering rigor are brought together. More broadly, this thesis demonstrates how a multi-perspective approach — supported by structured research and iterative prototyping — can produce a solution that is not only technically sound, but also emotionally and strategically aligned with the people it is designed for.

Figure 58: Final design of the venturi system with the mockup of the coffee tap

8.1 Reflection

Growth as a Designer and Evolving Priorities

At the beginning of the project, I was eager to create something technically innovative, ideally a product that would feel revolutionary or groundbreaking. Like many designers, I have a tendency to design for myself, driven by personal interests in technology, electronics, and control systems. My natural comfort zone lies in building prototypes with sensors, actuators, and PCBs, and I initially imagined this project taking a similar direction.

However, throughout this graduation process, I made a deliberate effort to challenge that mindset and place the customer at the center of every design decision. Rather than designing something that fit my own preferences or technical interests, I focused on creating something that genuinely fits the needs and expectations of Quooker's users. By targeting a specific user group, the Automation Seeker, and grounding the concept in their lifestyle, habits, and priorities, I was able to design a solution that feels intuitive, unobtrusive, and genuinely valuable in context. This shift in focus, from innovation for its own sake to meaningful, user-driven design, has significantly broadened my perspective on what successful design looks like.

The real design process also differed from the structured diagrams we often rely on. While the Triple Diamond model provided a useful foundation, the reality was far less linear. For example, many of the interviews and user engagements took place during the design phase rather than solely at the front end. This allowed me to continuously check assumptions, adjust direction, and keep the user's perspective in focus throughout development. Rather than locking in decisions early on, the evolving research helped guide ongoing refinements.

I also reconsidered the role of design tools such as criteria matrices. Initially, I viewed them as decision-making frameworks, but I have come to see them more as communication tools, ways to explain and justify my choices to stakeholders, rather than mechanisms that dictate the outcome. This realization helped me better connect technical arguments with user value and translate abstract qualities into clear, defensible decisions.

Ultimately, this project helped me grow not only in technical ability but also in mindset. I learned how to design not just what I wanted to make, but what others truly needed and that distinction, I believe, is what makes a designer truly effective.

8.2 Recommendations

While the current solution successfully addresses the primary design challenge, several areas remain for further development. First, broader testing is advised with a range of plant-based milks, as their composition can significantly impact foam quality. Additionally, offering app-based customization could support advanced users without compromising the core simplicity of the product. From a technical perspective, future iterations should prioritize the use of food-grade certified materials and surface finishes, alongside tolerance optimization for injection molding to enable efficient scaling. A more refined version of the seal and its clamping mechanism should also be developed to improve usability and ensure consistent, leak-free assembly in daily use. Deeper integration with Quooker's internal software and control logic is recommended to ensure seamless operation and maintenance. As the product moves toward market readiness, CE certification, hygiene testing, and further design-for-manufacture refinements will be essential to meet regulatory and production requirements while preserving user experience and product reliability.


Figure 59: Final Prototype

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Appendix

links/5eb2ec0b45851523bd4708f1/COMRAP-2018.pdf#page=43

Appendix 1 – Project brief

Personal Project Brief – IDE Master Graduation Project

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

As this project is part of a double degree between SPD and IPD, it will have two main goals, divided into three parts. First, market research will be conducted to understand the Quooker coffee user and the type of experiences they seek. The aim is to determine whether the product should be a luxury manual frother, a fully automated integrated system, or another solution. This research will also help identify the target group. Additionally, data-driven user research will be performed to uncover coffee-drinking habits. Using sensors (either custom or existing) along with interviews, latent patterns will be discovered. The goal is to understand the user's needs and create a product that genuinely resonates with them.

In part two, concepts will be designed and prototyped, focusing on (potential) automating cleaning and milk-type sensing. The challenge here will be to create a system that integrates the users' needs, identified in part one, while ensuring sustainable practices.

The third part will involve testing prototypes and developing an implementation plan for Quooker.
The main challenge will be integrating the product into Quooker's ecosystem and coffee project. Due to the dual degree nature of the project, an extended timeframe of 150 days, rather than the standard 100, will be allocated to complete it.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence) As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Create a prototype and strategy to improve the coffee-making experience for Quooker users in the context of integrating a frother system into Quooker's ecosystem.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

My goal during this graduation project is to first use data-centric research methods to fully understand the (latent) needs of the customer. Then I will use a double diamond approach to first create a range of concepts and then narrow them down. During this process, I want to use an agile working method to constantly design, test, and iterate. With this approach, I will reach a stage where I have a working prototype combined with an implementation strategy for the Quooker coffee ecosystem.

Project planning and key moments

*To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a **kick-off meeting**, **mid-term evaluation meeting**, **green light meeting** and **graduation ceremony**. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	11 Nov 2024
Mid-term evaluation	20 Jan 2025
Green light meeting	6 May 2025
Graduation ceremony	26 Jun 2025

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

What fascinates me about Quooker is that it is a Dutch company that designs, engineers, produces, and markets all its products in-house. The company has an eager and innovative spirit, which I believe aligns with my own. Additionally, Quooker is highly compatible with my double degree, as they handle both the strategic side of product development and the technical development.

Through this project, I hope to learn how a product is developed within a company like Quooker. I am excited to learn how to manage all stakeholders and create a product that truly meets customer needs. I am also enthusiastic about utilizing the extensive knowledge and facilities Quooker offers to create a working prototype.

I will challenge myself with the data-centric exploration phase, as this is something I have never done before and seems challenging to me. However, it is something I am enthusiastic to learn, and I believe I have the right mentor and chair team to guide me through this phase.

Appendix 2 – HREC Approval

Date 12-May-2025
Correspondence hrec@tudelft.nl

TU Delft Delft University of Technology

Human Research Ethics Committee TU Delft
(http://hrec.tudelft.nl)

Visiting address
Jaffalaan 5 (building 31)
2628 BX Delft

Postal address
P.O. Box 5015 2600 GA Delft
The Netherlands

Ethics Approval Application: Designing a Milk foamer for Quooker B.V.
Applicant: Wüst, Philip

Dear Philip Wüst,

It is a pleasure to inform you that your application mentioned above has been approved.

Thanks very much for your submission to the HREC which has been approved.

In addition to any specific conditions or notes, the HREC provides the following standard advice to all applicants:

• In light of recent tax changes, we advise that you confirm any proposed remuneration of research subjects with your faculty contract manager before going ahead.

• Please make sure when you carry out your research that you confirm contemporary covid protocols with your faculty HSE advisor, and that ongoing covid risks and precautions are flagged in the informed consent - with particular attention to this where there are physically vulnerable (eg: elderly or with underlying conditions) participants involved.

• Our default advice is not to publish transcripts or transcript summaries, but to retain these privately for specific purposes/checking; and if they are to be made public then only if fully anonymised and the transcript/summary itself approved by participants for specific purpose.

• Where there are collaborating (including funding) partners, appropriate formal agreements including clarity on responsibilities, including data ownership, responsibilities and access, should be in place and that relevant aspects of such agreements (such as access to raw or other data) are clear in the Informed Consent.

Good luck with your research!

Sincerely,

Appendix 3 – Quooker in the Kitchen

Quooker in the kitchen

The kitchen triangle is a key concept in kitchen design, introduced in the 1940s to enhance efficiency by optimizing the movement between the stove, sink, and refrigerator. These three points form a triangle that aims to minimize unnecessary movement, improving convenience and reducing physical strain during meal preparation (Al-Qamadi, 2024).

Over time, the kitchen triangle has evolved to accommodate the changing role of kitchens as multi-functional spaces. Modern kitchens often include additional "work zones" for baking, coffee preparation, or technology, adapting beyond the traditional triangle.

Quooker's multifunctional tap system integrates well within this evolving kitchen concept. By providing instant boiling, chilled, and sparkling water, Quooker replaces multiple appliances, optimizing workspace and making the kitchen triangle more fluid and adaptable to modern needs. However, research by Mihalache et al. (2021) highlights that while ergonomic efficiency is important, food safety practices are essential for modern kitchens. The placement of the sink is crucial, as having a sink far from the countertop increases the risk of cross-contamination between food (see Figure 59). The research suggests that the sink-to-countertop distance should be less than 1 meter to enhance food hygiene practices.

The Quooker system, along with the coffee system that Quooker is currently developing, will be placed within 1 meter of the water reservoir. This positioning means that if an integrated milk frothing system is designed, it will be located in close proximity to the sink. While this can be beneficial for promoting the proper cleaning of the device, care must be taken to ensure that it does not hinder the overall cleaning process of the kitchen counter.

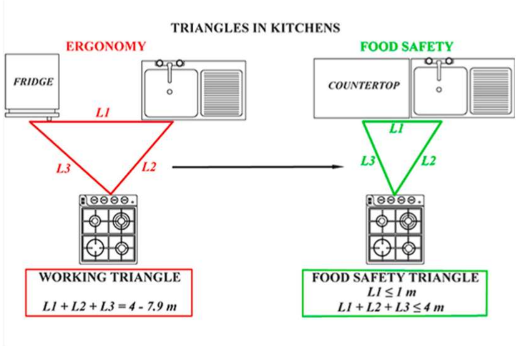


Figure 59: Food safety triangle (Mihalache et al., 2021)

Appendix 4 – Understanding Coffee

In the Netherlands, nearly 80% of people over 16 years old drink at least one cup of coffee a week (Van Maarschalkerweerd & Van Teeffelen, 2024), making it the second most consumed beverage after tap water. Coffee has not only become a crucial part of the daily routine for many, but it has also embedded itself into our culture. From black filter coffees to pumpkin spiced lattes, coffee has become a way of expressing one's identity. Whether it is a quick cup of coffee at a petrol station or a leisurely brew at a bookstore, everyone experiences this moment in a unique way. One thing is certain: coffee is indispensable in our modern world.

This, however, has not always been the case. It was only towards the end of the 16th century that coffee found its way to Europe (De Geschiedenis Van Koffie, 2020). A few years later, in 1733, the Dutch began cultivating coffee in Java, making the supply cheaper and more accessible (Public History Student, 2024). By 1750, coffee had transformed from an elite drink to one that was consumed even more than beer. However, it is only in the last decade that supply chains and packaging have become so efficient that we have extended the shelf life of coffee beans, making premium coffee accessible to nearly everyone. This has led to an even more diverse coffee culture. From French press enthusiasts to Nespresso lovers, the perception of what makes a good cup of coffee is widely varied.

The origins of coffee

The origins of coffee can be traced back to the highlands of Ethiopia, where *Coffea arabica* first emerged. Genomic studies have traced its lineage back approximately 150,000 to 350,000 years ago (Ferreira et al., 2019). The domestication and cultivation of coffee began in Yemen during the 15th century, where it was used to support spiritual practices by promoting wakefulness during nighttime devotions. From Yemen, coffee's popularity spread to cities such as Cairo, Damascus, and Istanbul, leading to the establishment of coffeehouses (Krishnan, 2016).

Processing and Roasting of Coffee

There are three main botanical species of coffee crops. *Coffea arabica* (Arabica) is the most popular, comprising about 70% of global coffee production (Davis et al., 2012). Additionally, there is *Coffea canephora*, which includes the Robusta variety, and *Coffea liberica*.

After harvesting, coffee cherries can be processed in one of two primary ways: dry (natural) or wet (washed). In the dry process, whole cherries (the coffee beans with fruit around them) are spread out to dry in the sun, allowing natural fermentation to occur within the fruit, which imparts a fruity flavor to the beans. Alternatively, the wet process involves pulping the cherries to remove the outer skin, followed by fermenting and washing off the mucilage, resulting in a cleaner and more acidic taste profile (Poltronieri & Rossi, 2016). There are also intermediate methods, such as the semi-dry process. The choice of processing method significantly influences the chemical composition and flavor profile of the final coffee product.

Following processing, the beans are roasted, a stage that greatly shapes both the taste and color of the beans. Green coffee beans are heated to temperatures between 180°C and 200°C (Pereira & Moreira, 2020). During roasting, multiple chemical reactions take place, including the Maillard reaction and caramelization, which contribute to the coffee’s distinctive aroma and flavor.

Roasting levels are typically categorized as follows:

- **Light roast**: Characterized by a light brown color and mild body, with floral or fruity notes (Castanheira, 2020).(Figure 60, A)
- **Medium roast**: Known for a balanced flavor, aroma, and acidity (Castanheira, 2020). (Figure 60, B)
- **Medium-dark roast**: Full-bodied with deep flavors and a slightly spicy profile, along with lower caffeine content (Castanheira, 2020). (Figure 60, C)
- **Dark roast**: Very low in caffeine with a heavy mouthfeel and strong, sometimes bitter or smoky flavors (Castanheira, 2020). (Figure 60, D)

Figure 60: Most common types of roasting conditions (A=light roast, B=Medium roast, C=Medium-dark roast, D=Dark roast) (Haile & Kang, 2019)

Next, the beans are ground. The grind size is determined by the intended brewing method, as grind size influences extraction and flavor. For instance, coarse grounds are ideal for French press coffee, while finer grinds are suited for espresso. When coffee is packaged in pods or capsules, grind size becomes particularly important as it influences resistance to water pressure, affecting the final taste and texture.

In the brewing process, factors like water temperature, brewing time, coffee-to-water ratio, and pressure are critical to the coffee's quality. It's worth noting that coffee's taste can vary significantly depending on these parameters.

Appendix 5 – Pilot research step 2

To test the proposed data collection method, a pilot study was conducted. Given the extended approval process required to obtain HREC approval and the associated risk of needing re-approval should the research plan change, the pilot was carried out within my family. Guidance from *The Mom Test* (Fitzpatrick, 2013) was applied to mitigate biases associated with conducting research within a familial context, such as structuring question in a way that does not ask for approval. While

Figure 61: Image of card collection in situ

involving close family members cannot eliminate all potential biases, these principles helped minimize them sufficiently to extract valuable insights and identify areas for improvement ahead of the full-scale study.

The pilot study was conducted (see Figure 61) with two participants, over the course of one week. The instructions provided were straightforward: fill in the designated cards every time coffee was prepared. Based on initial profiling, the participant belongs to the "automation seekers" and "High-end Coffee Enthusiasts" segment. While she values high-quality, premium coffee, she prioritizes efficiency over quality due to specific situational factors. For instance, although her partner knows how to use the espresso machine, she does not want to wait for him to wake up in the morning. As a result, she opts for instant coffee, being reluctant to invest in a second, more user-friendly coffee machine. Furthermore, while she drinks milk in her coffee, the inability to use the espresso machine prevents her from foaming the milk.

The participant works from home, leading to frequent coffee consumption in a household setting. Key observations from the pilot include the participant reporting increased self-awareness; specifically, she discovered that she was more tired in the mornings than she had previously realized. Additionally, the coffee facts printed on the reverse side of the cards were well received. The participant expressed that these facts provided a motivational aspect, encouraging her to complete subsequent cards. However, a key issue was the cards needed to be thicker to adequately visualize progress through the indicator windows, particularly during the early stages of use.

In response to this feedback, adjustments were made to the card design. The cards were reprinted on 250g paper, significantly increasing their thickness. This modification improved the visual clarity of progress tracking.

Appendix 6 – Pilot research step 3

A pilot study was conducted to verify the research method. The participants were the same as in step 2 of the research. After a week of data collection using the card system, the participants were invited to bring their boxes to an interview session. During the session, the cards were sorted together with the participants. It was important to maintain the emotional clusters from the original data collection while arranging the cards in chronological order based on different times of the day, see Figure 62. This process revealed clear correlations between emotions and specific times of the day.

Although a few prepared questions were available, they turned out to be unnecessary. The conversation naturally began during the sorting of the cards. The entire session was audio-recorded, with participants' informed consent obtained beforehand. The audio recordings were then transcribed and coded using Atlas.ti. These codes were subsequently exported into Miro for thematic analysis.


Figure 62: Participant during Pilot

One key insight from the pilot was that the prepared questions were not needed, as the conversation flowed organically during the card-sorting process. It was surprisingly easy to steer the discussion beyond the cards toward deeper needs related to milk foaming. When the conversation slowed, we revisited the cards, which led to discussions about correlations between emotions and preparation time. This revealed certain pain points.

During the pilot, the cards were sorted on a table. However, it became clear that using a large piece of paper for this activity would be more effective. This setup would allow participants to take notes and draw connections during the session, enriching the data collection process.

Appendix 7 – Sales Projections and Assumptions

This table (Table 5) outlines the projected sales of the Quooker coffee system and estimates the potential attachment rate for the milk foamer between 2027 and 2030. It is based on internal assumptions regarding installed base growth, new system sales, and consumer behavior. The attachment rate for the milk foamer starts conservatively at 10% and rises to 35% as market adoption increases. These figures help estimate production volumes and inform decisions about the manufacturing scale and investment in tooling.

Table 5: Calculation of expected milk foaming systems (Internal, Quooker)

Assumptions	2027	2028	2029	2030
Installed base Quooker systems starting 2018	2272710	2591849	2940147	3320601
new Quooker systems sold	399300	439230	483153	531468
# new coffee systems with installed base	2272.71	2591	2940	3320
total new coffee systems	10258	24553	51255	56467
existing coffee systems	0	10258	34812	86067
Total # coffee systems	10258	34812	86067	142534
# servings per day per system	1.5	1.5	1.5	1.5
# servings per year per system (350 days)	525	525	525	525
total servings (x1000)	2692	11831	31730	60008
attachment rate milk foamer	0.1	0.2	0.3	0.35
total new milk foamers sold	1026	4911	15377	19764

Appendix 8 – Patents and freedom to operate LatteGo

The LatteGo system can be split into two main patents. The first one comprises the use of a Venturi system to suck up the milk and foam it, while the second patent covers the two-part LatteGo system that uses a seal to separate the components. We will analyze these patents to assess our freedom to operate. This means we are not evaluating the possibility of filing our own patent, as this is not within Quooker's ambitions, but rather determining whether we could create a similar design without risking patent infringement.

A Mixing apparatus for creating frothed milk

The first patent consists of an apparatus that uses a Venturi system to steam milk with steam and air. The benefit of this system is that the milk gets steamed automatically in a steaming chamber, with the correct milk-to-air ratio being maintained through automatic suction. This provides the advantage of producing high-quality steamed milk without requiring a manual process. The patent describes the following (the patent is by (Koninklijke Philips N.V., 2019) and see Figure 63 for the important image numbers:

> *A mixing apparatus for creating frothed milk, comprising: a first container (110) for containing milk; a mixing chamber (160) for mixing milk, steam and air; a steam inlet channel (220) which leads to the mixing chamber; a milk passage (210) which leads from the first container to the mixing chamber; and a steam separator (211) in series along the steam inlet channel.*

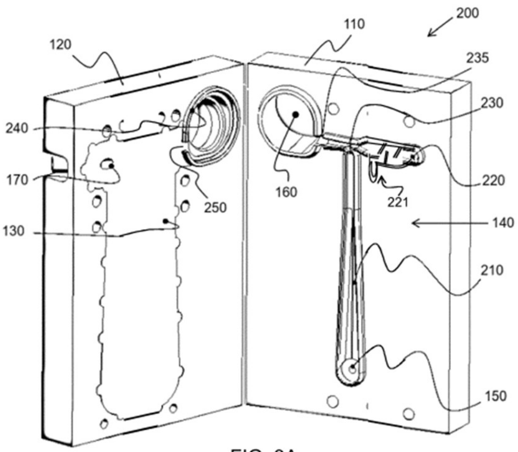


FIG. 3A

Figure 63: Image of venturi system in the LatteGo (Koninklijke Philips N.V., 2019)

There are several ways to work around this patent to establish freedom to operate. This could be achieved by:

1. Changing the steam inlet to a different system. This would likely be necessary for a design like this, as it would have a different method of attachment.
2. Redesigning the steaming chamber, which could not only help circumvent the patent but also improve the quality of the foam.
3. Using a different type of Venturi system.

A mixing apparatus having a seal

The second patent comprises the use of a seal that joins two sides of the milk foaming device. This design is useful because it allows the mixing chamber to be split into two parts, which can then be placed in the dishwasher, an important feature for Quooker's client base. The core claim of the patent is as follows (the patent is by: (Koninklijke Philips N.V. & Roumen, 2017) and see Figure 64 and Figure 65 for the important patent image numbers)

> *A mixing apparatus comprising: a first container (110) comprising a mixing chamber (160) for mixing milk with steam and/or air; a second container (120), adapted to receive the first container (110) and comprising a third port (180) that in assembled condition is connected to the mixing chamber (160); a seal (130) disposed between the first container (110) and the second container (120), wherein the seal comprises:*
>
> > *a first sealing member (240) disposed between the mixing chamber (160) and the third port (180); and a transition seal portion (250), the transition seal portion comprising:*
> >
> > *a seal split (720); and an air intake channel (725);*
>
> *and a channel (140) connected to the mixing chamber (160) and the seal split (720), wherein the channel (140) is defined by the first or second container (110, 120) and the transition seal portion (250) (Koninklijke Philips N.V., 2017)*

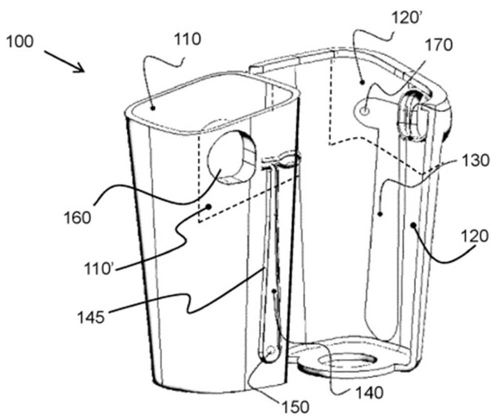


Figure 64: The two parts of the LatteGo system (Koninklijke Philips N.V. & Roumen, 2017)

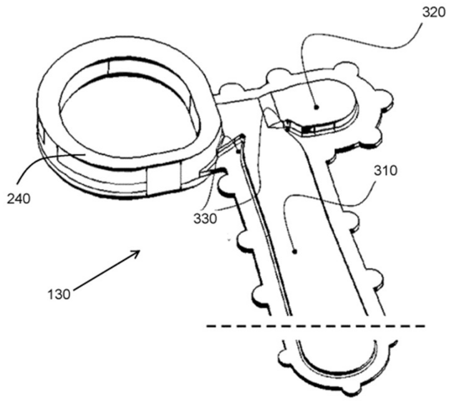


Figure 65: The Seal of the LatteGo system (Koninklijke Philips N.V. & Roumen, 2017)

While this patent is well-structured, the freedom to operate is relatively broad. This is due to the fact that the primary claim is quite specific. This makes sense, as a seal that joins two parts is a common practice. A few ways to circumvent this patent include:

1. Placing the mixing chamber (160) in part 120 instead of 110.
2. Positioning the air inlet channel (725), which prevents the seal from becoming vacuum-sealed, at a different location than specified in the patent.
3. Using a different Venturi shape.

4. Avoiding the use of a seal altogether by designing the materials to fit perfectly together or using a softer material, such as TPU, that functions as a seal itself.

While these four options are listed, there are numerous other ways to work around the patent.

Appendix 9 – Methods to diverge on ideas

How to's

The first "How To" was *How to Make Milk Foam,* see Figure 66. This method involves exploring all the different ways that milk foam can be produced. It encourages us to think outside the box and consider various techniques that can be used to achieve foam production. It is noteworthy that, although there are many methods to create milk foam, most approaches rely on either steam or mechanical properties.

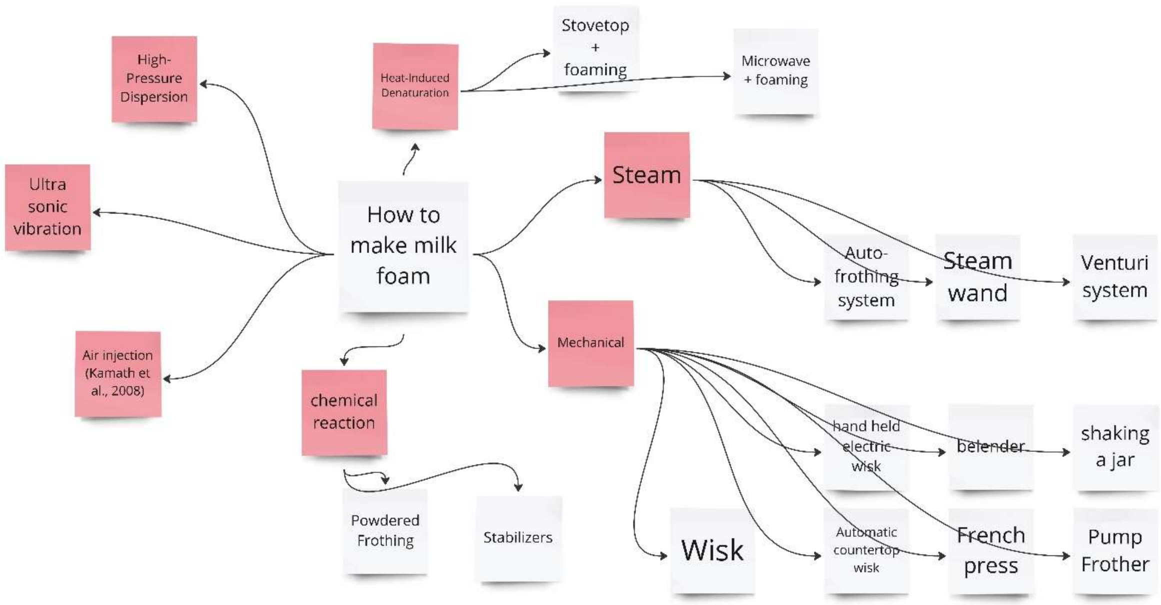


Figure 66: How to make milk foam

Morphological chart

To generate different ideas, a few of the how-to's were translated into subfunctions of the system. These subfunctions were then translated into a morphological chart, See Figure 67. This chart is then connected with lines; these lines resemble the subfunctions of potential ideas. To make this as clear as possible, all "dead ends" were left out. These dead ends are unused subfunctions or connections that did not become an idea.

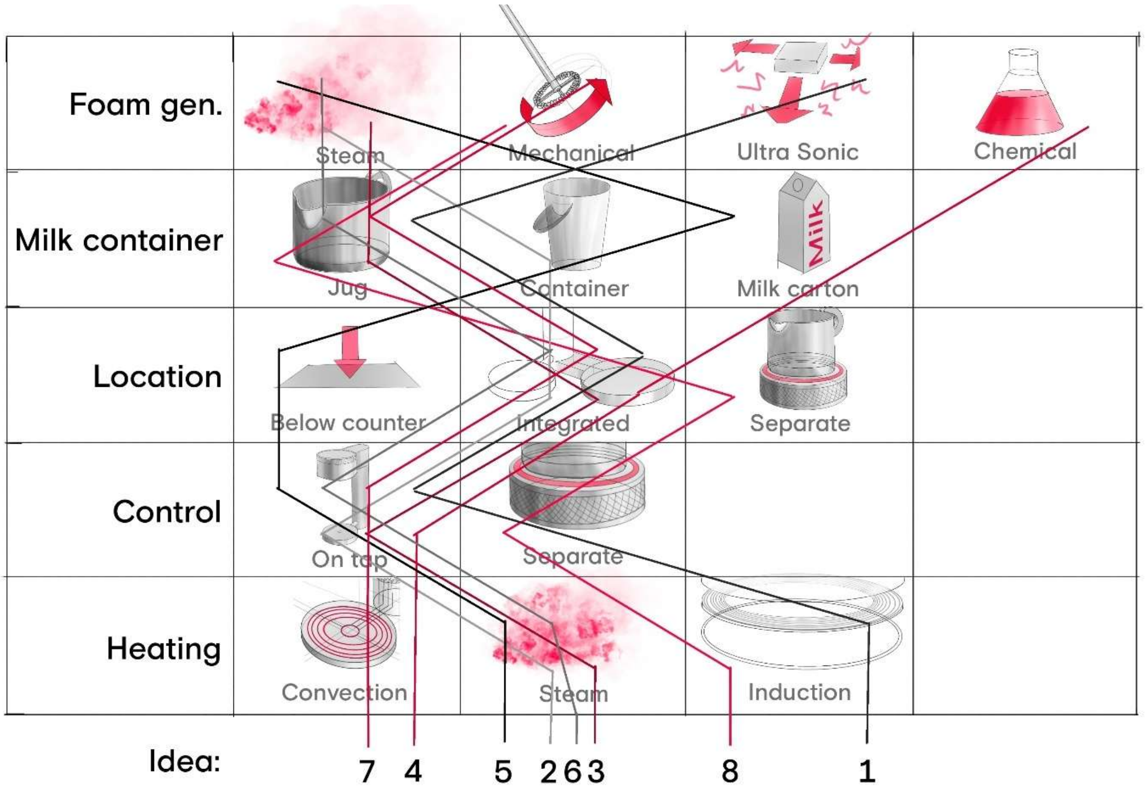


Figure 67: Morphological chart

Appendix 10 – The 8 Ideas

Through the ideation methods, multiple ideas have been generated. It is important to consider that in this exploratory phase, we keep our target segment in mind and design based on the knowledge gained from previous research. However, this phase is also about keeping an open mind, so we do not want to rule out ideas too quickly.

If an idea arises, even if we know it is unlikely to appeal to our user segment, it may still be mentioned in this subchapter. This is because it is important to document not only the ideas that were chosen but also the reasoning behind rejecting certain concepts. At this stage, we adopt an "everything is valid" mentality. Only later will we become more critical of our ideas.

In addition, it is important to mention that most ideas were generated over the span of a few weeks and were quickly written down or sketched. You will notice that ideas later in the thesis, which are deemed more promising, have higher-fidelity sketches. This is because the initial quick and rough sketches were digitized later, with more time allocated to refining the most promising concepts. However, at this stage, all ideas are considered equal.

Idea 1: Automatic Mechanical System

The *Automatic Mechanical System* is a standalone milk foamer that uses a motor-driven magnetic disk to create foam inside a detachable milk jug (See Figure 68). While the disk spins to introduce air into the milk, an inductive heating system warms the jug from below, ensuring simultaneous heating and foaming. The jug is dishwasher-safe, and the system integrates seamlessly with the Quooker Coffee Tap, operating via an intuitive control ring for temperature and foam duration selection. While the concept allows for precise customization and cold foaming, challenges include its bulky countertop presence, high component costs, and potential lack of synergy with the Coffee Tap. Additionally, using mechanical foam production instead of steam may not align with consumer expectations.

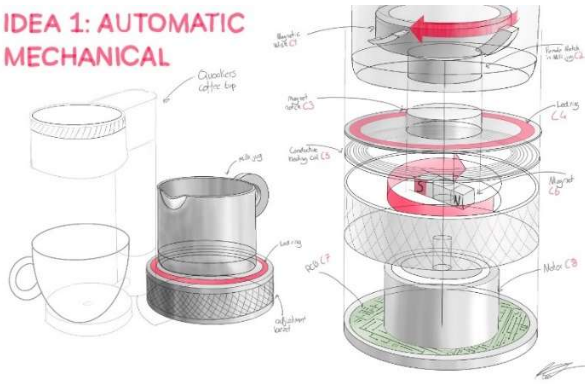


Figure 68: Idea 1, Automatic mechanical

Idea 2: Venturi Concept

The *Venturi Concept* is a milk foaming system that utilizes steam to create suction, drawing milk from a container and frothing it in a chamber (See Figure 69). It is designed to be an add-on to the Quooker Coffee Tap, as it integrates seamlessly with the existing Coffee Box, using the under-counter pump and heater to minimize additional components. The system consists of a detachable base, which connects magnetically to a two-part Venturi mechanism that ensures easy cleaning and dishwasher compatibility. By leveraging steam for both heating and foaming, the concept delivers high-quality milk foam with minimal effort. It offers a cost-effective and user-friendly solution. However, challenges include navigating existing patents, refining foam quality to a premium level, and requiring adjustments in the Coffee Box's hardware to enable steam generation.

Figure 69: Concept 2, Venturi System

Idea 3: Automatic wand

The *Automatic Steam Wand* concept replicates the way baristas steam milk but fully automates the process (See Figure 70). Powered by steam from the Coffee Box, the wand moves up and down automatically using a motor or stepper, while a sensor in the base monitors the milk's temperature. Controlled via the Quooker Coffee Tap, this system provides a premium experience, offering users greater control over milk texture and making it well-suited for alternative milks. While it delivers a professional feel and can handle larger portions of milk, challenges include the need for manual cleaning of the wand, potential mechanical failure points, and difficulty achieving consistently high-quality foam. Additionally, the system may not align with consumer expectations for convenience and ease of use.

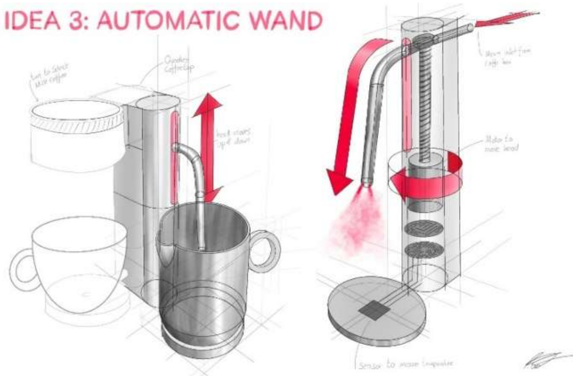


Figure 70: Idea 3, automatic wand

Idea 4: Milk Pods

The *Milk Pod Concept* is a straightforward approach (See Figure 71). Instead of only brewing coffee, specialized milk capsules could be developed, allowing the Coffee Tap to pump hot water or steam through them to produce milk foam. Users would need to swap between coffee and milk capsules when making a cappuccino, but the system would be highly cost-effective to implement. Due to the limited space in the capsules, typically around 6 grams, this solution would require milk powder rather than liquid milk, as 150 ml of milk would not fit. While milk powder could be dense enough to work, the perceived quality of milk foam from such a system is likely to be low, making it a high-risk solution.

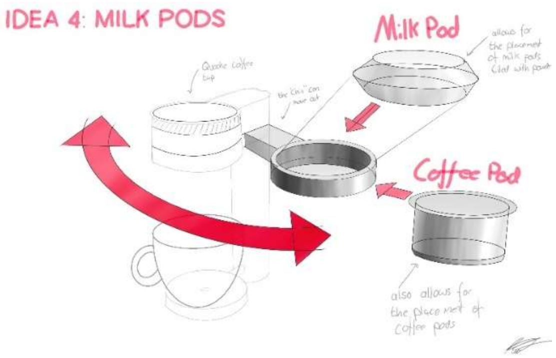


Figure 71: Idea 4, Milk Pods

Idea 5: Fully automatic

The *Fully Automatic Concept* foams and stores the milk beneath the counter, aligning perfectly with Quooker's *clean counter* philosophy (see Figure 72). The milk foam is dispensed through the same tap as the coffee, creating a fully integrated and seamless experience. However, this system comes with significant challenges. The foam is produced through steam injection, requiring the milk to be cooled while stored and the system to have a self-cleaning mechanism. A major hurdle is the lack of a drip tray connected to the plumbing, making waste management and cleaning, particularly challenging.

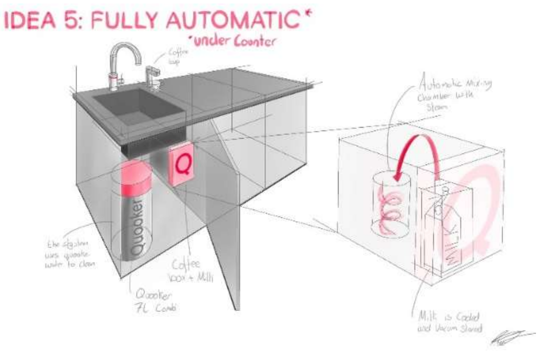


Figure 72: Idea 5, fully automatic

Idea 6: Steam Jug

Concept 6, called the *Steam Jug*, integrates the steaming mechanism directly into the jug itself (see Figure 73). This idea is still in a very preliminary stage, as its feasibility is uncertain. The concept utilizes the steaming capabilities of the Coffee Box, with integrated steam vents inside the jug. However, there are two major challenges. First, the jug does not detect the milk level, meaning steam vents would need to be distributed throughout the entire interior, making the process inefficient. Second, milk is likely to stick to the jug's inner walls. While the jug can be placed in the dishwasher, it may not be effectively cleaned inside, raising concerns about hygiene and usability.

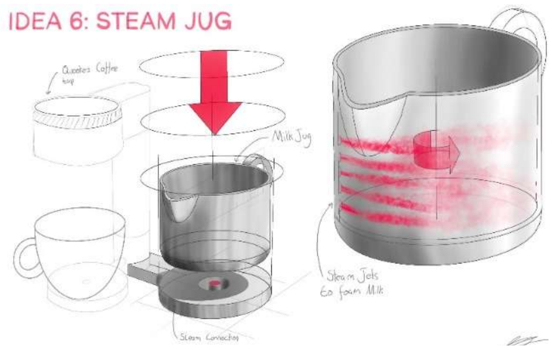


Figure 73: Idea 6, steam jug

Idea 7: Top Whisk

Idea 7 is similar to previous concepts, as it also uses mechanical power to foam the milk (See Figure 74). However, in this design, the mechanical movement comes from the top instead of relying on a magnetic drive at the bottom of the jug. The advantage of this system is that the magnetic drive does not have to pass through two different walls, allowing compatibility with any type of jug. The milk is heated by coils in the base, and the electronics could be integrated into the side of the tap, enabling a lower-profile design. However, this idea comes with several drawbacks. First, it is not very dishwasher-friendly. While the whisk can be removed from the steam, and the jug can also be detached, this requires multiple steps. Additionally, the system contains many moving parts and would need to lift up after use, requiring more electronics than other designs. Lastly, the system is quite bulky.

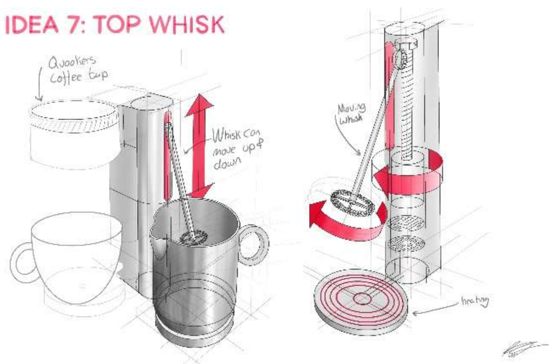


Figure 74: Idea 7, Top whisk

Idea 8: Ultra Sonic

Idea 8 is a more futuristic concept. It is based on the theory that vibrating milk with ultrasonic transducers can create foam (see Figure 75). Beneath the milk jug, there is a heating element that can also warm the milk. Similar to the mechanical option, this foamer could be used to prepare cold milk recipes.

The main advantage of this system is that it would be very easy to clean, as the jug could be placed in the dishwasher after use. However, a significant downside is that it would generate a lot of noise and vibration. Additionally, this system would likely be quite expensive to implement.

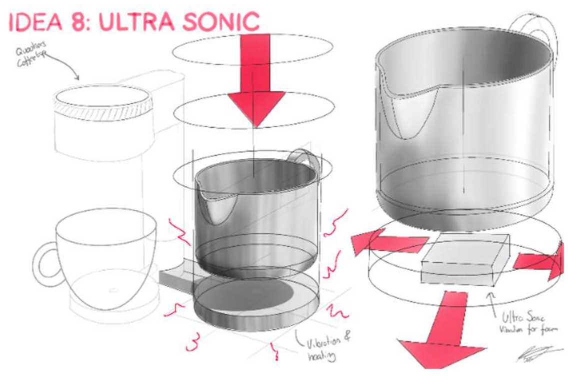
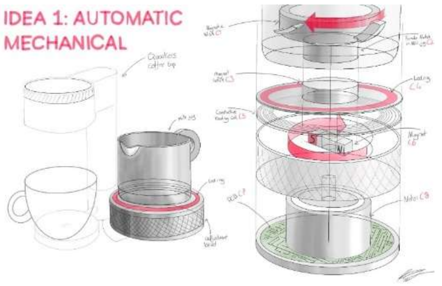


Figure 75: Idea 8, Ultra sonic

Appendix 11 - Choosing the Top 3

To review the 8 different concepts that have been made, a Harris Profile has been used. This design method, used to evaluate and decide between methods, works the following way: First, the requirements are listed that each concept has to fulfill. As this thesis features many requirements, the choice has been made to feature the requirement category. This means that requirements such as dishwasher compatibility or quick cleaning of the device are clustered and portrayed as usability. I am aware that this might make the exact choice vaguer, but it does make the process a lot more comprehensible. The requirements are rated from most important to least important. Here again, I would like to highlight a limitation. As you can see, safety and sustainability score a lot lower than, for example, usability. This is not because I think these are less important; probably, in a finished concept, these two requirements are the most important. However, for this thesis that focuses on getting a working concept and not a finished product, these criteria are less relevant, as they usually depend on material choices and details, something that is more profound in the finalization of a product. Next, the concepts are rated into four categories: : "--" (very poor), "-" (poor), "+" (good), and "++" (very good), each corresponding with a box. The idea is to see which blocks form a tower that would fall to the left (meaning the concept is not good) and which tower would fall to the right (Van Boeijen et al., 2014).

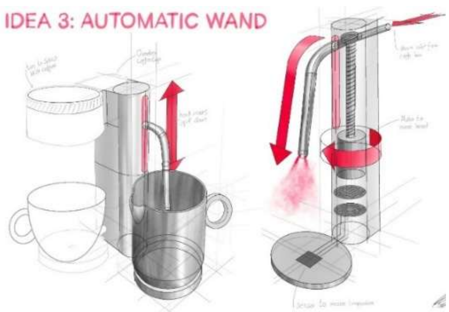


IDEA 1: Automatic Mechanical

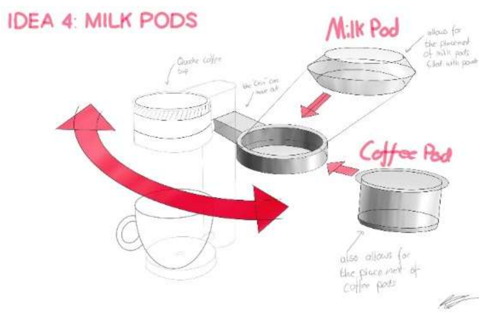
IDEA 2: Venturi

Usability	--	-	+	++
Performance				
Integration				
Aesthetics				
Sustainability				
Safety				

Usability	--	-	+	++
Performance				
Integration				
Aesthetics				
Sustainability				
Safety				



IDEA 3: Automatic wand



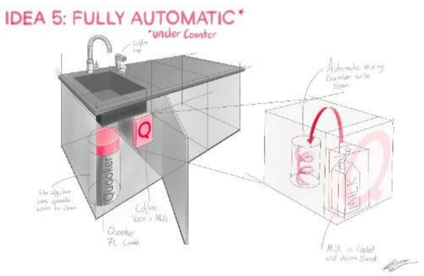
IDEA 4: Milk pods

Usability	--	-	+	++

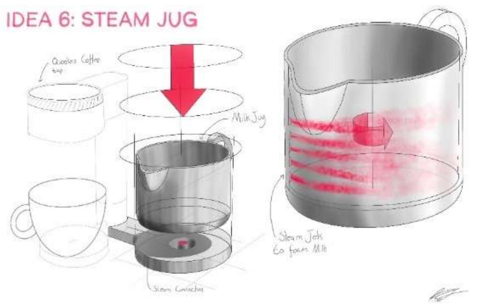
Usability	--	-	+	++

Performance				
Integration				
Aesthetics				
Sustainability				
Safety				

Performance				
Integration				
Aesthetics				
Sustainability				
Safety				



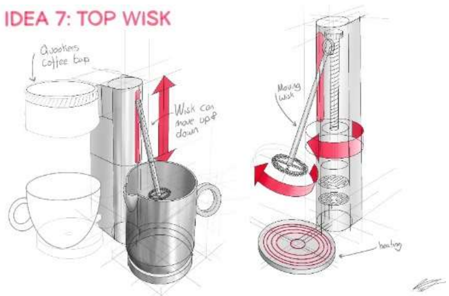
IDEA 5: Fully Automatic



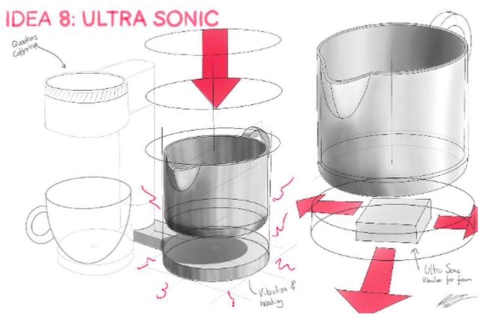
IDEA 6: Steam jug

	--	-	+	++
Usability				
Performance				
Integration				
Aesthetics				
Sustainability				
Safety				

	--	-	+	++
Usability				
Performance				
Integration				
Aesthetics				
Sustainability				
Safety				



IDEA 7: Top wisk



IDEA 8: Ultra Sonic

	--	-	+	++
Usability				
Performance				
Integration				
Aesthetics				
Sustainability				
Safety				

	--	-	+	++
Usability				
Performance				
Integration				
Aesthetics				
Sustainability				
Safety				

Appendix 12 - Steam generation

To test different prototypes, a custom steam setup was developed. This setup allows for mounting various steam-related prototypes and offers full control over all operational parameters. While it functions similarly to a standard coffee machine, the key advantage is that every variable can be precisely adjusted. The capabilities of this setup closely resemble those of Quooker's intended system. Everything that can be achieved with this setup will also be possible with the final Coffee Box, potentially even more.

In Figure 76 (front view) and Figure 77 (rear view), all components of the setup are labeled.

- **Component 1** is a water reservoir repurposed from an old Nespresso machine, which now functions as a potential milk reservoir. The reservoir includes a shut-off mechanism that prevents milk from leaking when removed from its base, allowing for quick changes between prototypes.
- **Component 2** is a labeled water reservoir with volume markings, enabling both storage and accurate measurement of water input.
- **Component 3** is the PCB, which connects via USB to a computer. Using a dedicated GUI, all system variables can be monitored and adjusted. The setup also supports serial communication with an Arduino or Raspberry Pi.
- **Component 4** is the USB cable linking the PCB to the computer.
- **Component 5** is the power cable that supplies electricity to the entire setup.
- **Component 6** is an exchangeable head. The currently mounted head is used for testing the LatteGo system and tuning its parameters.
- **Component 7** is the steam outlet, which connects to any prototype using a quick connector. This enables rapid switching and iteration between designs.
- **Component 8** is a pressure valve that releases steam if the pressure exceeds 4 bar. This is a safety feature designed to prevent prototype failure due to overpressure.
- **Component 9** is a blast shield that protects the user from debris or, more importantly, hot steam or water in the event of failure.
- **Component 10** is the heating module. This Ferro heater operates at up to 2300 watts and is commonly used in high-end coffee machines.
- **Component 11** is the E-fast unit, which protects the system from overheating. It also houses an NTC thermistor, which provides input for the PID controller.
- **Component 12** is the plunger pump. It is mounted in a rubber casing to reduce noise and vibration during operation.
- **Component 13** is the flow sensor. In the image, it is shown mounted vertically; however, it was later repositioned horizontally to improve performance.

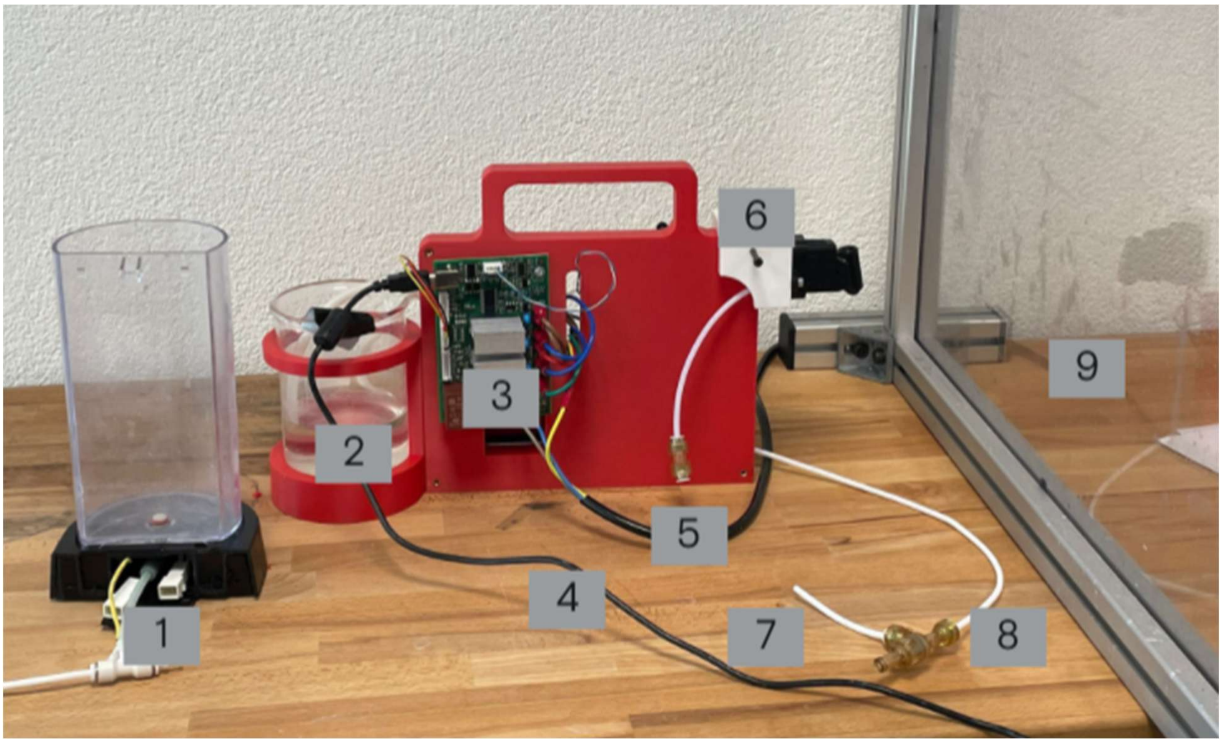


Figure 76: Front view of the custom steam testing setup

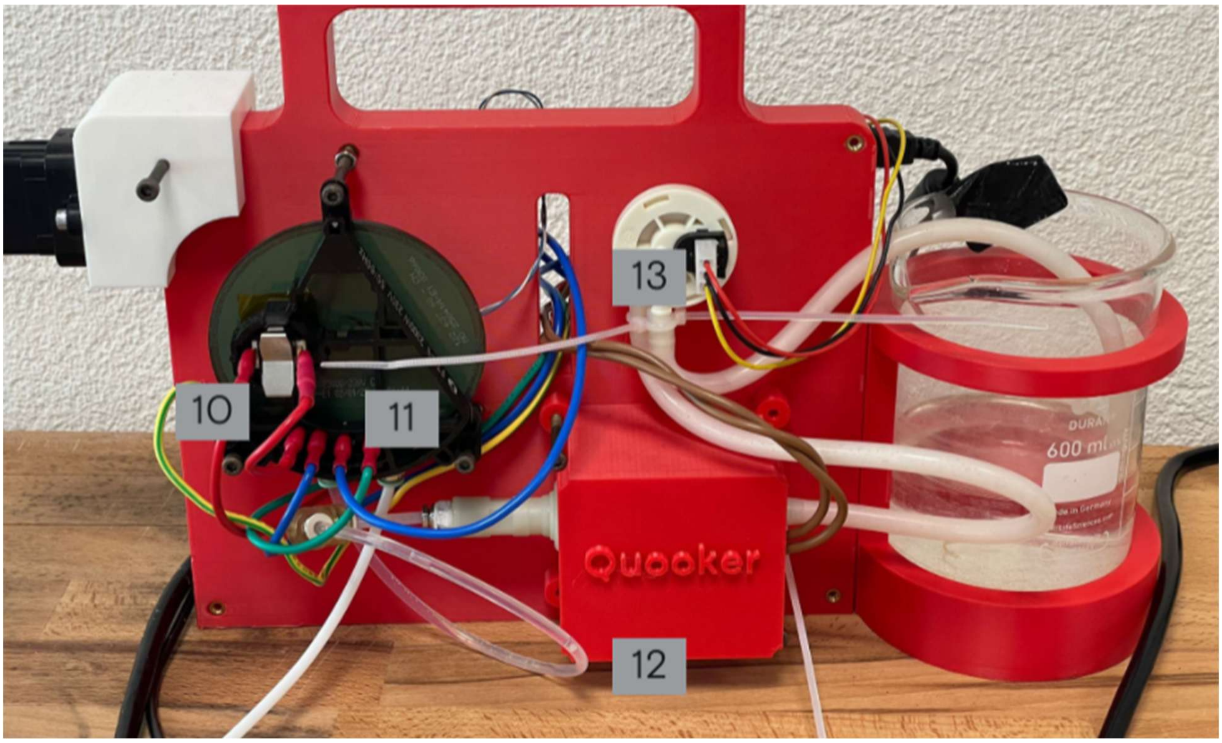


Figure 77: Rear view of the custom steam testing setup

Appendix 13 – Iteration on the Venturi system

Now that the concept is chosen, we will further iterate on it. Before we have a final concept that can be embodied in the next chapter, there is still a lot to do. The iterative process will consist of multiple steps. First, a 1:1 scale model will be developed. Then, I will take a step back and understand the Venturi system and how it is currently implemented within LatteGo. Once this system is understood and I can make milk foam with the backend (the steam lab setup) and with the simplified frontend (the part the customer sees, basically a lab setup of the Venturi system), then step-by-step adjustments and improvements can be made. Only then will it be reintegrated into a full design that will lead to the finished concept, which in the next chapter can be embodied, where we will focus on the correct production technique and fine-tune the interaction within the milk foamer and the Quooker Coffee Tap.

For this part, understanding and tweaking the Venturi system is important. It is essential to iterate quickly, make mistakes, and redesign. This is why 3D printing has been chosen. It is important to mention that most 3D printing materials are neither heat-resistant nor food-safe, but the goal is to test the Venturi system once or twice and then iterate. This is why this method is good enough and is preferred over milling the system from heat-resistant plastic. Even resin prints, which are more heat-resistant, will not be used for the first iteration, as the availability of these printers is lower, meaning the iteration loop will take longer.

In this subchapter, we will look at all the iterations, and I will explain the main changes made and the learnings gained.

1:1 Design model

The 1:1 design model represents the final design and dimensions. It incorporates a Venturi concept, though it is not functional. The primary purpose of this model is to provide stakeholders with a tangible reference for placement next to the Coffee Tap to evaluate dimensions.

As shown in Figure 78, this model is not yet made with the final materials and finishes. Additionally, the design is still subject to significant changes.

Figure 78: 1:1 Design model

Venturi V1

As mentioned earlier, it is now important to first understand the Venturi system. Aside from the theory about Venturi, we need to understand how this concept works in the real world. For this, it is important to have a simplified version that can be tested in a lab setup. This means there have to be quick connectors to connect the steam and milk, which can be stored in a reservoir. This is why the system has been divided into three parts: the base, top, and seal. This system mimics the real-world application of splitting the system to put it in the dishwasher.

Compared to other systems on the market, I have chosen to have all the Venturi elements in the base while placing all the connectors on the top plate. The reason for this is that in the eventual application, I also envision the Venturi elements to be in the part that is not removed, making it cleaner and improving the user experience. However, for this part of the project, this step also makes iteration easier because each time a new base is tested, a new top plate does not need to be made.

Next, quick connectors used for high-pressure air hoses are screwed into inserts that are heat-fitted into the soft 3D-printed material (See Figure 79). This is done for two reasons. First, this method is more waterproof, especially when extra glue is applied to the threads. Second, it allows for the reuse of the rather expensive quick connectors. While these inserts are best used with materials such as PLA, they are also usable with high-heat materials such as PC or PPS. However, this requires more heat to be applied.

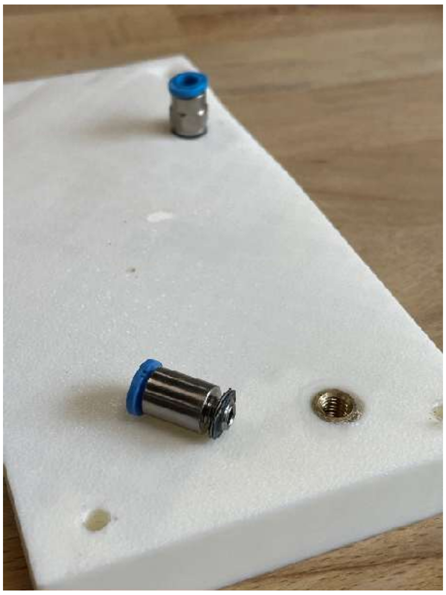


Figure 79: Festo air connector and insert in top plate

Design features

This Venturi system has a very similar Venturi setup to the LatteGo. The goal was to have a 1:1 copy as a baseline to understand the system. Both the base and top plate are printed with PLA with a 10% infill on a high-quality print. A silicone seal is placed between the two parts, and the system is held together with four M4 screws. For a detailed description of this system, see Appendix 12.

Learnings from tests

When attaching this system to the lab setup, it worked better than expected. The Venturi system successfully used the flow of steam to pull up milk from the container. The milk then mixed with steam and exited through the designated hole. The mixture that came out would be better described as warm milk rather than actual foamed milk. However, this can be seen as a victory, as the Venturi part already functions correctly.

This test also made it clear that PLA is not heat-resistant enough, especially the top plate, which warped due to the heat (see Figure 80). The next iteration will feature a PC-printed top plate and a larger steam hole to direct steam more efficiently through the Venturi. Additionally, the hole from which the mixed steam and milk exit the device will be enlarged, as the test showed signs of warping in that area, indicating that it became quite warm.

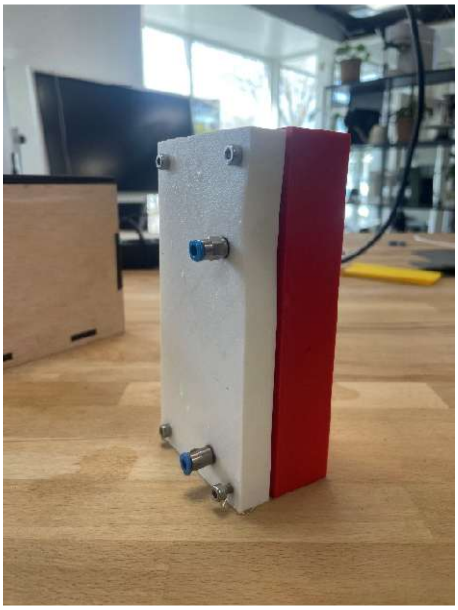


Figure 80: Lab Setup of Venturi V1, see the warping of PLA

Venturi V2

Version 2 of the Venturi system features a PC top plate and a redesigned base plate. The base plate has improved steam flow, allowing for a better turn, which increases the speed of the steam passing through the Venturi, see Figure 81. Additionally, the mixing chamber has been made larger.

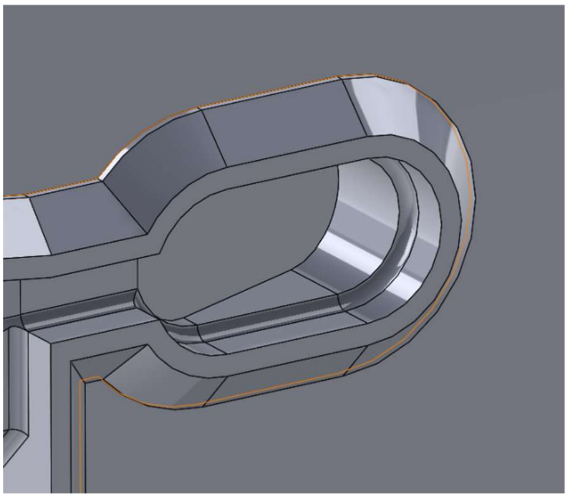


Figure 81: Adjusted steam inlet in version 2

Learnings from tests

The next step will be to add an air inlet, which should improve the milk steaming process. This iteration already demonstrated better flow, and the material did not melt, confirming that PC will be used for future systems. Additionally, the holes in the seal will be enlarged to optimize performance.

Venturi V3 – Unsuccessful test

Venturi V4

Iteration 4 features a small yet essential adaptation. As seen in Figure 82, a small gap allows air to be infused into the system. Initially, it was thought that this was unnecessary, as the steam and milk already contained enough air in the mixing chamber. However, this assumption proved incorrect. When testing V4, foam was successfully achieved for the first time.

Figure 82: Venturi V4 PC print

Unfortunately, this success was short-lived. Another modification in this iteration was the shortening of the steam tube, which resulted in hotter steam entering the PLA Venturi system. This caused the system to melt and fail after just 10 seconds. However, the key takeaway from this test was the confirmation that an air intake is necessary.

The same design was later reprinted using PC, a more heat-resistant material. However, this version did not successfully produce foam. The likely explanation is that the PC print was made using a 0.6 mm nozzle instead of a 0.4 mm nozzle, leading to a less effective seal and impacting the system's performance.

Venturi V5

The fifth version of the Venturi system incorporates insights gained from previous iterations (See Figure 83). It is designed to induce air and blasts it within the milk stream. This system introduces a second Venturi mechanism, which draws in air and then directs it at an angle within the mixing chamber. Additionally, the steam channel splits earlier in the system, optimizing the distribution of steam for improved performance.

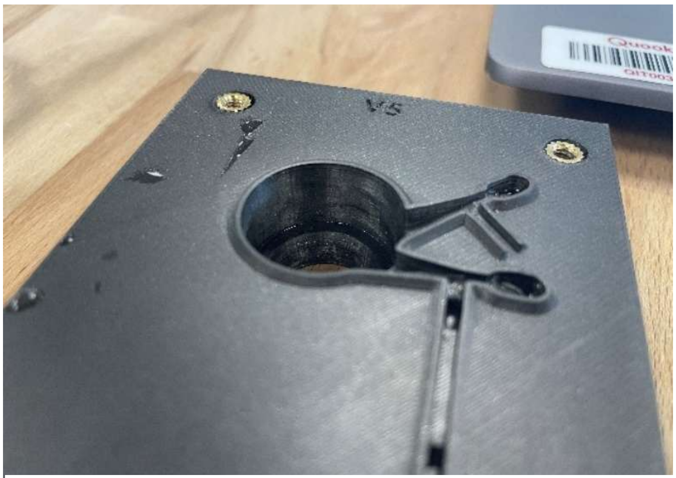


Figure 83: Venturi V5, with an extra venturi valve

The tests, however, were not entirely successful. The second Venturi system, which was intended to draw in air, instead allowed steam to exit through the air intake. There are possible solutions to mitigate this issue, such as implementing a one-way valve. However, adding such a component would significantly increase design complexity and the number of parts. Due to this, I have decided not to pursue this direction further.

Venturi V6

Version 6 takes a step back, as this version is a slight improvement over version 4. It adds a nozzle to direct the milk flow into a cup, allowing better analysis of the foaming results. Additionally, the design optimizes print quality and reduces printing time. The results from this design were positive. However, I noticed that for the first 5 seconds, the model does not produce good foam, likely due to excess water in the steam channel. After 5 seconds, the system produces very light foam, as shown in Figure 84. The next iteration will focus on enlarging the air inlet, as I suspect it might be obstructed by the rubber.

Figure 84: Results of Venturi V6

Venturi V6 – PC

A subsequent iteration was printed using polycarbonate (PC). Although this material has significantly better heat resistance, it tends to deform extensively after printing, greatly reducing the likelihood of successful foaming. This issue was particularly evident in version 6 PC.

Venturi V7

Venturi V7 was made to test the air intake (see Figure 85). The hypothesis was that the silicone seal might be pressed down so firmly that it seals the air intake; this can result in not enough air entering the system needed to foam the milk. Thus, a separate air channel was made; this air channel also has a gap in the side so the Venturi does not have to "suck" in the air far. However, a longer air channel was also added, making sure the channel goes all the way under the silicone seal. The results were mixed; the system was printed with PC, and a little foam did come out of the system. However, the system was leaking milk, indicating that there was no good seal. The reason for this might be the 0.6 printing nozzle used to print the Venturi V7.

Figure 85: Venturi V7, see the air channel

Venturi V8

The main issue with the Venturi system has now been identified as limitations in the manufacturing process. When the Venturi is printed with PLA, it only functions correctly for about 5–10 seconds, which is insufficient to confidently confirm its effectiveness. However, printing the design with PC using a 0.6 mm nozzle currently results in significant warping and insufficient dimensional accuracy. To address this, a complete redesign of the block was necessary. The goal of the redesign was to reduce material usage while maintaining the positioning and shape of the four holes to ensure compatibility with the top block. Additionally, the inserts were relocated to the opposite side to enhance structural strength. The redesigned component was initially printed with PLA to verify the printability before proceeding with a final print in PC (See Figure 86).

Figure 86: Venturi V8, redesigned

Venturi V9

Venturi V9 integrates all the learnings of the last versions and is made with PC (See Figure 87). During the making of this version, the nozzle of the printer was replaced with a 0.4 mm version, and the settings were tweaked to minimize warping of the model. The full redesign in V8 made sure this version was better printable. The tested results were positive; this version did indeed seal very well, and it survived tests of more than a minute. Before the test, all settings of the steam generation were tweaked to optimize this test. The model lasted long enough to test multiple steam settings with this model (See Figure 88). The biggest impact of the different settings was the flow rate of the steam, controlled with the pulse time of the pump. The milk foam that came out of the Venturi was good enough. The milk foam could be used in a product, and this was verified by multiple colleagues that were not involved with the coffee project (N=5). This gave a proof of concept and allows for the next step in the design process: the embodiment, where this Venturi system will be integrated into a working prototype. It is important to note that more iterations will be done to optimize the milk foam.


Figure 87: Venturi V9


Figure 88: Lab setup Venturi v9

Appendix 14 – Iteration on the embodiment of the Product

In this chapter, we will take the learnings from the last chapter and start integrating them into a product. Until now, loose principles such as the Venturi effect have been simplified as much as possible. This approach helped in understanding the finer aspects of this principle while keeping complexity to a minimum. Now that we understand how this system works, we will gradually increase complexity and slowly build towards a final product. In this chapter, you will still see many versions and iterations, but the focus will be different. The primary learning objective will be to understand how each part interacts with others and forms a complete concept.

Integration V1

The first iteration of the integration uses the exact same Venturi system as found in Venturi V9 and incorporates it into an embodied design (see Figure 89 & Figure 90). In this version, the focus is on how to tension the seal between the two parts effectively. Additionally, the location of the steam inlet has been adjusted to a more realistic angle. However, the steam still enters from the side via a quick connector, as achieving a more integrated solution would be challenging with 3D-printed materials.

The seal is tensioned in a simple yet effective way. At the bottom, there is a notch where the milk container clicks into place. The milk container then presses against the seal, securing it tightly with a top click mechanism. For this iteration, it was crucial to get the tolerances right and ensure that the seal is pressed in sufficiently. This was a significant success, as the system worked on the first attempt!

However, since this version was printed using PLA, it is still uncertain how it will react when steam flows through it. Nonetheless, it serves as a first proof of concept for the latching system and will be integrated into future versions that aim to increase durability. It is also worth noting that this version is still relatively large, with a milk reservoir of around 350 ml, while only 150 ml is required. The next steps will focus on reducing the size and printing it with polycarbonate (PC) material.

Figure 90: Integrated V1

Figure 89: All parts of the Integrated V1 prototype

Optimization V1

The first proof of concept for the Venturi system was achieved during the design iteration stage with Venturi V9. This provided the foundation for integrating the Venturi system into an embodied design and marked the start of the third diamond, Embodiment, in the triple diamond methodology. During this diamond, the Venturi system will be integrated into a fully developed prototype with increased complexity. Simultaneously, iterations on the lab setup will continue in order to fine-tune and optimize the milk foaming process. These optimizations will be covered in this chapter under the heading "Optimization," and can subsequently be integrated easily into the embodiment prototypes.

For this optimization, the chamber has been closed, and the output has been moved to the other side (See Figure 91). This resulted in excellent milk foam quality (See Figure 92)! This is a significant milestone. However, there is a problem: moving the opening to the other side will make integration much more difficult, as the Venturi system will need to be placed within the milk jug instead of the outer shell. This could serve as a good plan B, but further iterations might achieve the same result with the correct orientation.

Figure 91: Lab setup Optimization V1

Figure 92: Milk Foam Quality Optimization V1

Optimization V2

The main learning from the last optimization was that turbulence within the chamber is essential. This is why a flow analysis in SolidWorks was conducted to better understand the flow direction of the milk, steam, and air. The SolidWorks flow analysis required some simplifications, as the entire system must be closed. Additionally, milk was simplified as water, which comes with limitations, most notably, the formation of foam cannot be simulated.

The flow analysis helped in better understanding the flow pattern (See Figure 93). However, I initially hoped to use it as a quicker way to test prototypes. This turned out not to be feasible. Creating a flow analysis often takes longer than actually prototyping and testing the system, and the simulation cannot accurately capture the complexity of the process.

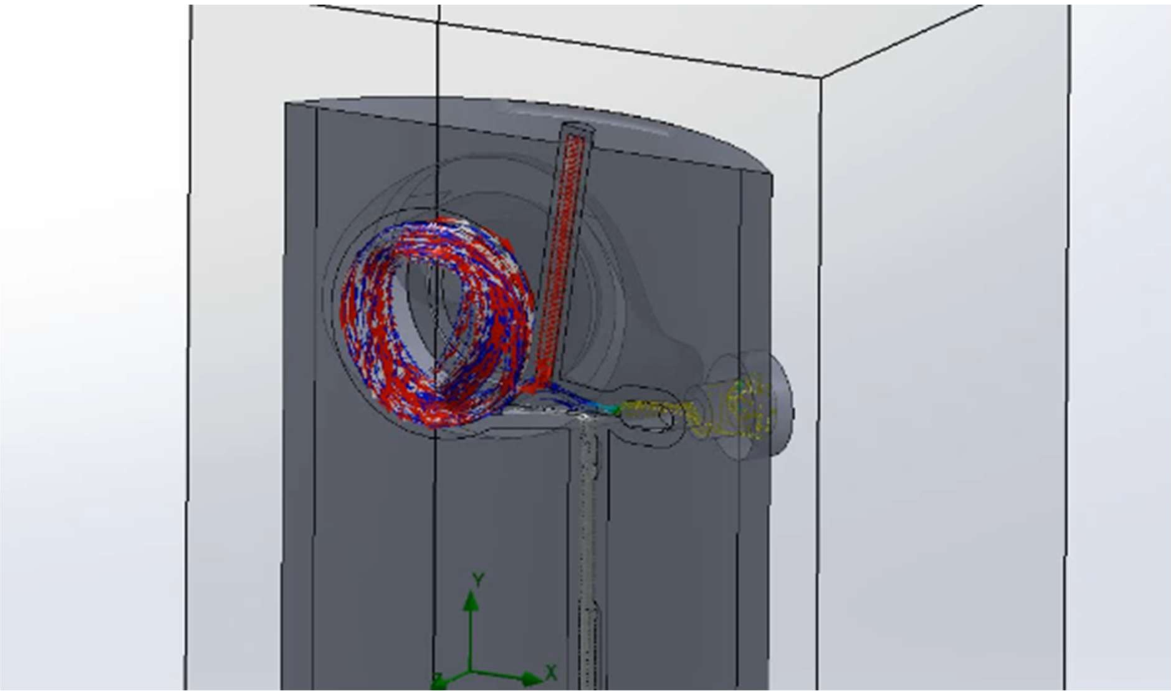


Figure 93: Flow simulation of the Venturi system in SolidWorks.

Figure 93: Flow simulation of the Venturi system in SolidWorks.
This flow analysis visualizes the internal mixing behavior within the Venturi chamber. The yellow stream represents the incoming steam, the white stream represents the milk, and the red stream shows the airflow. The primary learning from this simulation was the role of turbulence, particularly how the angled flow and chamber geometry influence mixing performance and foam quality.

Optimization V2 focused on improving turbulence by adding a small slope to ensure that the milk hits the back wall before spiraling out (See Figure 94). Additionally, this version was made with high-quality polycarbonate and has been sanded down to minimize the impact of any grooves.

The results are extremely positive! The venturi works very well, better even than the LatteGo system (See Figure 95). Most importantly, it is in the correct orientation to be easily integrated.

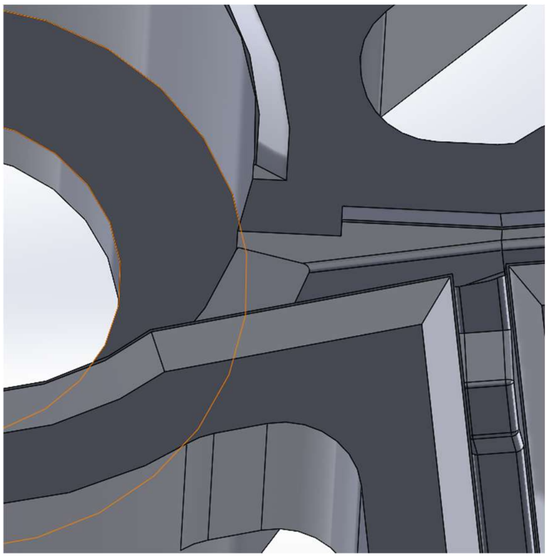


Figure 94: Optimization V2, small ramp


Figure 95: Results of Optimization V2

Integration V2

The goal of Integration V2 is to significantly reduce the size of the system (Figure 96). Integration V1 had space for 350 ml of milk, while the target volume is around 150 ml. Visually, Integration V1 was also too large in comparison to the Coffee Tap (Figure 97). V2 has a volume of 155 ml and shares the same footprint as the Coffee Tap, making it much more visually pleasing when placed next to it. The main challenge was integrating the venturi system into this compact space.

Figure 96: Venturi Integration v2

Figure 97: Venturi Integration V1 (left) and Venturi Integration V2 (right)

Optimization V3

Optimization V3 simplifies the design. Since V2 was a success, I hypothesize that part of its performance was due to the optimized manufacturing process, particularly the sanding. That's why V3 features a straight ramp (see Figure 98). The results were also very positive, not as good as V2, but still strong. This clearly highlights the significant influence of surface finishing, such as sanding, on performance.

Figure 98: Optimization V3

Optimization V4

Integration V4 uses a large ramp to ensure that the turbulence hits the back wall (see Figure 99). The prototype was also made with polycarbonate (PC) and sanded for a smooth finish.

The results were excellent, the foam had a microfoam quality, with small bubbles and a soft texture. When showing the foam to colleagues, they rated it as very good (see Figure 100).

Figure 99: Optimization V4

Figure 100: Optimization V4 results

Integration V3

Integration V3 builds upon the learnings from Optimization V4 (the ramp) and incorporates them into the integrated prototype. For the system to function properly, it is essential that the clamping force of the lid presses the milk container firmly against the rubber seal, ensuring the venturi does not leak. This prototype is fully 3D printed using polycarbonate (PC) and features a specially designed food-safe silicone seal. Due to the use of PC, extra care was taken during printing to prevent warping. The tests yielded mixed results. Initially, the prototype leaked, making it unusable. However, once a small amount of clamping force was applied, the leaking stopped, and the device produced very good milk foam.

Figure 101: Integration V3 in lab setup

Figure 102: components of integration V3

Appendix 15 – List of all criteria's

In Table 6, all the criteria drafted for this project are listed. While only the most important criteria were included in the main evaluation see chapter 6.4, the additional criteria still played a role in guiding design decisions.

Table 6: List of all criteria

#	Requirement	Subcategory	Importance	How/Why	Quantification or Rationale	Quantified Value
1	The system should produce foam in a quick and efficient manner.	Performance	Should	Ensures user satisfaction by aligning with the need for a fast, modern kitchen experience.	Foam production and heating should not take longer than 90 seconds.	90 seconds
2	The system must require minimal cleaning or be dishwasher safe.	Usability	Must	Users prioritize convenience and hygiene. Dishwasher-safe parts simplify cleaning.	Components should be dishwasher-safe or require cleaning in under 30 seconds.	30 seconds
3	The system must fit into Quooker's clean and minimalist design language.	Aesthetic Integration	Must	Quooker's brand identity focuses on sleek, clutter-free designs.	Dimensions should match Quooker's product line and maintain minimal visible components.	-
4	The system should allow automatic operation with minimal user interaction.	Usability	Should	Aligns with user demand for automation and convenience.	Operates with a single button press or automatic detection of milk presence.	-
5	The system must handle standard milk volumes for household use.	Capacity	Must	Ensures suitability for typical use cases, like making coffee for one to four people.	Should foam 100-250 mL of milk in one cycle.	100-250 mL
6	The system could offer manual adjustments for advanced users.	Customization	Could	Adds value for users who enjoy fine-tuning temperature or foam density.	Option to adjust temperature (0–75°C) or foam density with a secondary interface.	0–75°C
7	The system should work with various types of milk, including alternatives like oat milk.	Compatibility	Should	Addresses the growing demand for plant-based milk options.	Effectively foams dairy and non-dairy milk types with consistent quality.	-
8	The system must include safety mechanisms for overheating and dry operation.	Safety	Must	Ensures user safety and device longevity.	Include thermal cut-off and sensors for liquid detection.	-
9	The system could connect to the Quooker tap system directly.	Integration	Could	Enhances convenience by leveraging existing Quooker infrastructure.	Optional integration with Quooker tap for direct milk steaming.	-
10	The system should operate quietly to match Quooker's premium standards.	Performance	Should	Quiet operation improves the user experience and aligns with Quooker's high-end appeal.	Noise level should not exceed 50 dB during operation.	50 dB
12	The system should be durable and have a long lifespan.	Longevity	Should	Matches user expectations for premium-quality products.	Expected lifespan of 5+ years, backed by warranty.	5+ years
13	The system could include a self-cleaning feature.	Usability	Could	Further reduces user maintenance effort.	Automatic cleaning in under 1 minute post-operation.	1 minute

14	The system must prevent milk scorching or over-foaming.	Performance	Must	Ensures consistent results and user satisfaction.	Built-in temperature sensors and foam consistency algorithms.	-
15	The system should be compact to save counter space.	Space Efficiency	Should	Fits into Quooker's clean counter philosophy.	Footprint should not exceed 20x20 cm.	20x20 cm
16	The system could be modular for easy upgrades.	Customization	Could	Allows future-proofing and personalization options.	Modular components for easy replacement or add-ons.	-
17	The system must comply with CE certification and safety standards.	Certification	Must	Required for market entry and consumer safety.	Adhere to EN standards for electrical appliances and CE marking requirements.	-
18	The system must not exceed the maximum allowable power draw for typical kitchen sockets.	Safety	Must	Prevents circuit overloads and aligns with household electrical standards.	Maximum power draw should be under 2300 watts.	2300 watts
19	The system should include child-safe operation features.	Safety	Should	Prevents accidental burns or misuse in households with children.	Includes a child lock or temperature-safe external casing.	-
20	The system could provide visual or auditory feedback for operation and readiness.	Usability	Could	Enhances the user experience and ensures clarity during operation.	Use of LED indicators or beeps to confirm readiness.	-
21	The system must maintain a stable temperature during foaming.	Performance	Must	Ensures consistent foam quality regardless of external conditions.	Temperature variation should not exceed ±1°C during operation.	±1°C
22	The system could include a digital display for settings and feedback.	Usability	Could	Adds a premium feel and enhances usability for users.	Include an OLED or LCD display for temperature, duration, and error messages.	-
23	The system must support multiple foaming cycles back-to-back without overheating.	Performance	Must	Prevents downtime for households preparing multiple drinks.	Allow at least 5 consecutive cycles without thermal shutdown.	5 cycles
24	The system should be made of recyclable materials.	Sustainability	Should	Aligns with modern sustainability standards and user expectations.	Use at least 50% recyclable materials in construction.	50% recyclable
25	The system must avoid spills or leakage during operation.	Usability	Must	Enhances safety and convenience, preventing messes on countertops.	Design a sealed operation mechanism with anti-spill features.	-
26	The system could include a warming function for milk without foaming.	Functionality	Could	Expands functionality for users who prefer warm milk over foam.	Adjustable temperature range from 30°C to 75°C without foaming.	30-75°C
27	The system should include intuitive setup and installation instructions.	Usability	Should	Ensures users can quickly start using the product.	Include a setup manual or digital guide with video instructions.	-
28	The system must indicate when cleaning is required.	Maintenance	Must	Ensures hygiene and avoids performance issues due to neglect.	Provide a visual or audible alert after every 10 cycles.	10 cycles
29	The system could have a customizable exterior color or finish.	Customization	Could	Matches the user's kitchen style and preferences.	Offer at least 3 finish options (e.g., stainless steel, matte black, white).	3 finishes
30	The system must be compatible with standard 220-240V household power supply.	Compatibility	Must	Ensures safe and reliable operation in standard European households.	Operates at 220-240V, 50Hz.	220-240V, 50Hz

31	The system should have an accessible parts replacement process.	Longevity	Should	Prolongs product lifespan and reduces repair costs.	Spare parts must be available for at least 5 years post-launch.	5 years
32	The system should withstand minor impacts without damage.	Durability	Should	Ensures robustness for daily use in kitchen environments.	Survives drops from a height of 0.5 meters without functional damage.	0.5 meters
33	The system could include wireless connectivity for firmware updates or app integration.	Connectivity	Could	Provides modern functionality and allows performance improvements post-launch.	Supports Wi-Fi or Bluetooth for app pairing.	-
34	The system must include clear visual indicators for operational status.	Usability	Must	Reduces user confusion and aligns with premium usability standards.	Include color-coded LED lights for power, operation, and errors.	-
35	The system should include a timer to delay start or auto-turn-off.	Energy Efficiency	Should	Saves energy and allows flexible operation.	Auto-turn-off after 2 minutes of inactivity.	2 minutes
36	The system must be tested for electrical safety under wet conditions.	Safety	Must	Ensures compliance with safety standards for kitchen appliances.	Tested under IPX4 water resistance standards for operational areas.	IPX4
37	The system could support multi-language labels and instructions.	Usability	Could	Broadens market appeal by addressing diverse consumer bases.	Provide documentation in at least 5 major languages (e.g., English, Dutch, French).	5 languages
38	The system must maintain stable operation across a range of ambient temperatures.	Performance	Must	Ensures reliability in various environments, such as warm kitchens.	Operates between 10°C and 40°C ambient temperature.	10°C–40°C
39	The system should have a standby power mode for energy conservation.	Sustainability	Should	Reduces environmental impact and operational costs.	Standby power draw should not exceed 1 watt.	1 watt