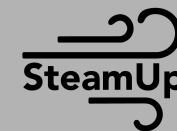




DESIGNING A MARKET-READY STEAMUP

Developing the minimum viable product configuration of a premium milk steamer for home use



Executive summary

SteamUp is a premium standalone milk steamer designed for home baristas and coffee hobbyists who seek café-quality milk frothing from the comfort of their home. As specialty coffee culture continues to rise, so does the demand for better milk preparation at home. While most espresso machine brands focus on perfecting espresso, they often treat milk steaming as secondary, delivering average performance. SteamUp addresses this market gap by offering high-end, standalone steam performance in a design-forward product.

In-depth milk research shows that producing consistent microfoam with stable texture and precise temperature control can only reliably be achieved using a boiler-based system. SteamUp embraces this premium technology, while most competitors avoid it due to higher costs and complexity. Its boiler core provides a distinct technical advantage, enabling it to deliver professional-grade steam performance at home.

The project set out to explore whether SteamUp could be designed and produced with both competitive advantage and financial viability. In addition to assessing performance, usability, and cost, the project aimed to evolve the prototype into a market-ready minimum viable product (MVP). User research confirmed that the target audience values aesthetics nearly as highly as performance. This guided a shift toward design embodiment, where the goal became to express SteamUp's technical power through an elegant, recognisable design language.

An extensive form-giving process led to four concept directions, each evaluated for its emotional resonance, spatial proportions, and semantics. The final concept, Duck by SteamUp, was selected for its ability to balance performance and personality. It features a minimal yet expressive form, compact proportions, and soft curves that communicate both quality and calmness. Validated by 41 target users and rated 8+ by over 50%, Duck sets a strong foundation for brand identity. Moreover, its design enables future variation in materials and colours, allowing for tailored visual identities across user segments.

Beyond visual identity, sustainability was considered through the lens of repairability. While not a primary focus, the design was developed with disassembly in mind: all parts are mechanically fastened, reversible, and serviceable. This aligns with the values of the home barista community, where the ability to tweak and maintain machines is often celebrated.

Cost modelling revealed that the boiler is both SteamUp's largest cost driver and its strongest differentiator, accounting for 25% to 50% of the unit cost. At a 500-unit batch size, the manufacturing cost (MC) lands around €170, making the original €100 MC target for a €350 retail price difficult to meet. However, from 1,000 units onward, cost structures become more favourable, and the MC multiplier (typically 3 to 5x) falls within the feasible retail range of €350 to €500. This top-down estimate aligns with market expectations for premium milk frothers, especially when factoring in SteamUp's superior technology and design.

In conclusion, this thesis shows that SteamUp can be designed with clear competitive advantage and brought to market at a viable cost, if scale is reached. While the original €100/€350 target may now seem dated, it remains within reach at higher volumes. Production at 500 units is possible through early-stage startup strategies such as founder-led assembly or simplified tooling. These are not permanent solutions, but they offer realistic launch paths until full-scale production becomes viable.

SteamUp is set to advance beyond the prototype phase, blending premium steam performance with elegant design and a seamless user experience.

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01 Introduction

Coffee is a beverage enjoyed daily at home, work, and in cafés, each setting requiring different machines. Fully automatic models are common in offices, while large Italian espresso machines dominate cafés. Most café orders are milk-based drinks like cappuccinos and lattes. However, achieving the same milk texture at home remains a challenge. This gap led to the development of SteamUp, a stand-alone, powerful milk steamer designed to help home baristas recreate café-quality drinks with ease. Currently aiming at a retail price of approximately €400.

SteamUp is an early-stage hardware startup targeting a niche market with limited financial resources. It must ensure the feasibility of producing a product that meets user needs while remaining cost-effective, within a small initial market size. A functional prototype (TRL 5/6) with custom-sourced components was the starting point of this project, which is displayed left the figure on the right.

The first chapters provide essential background, introducing the assignment, context from earlier research, and the methodology used. Chapters 05 to 10 form the analytical core: Chapter 05 assesses the current prototype; Chapters 06 and 07 explore steam performance and system modelling; Chapters 08 and 09 cover user research and define the MVP; Chapter 10 synthesises key findings into four main product drivers. Chapter 11 builds a vision from these insights. Chapters 12 to 15 trace the form-giving journey: from semantics and concept development to selection and validation. Chapter 16 presents the final embodiment, where visual, technical, and user considerations converge into one cohesive product. Chapter 17 integrates sustainability through disassembly and repairable construction. Chapter 18 addresses cost estimation and early pricing strategy, highlighting financial feasibility for hardware startups. The thesis concludes with final reflections and future outlook.



02 Assignment

This master thesis project focuses on developing the Minimum Viable Product (MVP) configuration of SteamUp, advancing the current prototype from TRL 5/6 to TRL 7/8. The focus has shifted during the first months from production feasibility to embodiment design, emphasising aesthetics, size reduction, and intuitive usability.

Generally, early-stage startup research focusses on customer-problem fit. Giving insights in the potential sales the company can achieve, based on customer data. On this topic further research is currently run by another SteamUp founder. This project focusses on the design engineering side of SteamUp. Asking the main question, can SteamUp be designed and produced with competitive advantage and at a reasonable price point? What if people want to buy this product for €350, are we able to go through the full design process and produce the product for less than €100?

03 Context

SteamUp was founded in the Master's elective Build Your Startup in December 2023. Since then, a lot has happened. This chapter outlines the key developments that inform this thesis, including market exploration and technical decisions that shape the current design.

Target audience

While coffee is a widely consumed beverage, SteamUp is designed for a specific audience. The initial beachhead market was defined as: “(Aspiring) home baristas who have experience with professional machines and seek to replicate that experience at home.” These users appreciate the craftsmanship behind milk frothing and value control over their results.

Wouter's thesis (in progress)

The original target audience was identified through customer conversations and online tests yet lacked scientific validation. Currently, SteamUp co-founder Wouter is conducting research into customer segmentation, defining the beachhead market, and assessing willingness to pay. While his findings are still in progress, collaboration between this thesis project and Wouter's research ensures that technical and market insights are aligned.

Jeppe's thesis (finished)

Another SteamUp co-founder, Jeppe, previously completed his thesis on replicating the performance of commercial steam wands for home use. His research compared foaming methods, mechanical agitation, steam injection, and venturi injection, concluding that only steam injection could produce the necessary fine microfoam. Further analysis of heating elements, thermocoil, flow-through heaters, and boilers, found that boilers provided the most consistent and dry steam. Closely mimicking professional machines. A small boiler was ultimately chosen as the best balance between performance, size, and heating time. While the larger boiler performed marginally better, the compact version aligned better with home use requirements.

This project builds upon the internal system defined by Jeppe's research and subsequent refinements made by the SteamUp team. While the boiler remains a key selling point, other design aspects, such as usability, form factor, and aesthetics, are less defined and open for development. This thesis focuses on refining these elements to improve the product's appeal and user experience.

04 Method

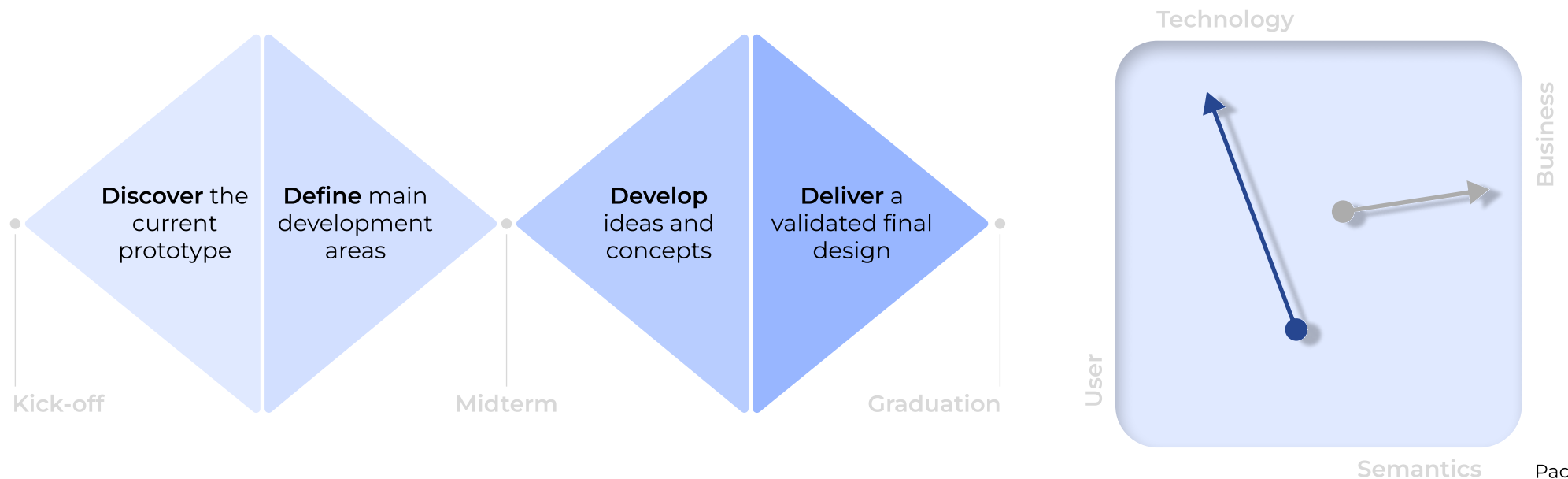
This thesis follows the Double Diamond methodology, a structured design approach consisting of alternating divergent and convergent phases. Figure 4.1 shows the structure and content per phase. The midterm moment presents the key development area for the second phase, based on findings of the first phase. The graduation moment presents the final design within the design space.

Traditional design projects focus on Human, Business, and Technology (Stanford Design Thinking). However, this project discusses a luxury consumer product, where emotional factors influence purchasing decisions beyond functionality.

To support this, Creative Reflection is integrated as an iterative rather than purely analytical approach. Instead of breaking problems into parts, it frames challenges within four key dimensions: Business, Technology, User, and Semantics. Designers move fluidly between these parameters to refine concepts, fostering creativity, intuition, and holistic thinking, leading to compelling, user-driven solutions.

By combining Creative Reflection and Double Diamond, this thesis balances functionality and emotional appeal in SteamUp's final design.

Figure 4.1: Project combines structure of Double Diamond and quick iteration by doing method from Creative Reflection



DISCOVER

This section comprises five analytical chapters that collectively inform the technical, functional, and experiential foundation of SteamUp. Chapter 5 assesses the current prototype's readiness for market and identifies four critical engineering focus areas. Chapter 6 dives into milk frothing principles to define performance requirements for achieving café-quality results at home. Chapter 7 analyses the thermal and fluid dynamics of the steam generation system to optimise efficiency and consistency. Chapter 8 evaluates user interaction with the prototype to uncover usability improvements and technical refinements. Chapter 9 outlines the essential features for a Minimal Viable Product, based on direct input from potential users.

Discover - Analysis

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05 Prototype evaluation

This chapter reviews the current prototype by assessing its level of minimal viable product readiness and potential for a short time to market. Four key development areas were identified: the steam wand and connection system, internal steam piping, electronics to PCB design, and the embodiment structure.

5.1 Minimum Viable Product

Minimum Viable Product (MVP) is a Lean Startup strategy to test product hypotheses with minimal resources, accelerate learning, and reduce wasted development time (Robinson, 2016; Ries, 2011). An MVP varies by startup stage and learning objectives. It must deliver value and be sellable, even if not scalable (Coelen, 2023). For SteamUp, the prototype must produce high-quality milk foam and validate demand at €350. An MVP must provide enough value to engage early customers and confirm market potential (Ries, 2011).

5.2 Time to market

A product's time to market (TTM) is crucial for success, balancing development speed, production costs, and product quality. TiToMa and Moore (2020) outlines several cost-reduction strategies that impact both TTM and overall profitability. Key approaches relevant to SteamUp's development include:

- Using pre-manufactured off-the-shelf (OTS) components
- Minimising part variations and unifying design elements
- Reducing material costs
- Eliminating unnecessary features
- Analysing competitor for competitive benchmarking

5.3 Prototype review

The prototype was built before the start of this research. With the current understanding of MVP and TTM, the prototype was analysed using Alpha testing and hands-on building experience, to identify key development challenges. Figures 5.1 and 5.2 show representation of the design's internals and embodiment.

The steam wand and connection system (red area) require a fully custom design. The current assembly was constructed from spare parts due to the absence of OTS components. Spare parts are too expensive and often not form-optimised, making them unsuitable for long-term implementation.

The internal steam piping (blue area) suffers from excessive heat loss and flow disruption. Inefficient routing, abrupt diameter transitions, and excessive bends significantly impact steam efficiency. The round form constraint, combined with inexperienced design choices, further complicated the layout.

The electronics and interface integration (green area) also require significant improvements. The interface is unreliable, and the overall wiring system is highly sensitive to interference, leading to inconsistent performance.

The embodiment design is not suitable for production. The prototype consists primarily of 3D-printed parts, which lack the durability and refinement required for a consumer product.

These findings highlight critical design flaws that must be addressed to create a viable product. The next chapters analyse prototype segments, focusing on performance and usability.

5.4 Design implications

- The steam wand and connection system require in-house custom design.
- Optimising sourcing and implementing a structured piping design will enhance performance while minimising the number of unique components.
- A fully integrated PCB will eliminate wiring complexity, enhance durability, and reduce overall size, improving both assembly and reliability.
- The embodiments need transition to manufacturing-ready materials to ensure long-term reliability, premium aesthetics, and cost efficiency.

Figure 5.1: High priority prototype internal improvements highlighted.

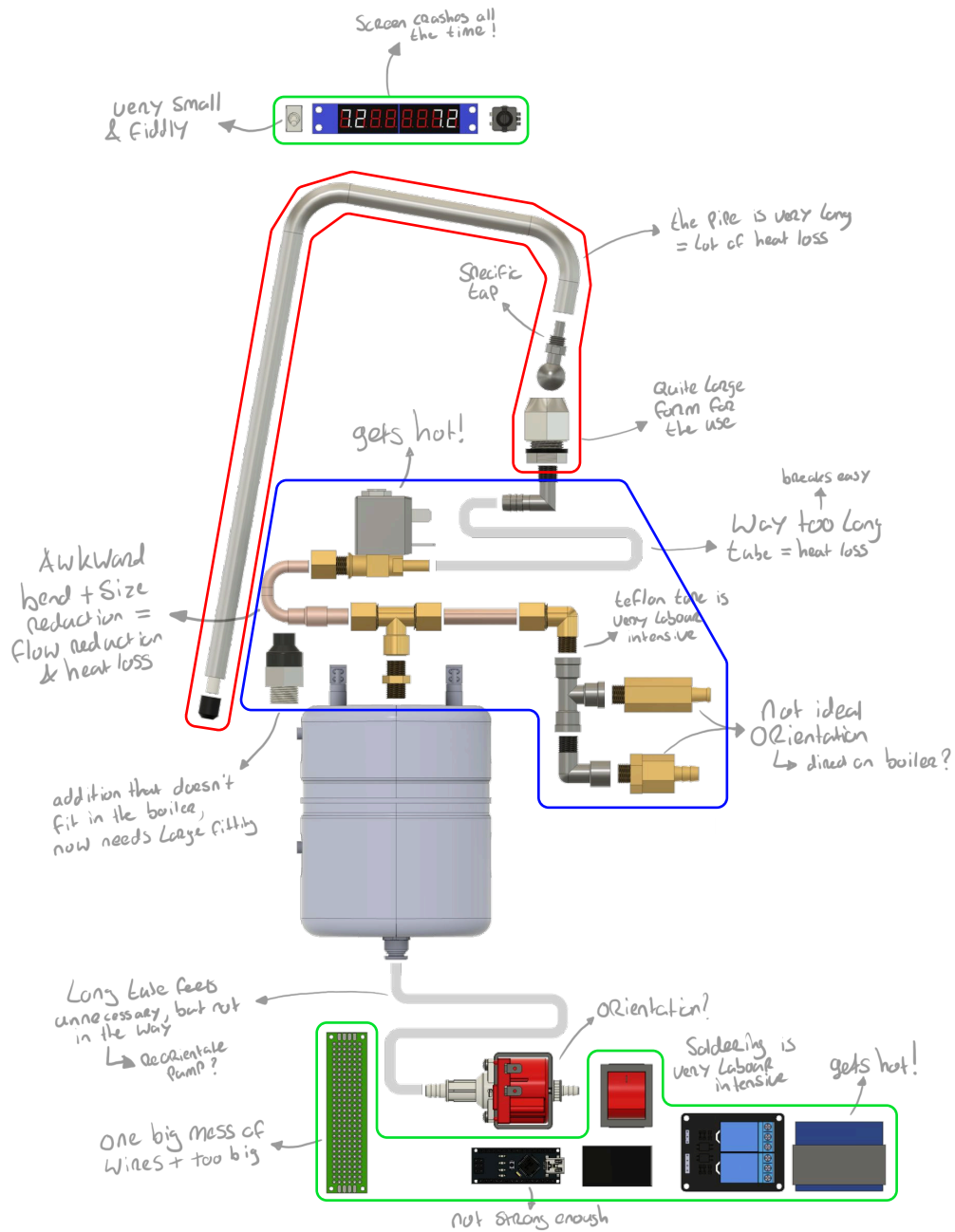


Figure 5.2: Overview of 3D printed prototype skeleton, proof of concept but embodiment needed.



06 Fundamentals of milk foam

This chapter explores the fundamental principles of milk foam formation, which are essential for designing a café-quality milk frother for home use. Understanding foam stability, air incorporation, and protein interactions allows for the creation of fine, stable microfoam, which is crucial for achieving latte art.

The ideal milk foam requires sufficient protein and fat content to provide a rich mouthfeel. It should significantly increase in volume, remain stable for at least 15 minutes, and be heated to approximately 60°C. To ensure smooth latte art, air bubbles should be below the threshold of human visual perception.

The SteamUp product must feature an adjustable air intake, provide a clear indication when frothing should stop at 60°C, and generate a powerful steam flow to create a strong vortex that breaks down bubbles. Additionally, clear usage cues are needed to guide less experienced users toward the correct frothing technique.

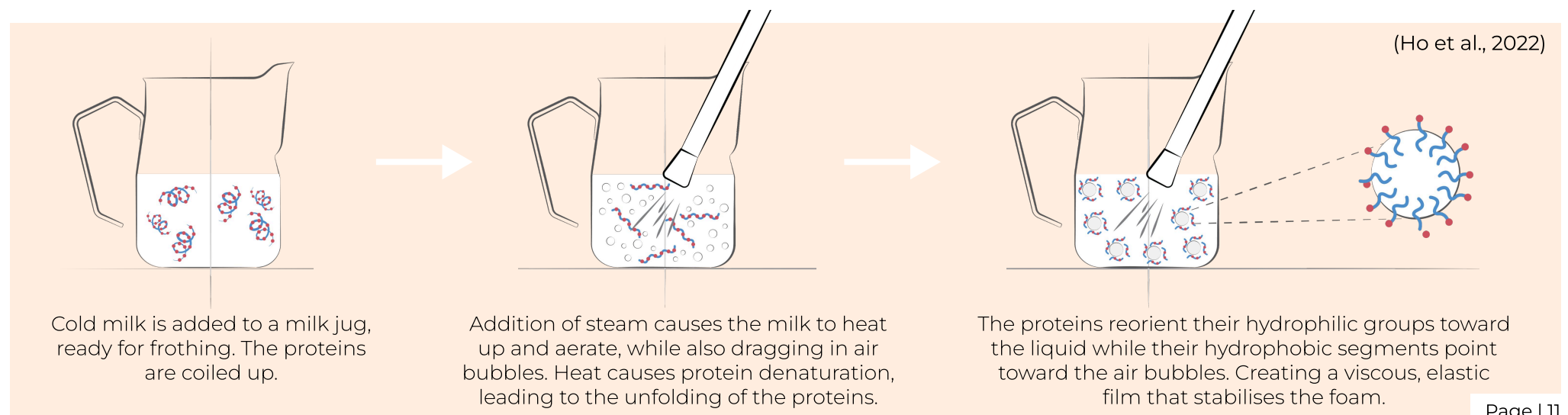
6.1 Foam formation

Foam is a colloidal system created by dispersing gas into a liquid medium. Generally, foam formation occurs through mechanical

agitation or gas injection, resulting in a two-phase system: a continuous liquid phase that encapsulates a dispersed gaseous phase (Smith & Culbertson, 2000). Two additional factors are crucial for successful foam generation. Surfactants reduce the surface tension between the gas and liquid, facilitating the formation of small, stable bubbles. In the context of milk foam, proteins act as natural surfactants (Hupperz, 2010). Energy, in the form of heat and moving milk vortex, is also required to overcome the interfacial free energy generated, when the surface area between the gas and liquid increases (Walstra, 2003; Campbell & Mougeot, 1999). Figure 6.1 shows a detailed view of the formation of milk foam with steam injection.

The protein and fat balance also play a vital role. Milk fat negatively impacts foaming ability. At temperatures between 10°C and 40°C, fat remains partially crystalline, which disrupts protein function and reduces foam stability (Hupperz, 2010; Ho et al., 2024). For this reason, milk is typically stored below 10°C and rapidly heated above 40°C during frothing. Interestingly, the general perception is that whole milk is better for milk frothing than skim milk, which is not scientifically accurate. The preference for whole milk stems from its richer taste and fuller mouthfeel, improving the overall drinking experience (Truong et

Figure 6.1: Proteins facilitating air encapsulation through the energy provided by hot steam.



al., 2020).

6.2 Defining ideal milk foam

Milk foam is often described as soft, creamy, or “microfoam,” but according to Huppertz (2010) a more scientific approach evaluates foam according to foamability, foam stability, and air bubble size.

Foamability, or the Steam Frothing Value (SFV), refers to the ability of milk to foam. It measures the volume of foam produced relative to the original liquid volume. This is typically measured 3 minutes after preparation (Rampini et al., 2007). Foamability is closely linked to protein content and the efficiency of protein adsorption at the air–liquid interface (Marinova et al., 2009).

Foam stability refers to the foam’s ability to retain its volume and structure over time. Processes like liquid drainage, bubble coalescence and disproportionation can lead to foam degradation, see Appendix C6. Foam stability is also influenced by the initial foam height (taller foams often collapse faster) and the uniformity of bubble size (Klimanova et al., 2022). Optimal foam stability is achieved between 55 °C and 65 °C, although temperatures above 60 °C risk whey protein denaturation (Kamath et al., 2008; Klimanova et al., 2022). In the context of espresso-based beverages, foam stability is generally sufficient if it retains most of its volume during the typical 15-minute consumption period.

Air bubble size and uniformity of air bubbles are critical determinants of foam texture and stability. Microfoam (<200 µm), characterized by uniformly small bubbles, offers a smoother mouthfeel and higher foam stability than foam composed of larger or unevenly sized bubbles (Walstra, 2001). Turbulence and shear forces govern the breakup of bubbles: once these forces exceed a critical threshold, larger bubbles fragment into smaller ones (Evans et al., 1992). In practice higher fluid velocity tends to reduce bubble size. This relationship holds only if the entrainment ratio remains constant (Varley, 1995). Achieving sufficient turbulence without introducing additional air can be challenging, particularly for unskilled home baristas or with low power frothing devices. Controlling these factors is essential for producing microfoam.

Several other factors influencing the formation like, protein and fat ratio’s, pH of the milk, temperature effects and addition of water, while important to milk foam quality are left out of scope for this project. Further discussed in the Appendix C6.

6.3 Rise of plant-based alternatives

Consumer demand for plant-based milk alternatives has surged, with 50% of coffee drinkers in 2020 consuming plant-based coffee beverages outside the home (Grant, 2020). Key motivations include health trends, allergen concerns (McCarthy et al., 2017), and environmental impact (Haas et al., 2019). These factors highlight the need to understand protein composition, fat content, and surfactant behaviour (Zakidou et al., 2022), when designing a milk frother. Figure 6.2 compares four popular plant-based options to typical whole milk.

6.4 Conclusion

A high-quality milk foam is characterised by its ability to evenly disperse gas within a liquid phase, forming a stable, voluminous structure that lasts at least fifteen minutes. Ideally, the foam consists of micro-bubbles too small to be seen, creating a smooth, velvety texture that supports latte art. Achieving this level of foam quality depends on several factors, including milk composition, frothing technique, and device performance.

A well-designed milk frother must introduce sufficient air while maintaining a strong and controllable vortex to prevent the formation of large, unstable bubbles. Effective control over air incorporation is critical for producing a fine, uniform foam structure.

Milk selection plays an equally important role, as protein and fat content directly influence foamability and stability. The initial cooling and subsequent heating to ~60°C are important steps in optimising both texture and taste. User technique is another key factor, as improper air injection, aeration, and temperature control compromise foam quality. **Thoughtful product design can help mitigate risks of user’s knowledge lack about milk foaming fundamentals, by guiding users toward optimal frothing techniques.**

Plant-based alternatives are gaining popularity due to health, allergy, and environmental concerns, but require different frothing techniques and often produce distinct foam structures. Advances in non-dairy formulations are improving foaming performance. **Optimal results for plant-based alternatives become achievable with a powerful and adjustable steam system.**

Understanding these principles is essential for consistently achieving high-quality, stable microfoam, ensuring an excellent cappuccino experience at home.

6.5 Design implications

- The system must allow users to modify the amount of air introduced during frothing to accommodate different milk types and preferences.
- The device must provide a clear indication to stop frothing when the milk reaches 60°C to prevent overheating and maintain foam quality and taste.
- The generated foam must retain its structure and volume for at least 15 minutes to ensure a consistent drinking experience.
- The vortex's turbulence and shear forces must be sufficient to produce air bubbles smaller than 200 μm, achieving smooth, stable microfoam.
- During the second frothing phase, the system must maintain a stable entrainment ratio to ensure reduction of bubbles.
- The device must incorporate visual or functional use cues to assist users in applying the correct frothing technique.

Figure 6.2: Plant-based milk alternatives vary in most terms from whole milk, impacting experience.

					
Milk type	Dairy full fat	Coconut	Soja	Almond	Oat
Protein content	High	Low	High	Low	Low
Fat content	High	High	Low	Low	Medium
Foamability	Easy	Difficult	Easy	Difficult	Medium
Heat resistance	65°C	65°C	65°C	55°C	65°C
Taste	Traditional	Distinctive	Beany	Sweet	Neutral

07 Theoretical steam system model

This chapter focuses on modelling and analysing the SteamUp steam generation system to evaluate its thermal and fluid dynamics performance. Looking at heating up time, steam generation rates, efficiency and heating up time of the milk jug. Understanding these principles is critical to optimising steam consistency, product efficiency, and usability in the final product.

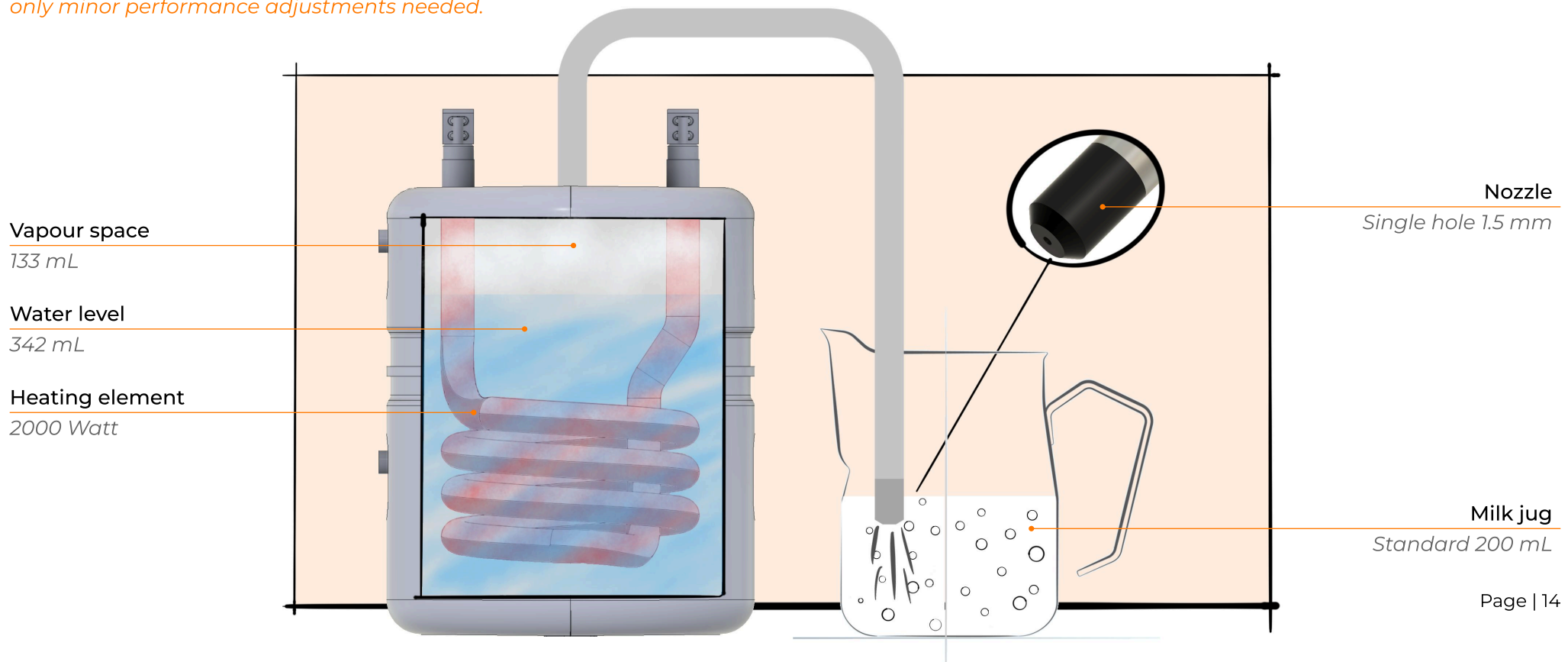
The findings indicate that the current boiler design is well-optimised; with an effective water-to-air ratio and optimised contact space to the heating element, resulting in sufficient steam generation. However, reducing the heating element from 2000 W to 1500 W is advised given the maximum power consumption of typical fuse boxes. Efficiency design improvements, reducing heat loss and optimising PID tuning, must be made to reach this goal.

Figure 7.1: Current configurations are close to ideal, only minor performance adjustments needed.

Nozzle geometry adjustments are discouraged based solely on this model, as usability effects cannot be fully accounted for in mass flow rate calculations.

7.1 The system model

Figure 7.1 shows visual representation of the theoretical model of the current SteamUp steam generation and distribution system. The model contains a static simplified state, with an equilibrium inside the boiler of 120°C equal to 1.0 barG, full model can be found in Appendix C7. The model was reviewed by Dr. R. Delfos, professor at the faculty Process & Energy, to check assumptions and calculations. General thermodynamics and fluid mechanics were used, combined by steam specific researched of Anderson (2003) and Munson et al. (2013).



7.2 Scenario adjustments

Adjusting the water-to-air ratio significantly impacts heating time, with less water leading to faster heating and vice versa. However, the amount of ready vapour remains largely unchanged, meaning steam performance consistency does not improve with lower water levels. In all cases, almost all steam is generated after opening the steam switch. Reducing the water volume also limits contact between the heating element and water, decreasing energy transfer efficiency and ultimately reducing steam generation. While increasing the water level could enhance thermal mass, it risks introducing water droplets into the steam piping due to the proximity of boiling water to the steam outlet, leading to unwanted moisture in the steam.

The heating element heats the boiler to 120°C in 72 seconds in the ideal theoretical model, generating steam at 0.90 g/s. Lowering power to 1500 W (a standard heating element option) proportionally reduces steam production to 0.68 g/s but increases warm-up time by 33% (to 96 seconds). Given the current calculated boiler's efficiency of 53%, this lower-power element cannot sustain the current nozzle flow rate. A theoretical boiler efficiency increases to 64% would be required for stable steam production with a 1500 W heating element, without considering steam heat losses and piping flow inefficiencies.

Reducing power consumption alone does not enhance sustainability, as total energy use remains unchanged. Instead, reducing heat losses is a more effective approach. The primary motivation for reducing power is electrical load constraints, as household fuse boxes typically support 3500 W. The current prototype, when used alongside a typical water boiler and other small continuous electronic devices, could overload the system. Significant improvements in thermal efficiency and PID control are required before reducing heating power is viable.

Practical tests indicate pressure drops of up to 0.3 bar when steam is drawn, causing temporary fluctuations in steam flow before recovering. This is due to both sensible heat loss of the water and the lag in time for the heating element to reheat the water. Contradicting the need for a more responsive and powerful heating system. In Chapter 08 user perception of current steam pressure is researched, if it is perceived as below expectations, redesign of a boiler should be considered. Altering to a boiler with a heat sink structured heating element, optimising contact area, is considered as an interesting research area.

The nozzle diameter directly influences steam mass flow, as flow area scales with the square of the diameter. Adjustments to nozzle size impact milk heating time, but steam flow rate alone does not determine usability. The vortex effect created by the nozzle significantly affects steam dispersion and frothing control, making nozzle design a too complicated factor in overall usability for this model. Especially when the geometry of the nozzle is changed to multiple holes with angles, the calculations get even more complex. Chapter 08 further discusses nozzle geometry preferences of users.

7.3 Conclusions

The analysis confirms that the system engineering of thermodynamics and fluid mechanics within the SteamUp product is highly complex but roughly modellable. Simplified calculations indicate that **the current boiler is well-optimised for the steaming appliance, optimising water-to-air ratio, generating new steam quickly, and ensuring extensive contact with a powerful heating element.**

A reduction from a 2000 W to a 1500 W heating element is preferred due to the 3600 W capacity limit of a standard **household fuse box**. However, this reduction would increase heating time by approximately 30%, which importance is discussed in Chapter 09. With the current efficiency of the boiler, this step-down cannot be achieved. **The step-down can only be achieved if system efficiency is improved, theoretically at least by 11% but ideally with 25% (equals step down in power).** Further research and design refinements on thermal heat loss reduction and PID tuning are necessary to reach this goal. Addressing these inefficiencies would also lower total power consumption, benefiting sustainability.

Specific modifications to nozzle geometry based on this model are discouraged. This model focusses on mass flow rate and lacks insight in the usability of different nozzles configurations. Further research is needed to make informed decisions. Chapter 08 provides insights on nozzle geometries from user's perspective.

7.4 Design implications

- The boiler must be filled to maximise steam availability while preventing water droplets from being drawn into the piping, avoiding wet steam formation and dilution.

- PID control and thermal energy losses must be reduced by at least 11%, with a preferred reduction of 25%, to enable the transition from a 2000W to a 1500W boiler without efficiency loss.
- The heating element must have a faster response time to compensate for pressure drops when the steam valve is opened, ensuring consistent steam output.

08 Usability observations and feature interview

This chapter investigates the usability of the current SteamUp prototype through observational testing and post-test interviews. Focusing on user interactions, frothing performance, and overall design feedback. The goal is to identify which elements of the design are intuitive and which require improvement to enhance user experience and product functionality.

The results indicate that a major interface redesign is needed to improve usability, including clearer labelling, improve switch design, and a more intuitive display. Minor technical optimisations, such as PID tuning, can refine steam consistency, which was perceived as suiting participants needs. Adjustments to size and user guidance will enhance accessibility, making the product more suitable for a broader audience.

8.1 Research goals and participant selection

The primary objective was to assess usability and identify areas for

improvement. Usability focused on turning on the device, setting pressure, and steaming milk. Observational testing revealed which aspects were intuitive and which required learning. Beyond usability, a key question was whether participants could create microfoam.

Post-test interviews gathered opinions on design elements, including power, adjustability, and performance comparisons to café machines. Feedback covered the interface, size, cleaning, drip tray, water reservoir, steam wand, nozzle, and aesthetics.

Nine high-priority potential clients were selected. This priority estimation was adjusted four times post-study. To reduce bias, eight of nine participants were unknown to the researcher before this project (Fitzpatrick, 2014). Participants varied in home coffee setups and frothing experience to represent a broader audience. Once SteamUp's beachhead market is defined, this research can be repeated for a more refined dataset.

Figure 8.1: Visual representation of the study setup and participants using the prototype.



8.2 Method

The study began with participants interacting with the prototype while the researcher observed. Participants were instructed to turn on the device, set the pressure, and froth multiple jugs of milk. They were free to experiment with different milk types, nozzle sizes, and pressure settings. Following the testing phase, a semi-structured interview was conducted to explore their experiences and preferences in greater depth. Figure 8.1 provides a visual representation of the test setup, participant interactions, and examples of latte art produced during the study. A detailed and reproducible report of the study, along with the collected data, can be found in Appendix C8.

8.3 Results

Usability and perceived performance

User testing highlighted key usability challenges, particularly in locating the power button and interpreting display values. Seven out of nine participants were unsure whether the bar indicators represented actual or target pressure, but bar pressure was preferred over temperature or percentage-based readings. Six participants disliked the steam on/off switch placement, and two found it too fiddly. The timer feature was never used. These issues indicate a need for clearer labelling and a more intuitive interface. Once explained, pressure adjustment was intuitive, with all participants modifying settings. However, while the feature was appreciated, its necessity was questioned. Suggesting it should be available but not a prominent interface element.

Experience level influenced adaptation speed. Skilled baristas created microfoam instantly (4/9), while less experienced users needed guidance but remained engaged (2/9). Steam power was compared to professional machines, though minor inconsistencies in pressure were noted due to suboptimal PID control. Overall, the prototype was perceived as powerful. Only two participants noticed the steam being too wet, but both still found the frothing quality to meet their needs. This performance result exceeds the researchers' expectations.

Product size and steam wand

Most participants (8/9) found the prototype too tall, with three preferring a more compact and narrower design for smaller kitchens. While size concerns may be influenced by aesthetics, reducing the overall dimensions appears necessary. A height reduction of 10 cm and a width reduction of 2.5 cm were discussed with participants as suitable adjustments, though further research is required to validate these findings.

Nozzle customisation was favoured by six out of nine participants, with three expressing strong preferences based on previous experiences. This suggests that offering nozzle variations could be a viable business model consideration, though developing a proprietary nozzle is unlikely to be a major differentiator, as standard nozzles are preferred.

Steam wand interaction was intuitive for all participants (9/9), and six out of nine found the design aesthetically pleasing. Preferences on wand movement were divided, with four favouring single linear motion and five preferring full 360° rotation, though only if cost-effective. A cold-touch steam wand was seen as a nice addition but not essential. Based on these findings, a complete redesign of the steam wand is unnecessary, as it contributes to brand identity. Ensuring accessibility remains crucial for usability.

Other features and research limitations

No clear preference was found for cleaning, maintenance, drip tray, or water reservoir. None of these features were identified as high-priority design requirements. However, the research setup may not have provided unbiased responses or wasn't designed for these types of questions. Most users would naturally prefer an easy-to-clean, low-maintenance product. Similarly, design aesthetics are difficult to assess objectively, as participants may be hesitant to critique the prototype directly to the researcher who built it. Chapter 09 will explore more informed conclusions on design aesthetics.

8.4 Design implications

- A major interface redesign is required. This includes improving the steam switch placement, removing pressure setting as a primary interface feature, and redesigning the display interface.
- Prototype performance is nearly optimal, requiring only minor adjustments such as PID tuning for improved steam consistency.
- Clear instructions or usage cues should be added to help novice users achieve the correct steaming technique.
- Size reduction is necessary, with an estimated decrease of 10 cm in height and 2.5 cm in width, which should be validated.
- The steam wand design is visually appealing and corresponds to the machine's power, current accessibility is ideal, only optimisation adjustments needed.

09 Minimal viable SteamUp

This chapter explores the essential features required for a Minimal Viable Product (MVP) configuration of SteamUp, based on insights from a feature ranking study with nine participants. Understanding which features are critical to users helps inform design priorities and potential trade-offs in the final product.

The findings define the minimal viable SteamUp as a high-pressure steaming device with a visually appealing design. Contrary to expectations, the interface can be relatively simple. A compact counter size and quick heating time were identified as most important additional features.

9.1 Research goals and participant selection

The primary objective was to gain insights into the potential Minimal Viable Product (MVP) configuration of SteamUp. The method used was self-developed, and Figure 9.1 illustrates the features examined in the study alongside the test setup. The study involved the same nine

Table 9.1: Participants varied in home coffee setups and frothing experience to represent a broader audience.

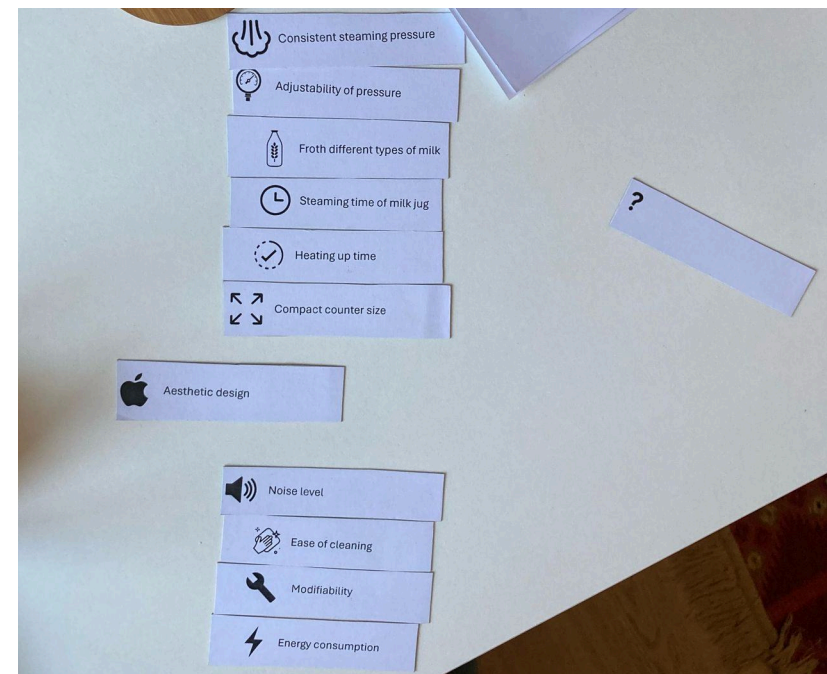
Part.	Current tech	Froth skill	Client pot.
P1	Thermoblock	Medium	Medium
P2	Single boiler	Medium	High
P3	Thermoblock	Low	High
P4	Nespresso cup	Low	Low
P5	Thermoblock	High	Medium
P6	Single boiler	High	High
P7	Dual boiler	High	Medium
P8	Boiler with heat-exchanger	High	High
P9	Full automatic	Medium	High

participants from Chapter 08, identical selection criteria applied. Table 9.1 presents participant demographics, home setups, frothing skills, and adjusted potential. Home setup was included because research indicated that participants envisioned their ideal frother as a complement to their existing setup. The other factors provide an overview of the participant range, as discussed in the previous chapter.

9.2 Method and data processing

The study was conducted immediately after the previous chapter's study. Participants first ranked features from most to least important, considering their ideal milk steamer rather than using the prototype as a reference. The highest-ranked feature received 0 points, the second received 1 point, and so on, with the eleventh-ranked feature receiving 10 points. In the second exercise, participants categorised features as either must-haves or nice-to-haves. Must-haves were assigned 1 point, while nice-to-haves received 0 points. Table 9.2 presents the overall ranking from both exercises, along with shifts in feature importance. For

Figure 9.1: List of features and test setup.



both tasks, participants were asked explain their reasoning. A detailed and reproducible report of the study, along with the collected data, can be found in Appendix C8.

9.3 Results

The feature ranking analysis indicates that while steam pressure ranked highest in the free ranking, all participants (9/9) selected aesthetic design as a must-have. Suggesting visual appeal is a decisive factor in purchase decisions. Since performance was already well received, only minor adjustments are needed, whereas significant effort should be directed toward refining aesthetics.

Pressure control adjustability ranked joint second in the free ranking, yet only five out of nine participants considered it essential. Highlighting a divide between those who value customisation and those who expect an optimal default setting. This reinforces the need for interface improvements, as discussed in Chapter 08.

Compactness ranked mid-range (40/90 points), yet six out of nine participants ultimately deemed it a must-have, indicating that space constraints remain relevant. Size reduction is feasible through PCB

design and piping optimisations. Heating time, ranked highly in both exercises, and is already found sufficient according to Chapter 08.

Energy consumption (87/90) and noise were not prioritised, requiring no design changes. Modifiability (0/9) was not valued, confirming preference for a ready-to-use product. Ease of cleaning moved from low to mid-tier priority (5/9), making it a beneficial but non-essential feature that comes naturally with good design.

9.4 Minimal Viable SteamUp (design implications)

The findings conclude a minimal viable product of SteamUp to be a consistent high-pressure device with an aesthetically appealing look.

The interface can be minimised to an indication of readiness and a steam switch. To improve market size, the product must offer fast heating and a compact form factor. Heating up time of two minutes was deemed sufficient (Chapter 08) and proposed boiler modifications are not expected to significantly impact this (Chapter 07). The estimated final product size is expected to be smaller than standard espresso machines (~340 mm in height) and approximately 120 mm in width (a 25 mm reduction), though further validation is required.

Table 9.2: Performance features dominant in feature list, but aesthetics and size are large risers in must-have selection.

Ideal average order	Avg. score		Ideal order by must-have	Picked	
Consistent steam pressure	9 / 90		+6	Aesthetic design	9 / 9
Heating up time	25 / 90		-1	Consistent steam pressure	8 / 9
Adjustability of pressure	26 / 90		+3	Compact counter size	6 / 9
Steaming time of milk jug	38 / 90		-2	Heating up time	6 / 9
Froth different types of milk	39 / 90		-2	Adjustability of pressure	5 / 9
Compact counter size	40 / 90	→ difference	+2	Ease of cleaning	5 / 9
Aesthetic design	40 / 90		-2	Froth different types of milk	4 / 9
Ease of cleaning	52 / 90		-4	Steaming time of milk jug	3 / 9
Noise level	65 / 90		0	Noise level	1 / 9
Modifiability	74 / 90		0	Modifiability	0 / 9
Energy consumption	87 / 90		0	Energy consumption	0 / 9

At a mass production stage, a more advanced interface with adjustable settings can be introduced. Additional features, such as a removable water reservoir, easy cleaning mechanisms, and customisable nozzle configurations, can also be incorporated.

9.5 Limitations

This study was conducted with a limited sample of nine participants from various potential customer segments. Conducting larger studies focused on specific customer groups could yield more detailed insights into segment-specific needs. Additionally, integrating willingness-to-pay data could further refine the MVP strategy.

The study examined a predefined set of 11 features, but additional elements, such as a digital versus analogue interface, could significantly influence results.

A potential bias was identified in the pilot test, where participants adjusted their rankings based on the prototype's existing performance rather than their ideal preferences. To mitigate this, participants were explicitly instructed to prioritise features based on their importance rather than how well the prototype already met their needs. This bias does show the potential of inconsistencies due to the test setup.

DEFINE

*This section builds the strategic foundation for the design direction.
Chapter 10 scopes the project focus by analysing the balance between
aesthetics, performance, usability, and production feasibility.*

Define - Scoping

10 Scoping

23

10 Scoping

The analysis phase showed that developing a minimum viable version of SteamUp involves balancing four product design factors: aesthetics, performance, usability, and production feasibility. These topics are further discussed in this chapter and a scoping of these topics is made for the project.

10.1 Translating insights into development goals

The **embodiment design (semantics)** must balance premium aesthetics with optimised form factor. Chapter 05 highlights the need for manufacturing-ready materials, while Chapter 08 underscores that size reduction is highly valued by the target group, making a more compact form factor essential. Chapter 09 reinforces the necessity of an aesthetic and compact product, defining it as important parts of the MVP. Future work should focus on refining the external form and validating design choices with users.

Performance optimisation (technology) is critical to ensuring consistent steam functionality. Chapter 05 stresses the need for a custom steam wand, optimised piping and PCB design. While Chapter 06 highlights the importance of high-power steam for foam consistency. Chapter 07 emphasises thermal efficiency and system stability, and Chapter 08 confirms that current performance is strong but requires fine-tuning. Further development should refine steam system efficiency and electronic integration to improve durability and precision.

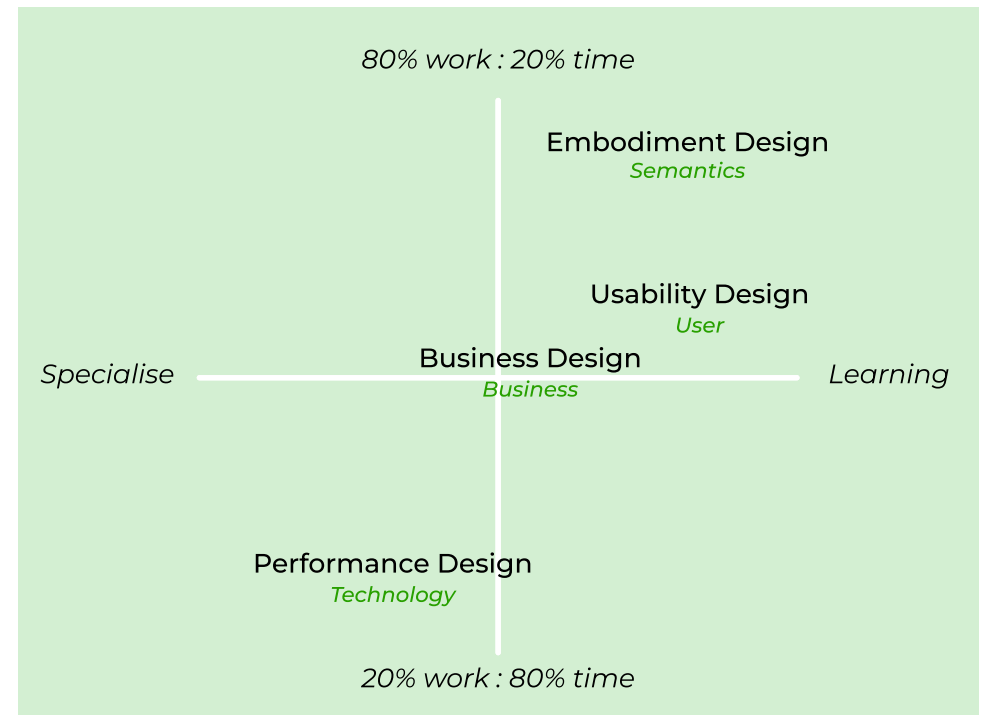
Usability reconstruction (user) is necessary to improve workflow and interface clarity. User interaction must be intuitive and efficient, with Chapter 06 identifying lack of clear feedback cues and Chapter 08 calling for an improved and simplified interface with better component placement. Chapter 09 suggests a minimalist approach to controls, prioritising ease of use over complexity. Future efforts should focus on interface testing and iterative refinement to enhance usability.

Business feasibility (business) is key to ensuring a sustainable production strategy. Chapter 05 emphasises the importance of cost-efficient sourcing and reducing unique components, while Chapter 09 suggests a phased approach to product expansion. Next steps include finalising production-ready designs and evaluating cost structures to support scalability.

10.2 Conclusion

A strategic direction must be chosen given the limited timeframe of this thesis project. Figure 10.1 illustrates the x-axis representing the researcher's potential for personal development and the y-axis indicating SteamUp's development opportunities. The 80/20 rule applies to most projects, where 80% of the work can be done in 20% of the time. While the final 20% of the work, will take 80% of the time. To enable projects to hit several milestones, the goal is often to move to the next phase when getting (close) to the 80% of the workload. This analysis concludes that embodiment design, with a focus on aesthetics and size reduction, will be the primary development goal of this thesis. As such, the project narrows in on the semantic layer; how meaning and value are expressed through form-giving.

Figure 10.1: Embodiment design is most important, due to the room for product improvements and researchers personal development goals.



D DEVELOP

This section focuses on semantics and the development of SteamUp's visual identity. Chapter 11 defines the strategic boundaries for form-giving, establishing how product semantics guide perception and brand identity. Chapter 12 presents the form-giving journey, showcasing the designer's growth and the development of four concept directions. Chapter 13 visualises all four concepts, including a comparative overview of their proportions alongside common espresso machines. Chapter 14 outlines the selection process of the most suitable concept for the beachhead market. Chapter 15 validates this choice with target users.

Develop - Form-giving

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11 Establishing a design vision

In product design, semantics means the way a product communicates its purpose, quality, and identity through its appearance. Within this project, semantics is most strongly expressed through form-giving. As a newly founded company, SteamUp lacks an established product line, corporate identity, or clear brand language. This absence offers full creative freedom but also requires deliberate choices to create a cohesive design direction. Through iterative exploration, sketching, 3D modelling, prototyping, and rendering, a general identity began to emerge. Before diving into the form-giving process (Chapter 12), it is essential to define the strategic boundaries that guided design decisions. These boundaries help narrow the design space, improve decision-making, and support future product development.

11.1 The boiler as a visual anchor

A key differentiator in SteamUp's product is the use of a boiler, an uncommon choice in the milk frother market, where most alternatives rely on thermoblocks or other cost-efficient heating methods. Piersma's (2024) prior research confirmed only boilers generate the steady high-pressure steam needed for microfoam. Boilers are typically cylindrical due to the shape's structural efficiency in managing internal pressure; while spherical forms are more stable, they are also more expensive to manufacture. To reflect this premium internal component, the product should visually reference the boiler's form, easiest reflected through a cylindrical geometry and metal finishes. The cylindrical boiler fits compactly into the housing, supporting the space-saving goals identified in Chapter 08. With direct competitors in the stand-alone milk steamer market, the boiler's presence must be communicated through form to reinforce SteamUp's identity as a high-quality, barista-level tool for home use.

11.2 Expressing power through form

To reinforce the product's premium positioning, the design should convey a powerful steaming experience that aligns with the professional standards found in cafés. Initial traction research identified steam power as the primary shortcoming in home espresso machines. While industrial machines often use boilers of 8 litres or more, a scale not feasible for home use, the design should reflect their robust, professional presence. This means aiming for a solid, grounded design that avoids any sense of lightness or flimsiness. Field research at Kookpunt, a kitchen appliance store in Rotterdam, confirmed that

heavier, sturdier products appeared more premium. While metal finishes are ideal, a combination with plastic components can also contribute to a high-quality feel. Interactions through the tactile feedback of buttons and levers, the illumination of indicator lights, and the device's sound all also contribute to the perceived quality and sense of control.

11.3 Designing for calmness and flow

Beyond performance, SteamUp's design should reflect the emotional side of making coffee, a ritualistic pause from the fast-moving rhythm of daily life. In a world that often feels like a bullet train, preparing and enjoying coffee offers a rare moment of calmness and connection. This should be mirrored in the form language: soft curves, flowing transitions, and the absence of sharp edges. Drawing a parallel from automotive design, a Porsche 911 appears elegant and composed, while a Lamborghini Aventador looks aggressive and angular, yet both are considered premium cars (Figure 11.1). SteamUp should follow the former: powerful in performance, but visually grounded in calmness and balance.

Conversations with baristas and coffee enthusiasts revealed that part of coffee's appeal lies in its smooth, purposeful rhythm of the coffee making process. The design should intuitively support this routine. Internally, the product follows a clear flow, from reservoir to boiler to steam wand, which can be subtly echoed in the external form to strengthen user understanding and emotional connection.

Figure 11.1: Both premium cars, but with opposite design language.



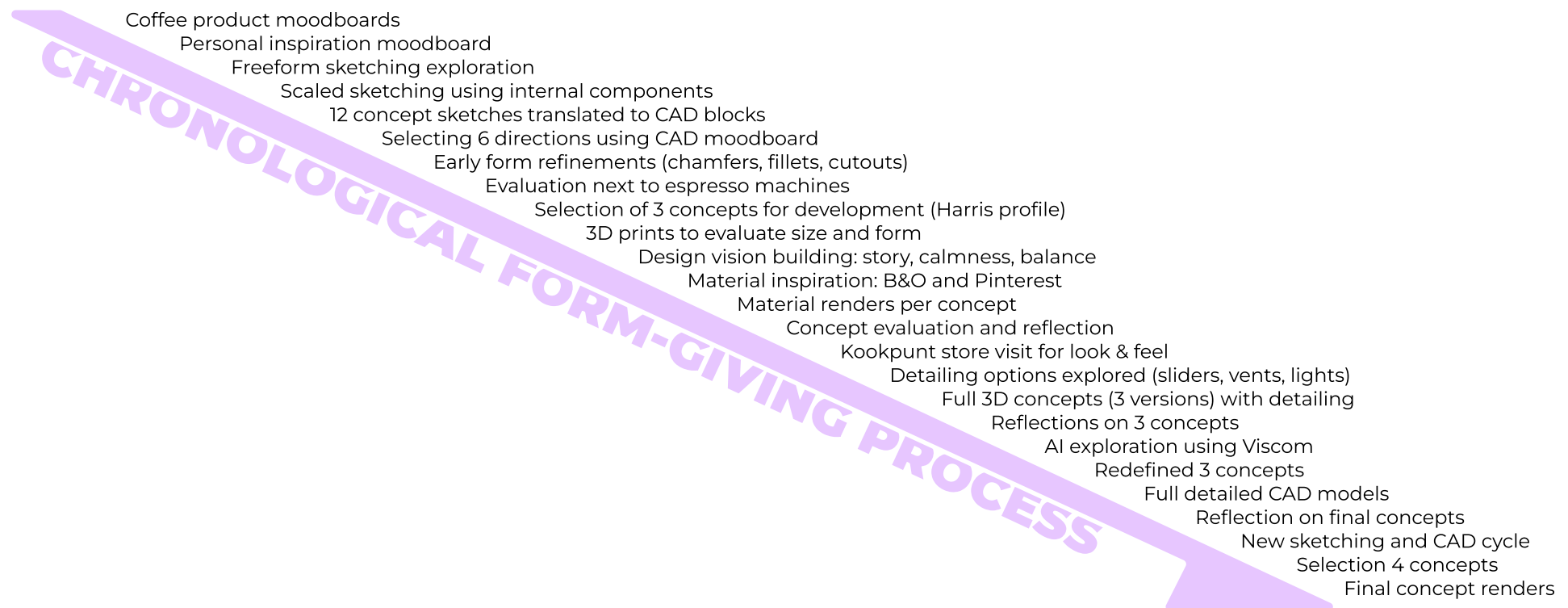
12 Form-giving process

The form-giving phase was an extensive visual exploration covering the biggest part of this project stage. With no predefined product line or brand identity to guide the design, the challenge was to build a compelling visual language from the ground up. Beyond establishing SteamUp's visual identity, this phase also fostered the designer's growth in aesthetic sensibility and coherence, laying the groundwork for a more mature design practice. This chapter presents the highlights and reflections of that journey, revealing how four concept directions were developed through continuous iteration and growing design maturity.

12.1 Process setup and documentation method

The full form-giving trajectory was mapped chronologically in Figma, where boards acted as evolving canvases for sketches, CAD iterations, mood boards, material tests, and evaluation notes. As a highly visual and intuitive process, form-giving resists linear explanation; it develops meaning through form exploration rather than written logic. To avoid overwhelming the reader with exhaustive visuals, a complete documentation is included as a booklet in Appendix C13, offering a closer look at the progression. The timeline in Figure 12.1 presents the entire process in a single visual overview, illustrating its sequence and iterative depth. The rest of this chapter highlights key moments, crossroads, and the underlying reasoning that shaped the design, with events arranged by relevance rather than timeline.

Figure 12.1: Form-giving is a cyclical process, but life happens in specific linear order.



12.2 Initial immersion and exploration

To frame the visual context of the coffee product landscape, three mood boards were created (Figure 12.2): curated images from Pinterest, AI-generated designs via Midjourney, and real-world coffee setups collected from a WhatsApp community of coffee hobbyists. These sources revealed consistent visual cues: espresso machines are typically boxy and chrome, complemented by subtle accents in black, white, or wood. Grinders and related accessories tend to exhibit matte textures, widely varying geometries, and a grounded aesthetic for the modern coffee corner. Interestingly, the AI-generated results mirrored both the curated and real-world references, suggesting that the benchmarks selected accurately reflect the broader design landscape.

Early sketching formed the foundation of the exploration, see Figure 12.3. Drawing from product references and the gathered visual context, initial sketches were made without constraints to encourage freedom of form and maximise idea generation. These were transferred to scale-corrected sketches based on the dimensions of key internal components, marking an important shift in the process. Proportions change drastically when abstract designs are fitted to real-world dimensions. What appears balanced on free sketching paper may not hold up once fitted with the functional hardware constraints. Figure 12.3 shows one sketch out of a large collection, selected to illustrate the way of working. To view the full range of ideation, the accompanying form-giving booklet in Appendix C12 should be consulted.

Figure 12.2: Mood boards of the coffee landscape and inspirational products guided the form giving process.

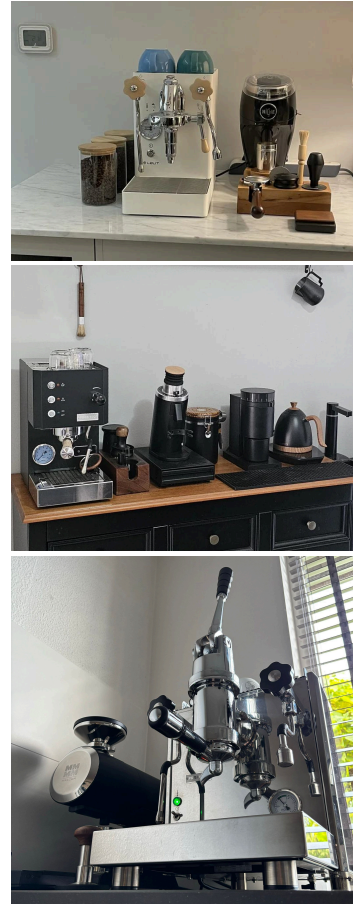
Pinterest



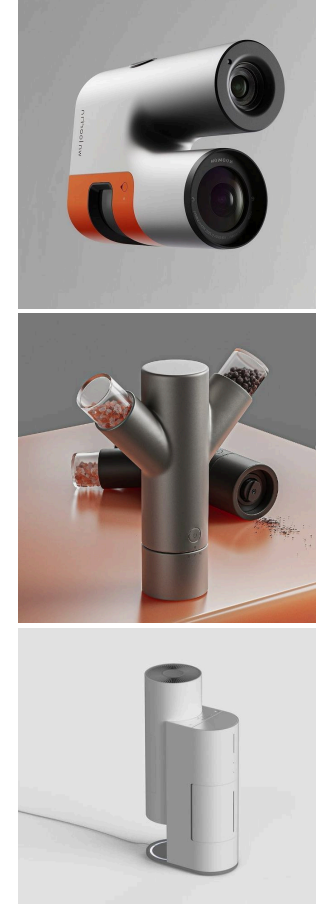
Midjourney AI



Target audience



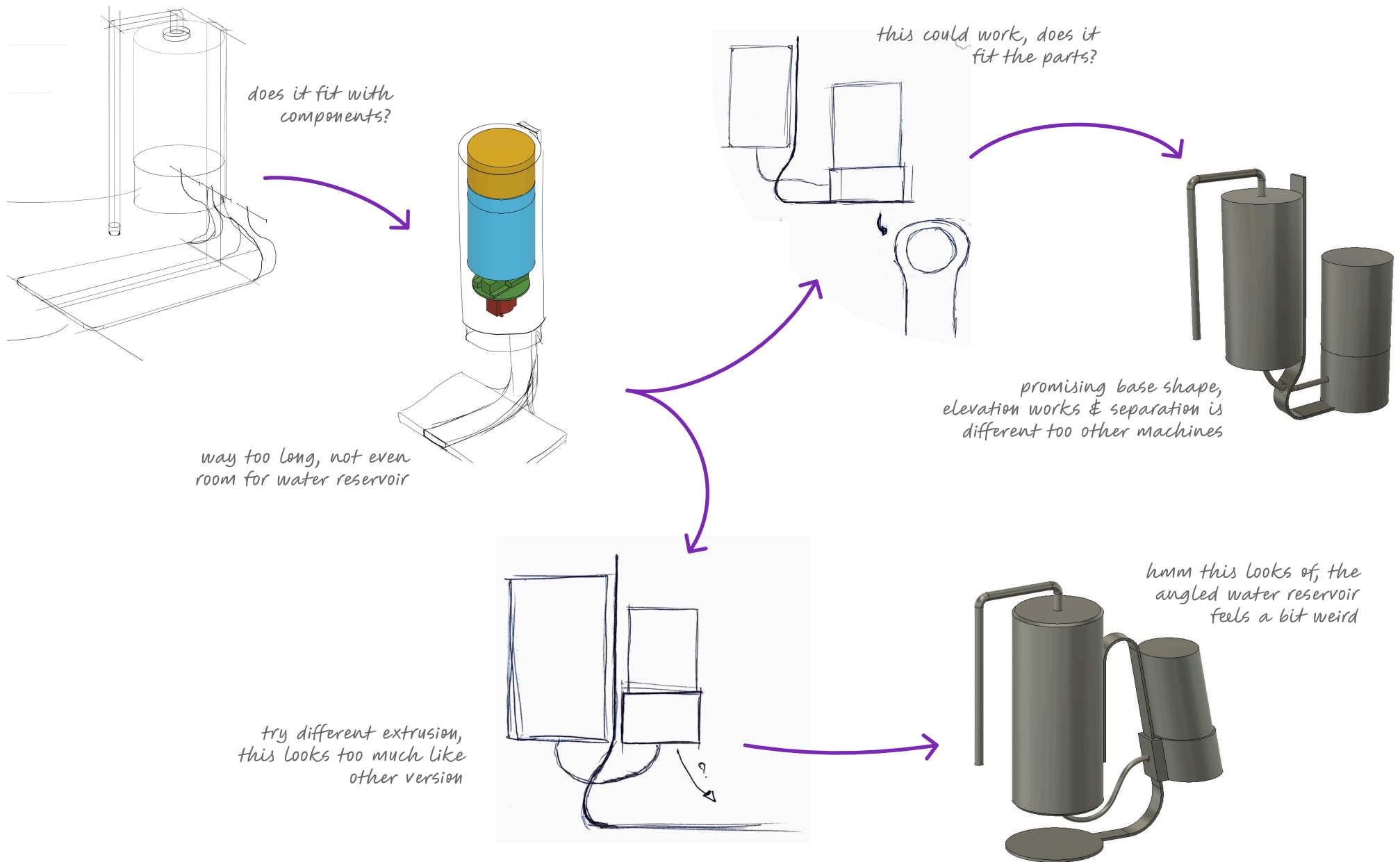
Inspiration



Grinders



Figure 12.3: Iterating from sketches to component fitting block forms; scale does matter for visual appeal.



12.3 From sketch to form language

The promising sketches were translated into simplified CAD models using Fusion 360, reducing each concept to primary volumes: cylinders, blocks, plates and tubes. Stripping away surface detail at this stage encouraged a focus on overall composition and silhouette, laying the groundwork for spatial clarity. This method closely aligns with Ger

Bruens' (2007) design methods in Form/Color Anatomy, which highlight the importance of unifying contrasting forms into a coherent whole. The exercise marked a key moment in developing a sense of volumetric balance and proportion. Figure 12.4 displays twelve base model results, and the researchers notes for further development based on instinct.

Figure 1324: Picking the concepts balancing contrasting forms into a coherent whole.



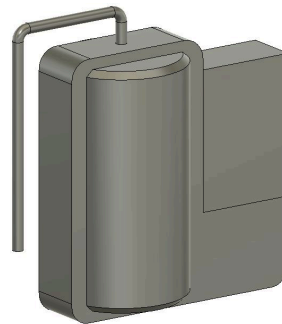
Id 1 - Potential

Round shape, possibility for loose parts and split lines.



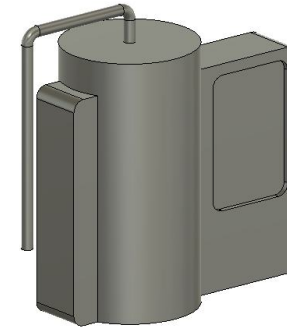
Id 2 - Potential

Play more with the legs, but look original.



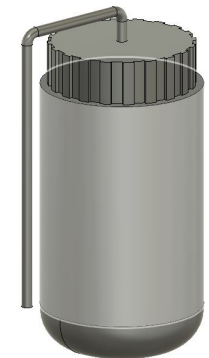
Id 3 - Potential

Rectangular and cylindrical shape come well together.



Id 4 - Doubts

Bit standard, id 3 is better version, looks like competitor.



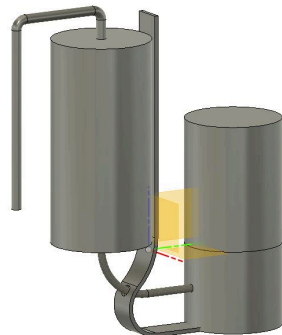
Id 5 - Doubts

Has resemblance to id 2, which looks more novel.



Id 6 - Doubts

Feels a bit out of balance, id 7 is better version.



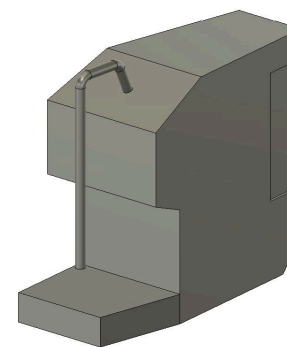
Id 7 - Potential

Innovative, balanced and options to play with extrusion.



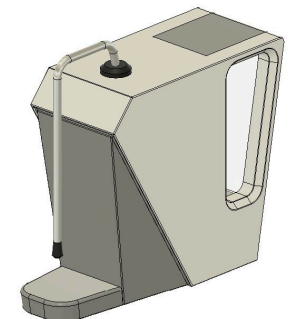
Id 8 - Potential

Pick due to Nespresso resemblance, with drip tray.



Id 9 - No

Way too boxy, id 10 is better non round version.



Id 10 - Potential

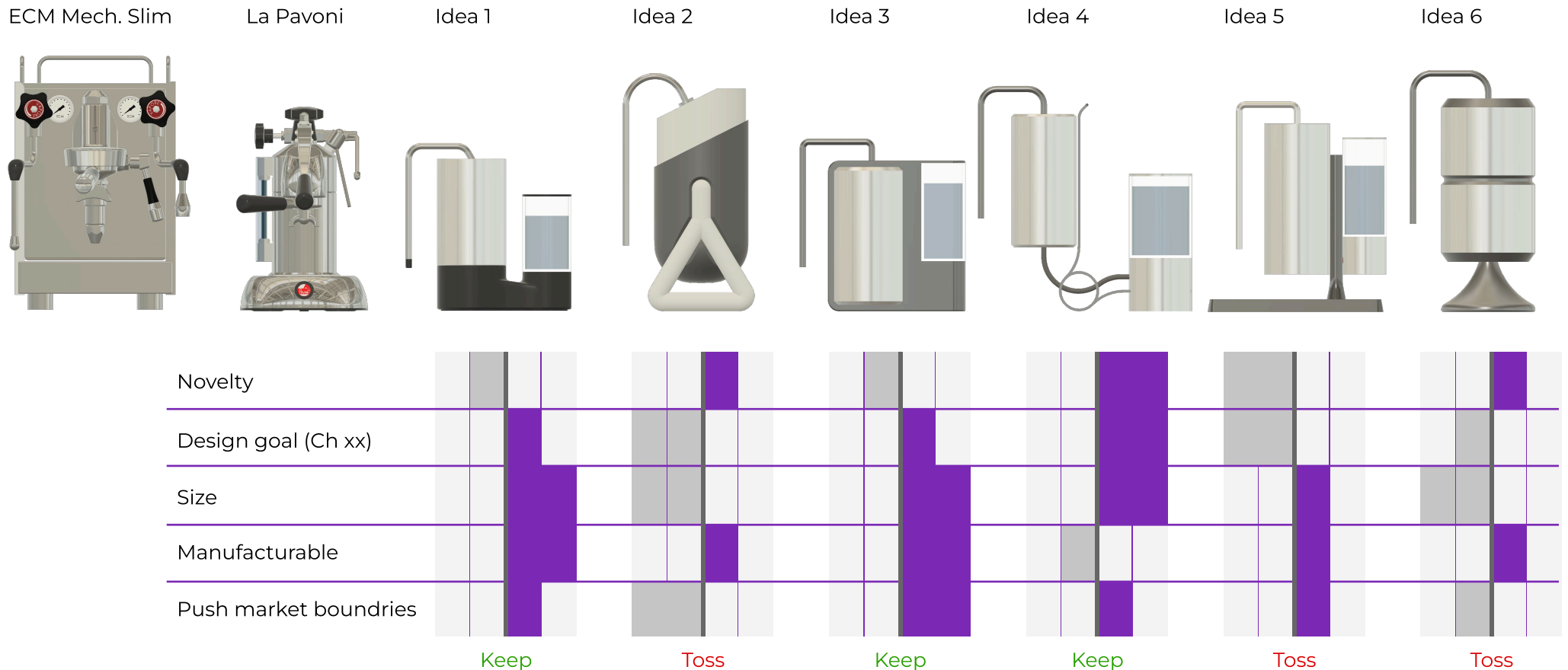
Not ideal, but best boxy model for completeness.

12.4 Refining the direction

The six selected ideas for further exploration each embraced the cylindrical boiler as a visual anchor. Subtle refinements, such as cutouts, chamfers, fillets, and parting lines, were iterated through to test the impact of early shaping decisions. Figure 12.5 shows the six selected variants positioned alongside two common home espresso machines. A Harris profile supported the selection process, evaluating each concept on novelty, semantic fit, size, manufacturability, and contextual alignment. These criteria were drawn from earlier analysis findings

(Chapters 5 to 9) and the project's design vision (Chapter 11). But real academic reasoning for the criteria is lacking. A perfect example of the designer calling the shots on gut feeling, which are hard to put into words. The side-by-side comparison with espresso machines did reveal that two designs felt too bulky for compact kitchen use, while one lacked distinctiveness and unwantingly resembled a Nespresso machine. These three were removed, narrowing the direction to three promising concepts for continued development.

Figure 12.5: Ideas 2 and 6 were tossed due to their size and idea 5 because it unwantingly resembles Nespresso machines.



12.5 Materials and meaning

The three selected directions were further developed through renewed sketching, CAD refinement, and full-scale 3D prints. While the models showed functional potential, they lacked identity without material definition or narrative context. This sparked a key design reflection: what should SteamUp express beyond performance? Chapter 11 explores this question, while Figure 12.6 shows the resulting 3D prints, promising in form, but still abstract in expression. Several iterations of 3D printing were used to evaluate size and shape, as well as interaction with buttons, sliders, levers, etcetera.

Material inspiration was drawn from Bang & Olufsen products, showing their refined use of metal, plastic, and wood. A field study at Kookpunt, a premium kitchen store in Rotterdam, confirmed that coherent material combinations and weight contributed strongly to a product's perceived quality. These insights guided the rendering of each concept in over 15 different material configurations, including refinements to parting lines and surface finishes. Figure 12.7 summarises the materialisation phase. The key is in making the parting lines and changes in materials feel logical, so for instance by enclosing a feature.

Figure 12.6: 3D printed forms show design potential but due to lacking materialism they lack allure.



Figure 12.7: The balanced use of metal, plastic and wood creates premium appearance.



Cheap look & feel

Premium look & feel

B&O balancing use of materials

Adding materials to the concept directions based on field research findings.

12.6 Concept detailing

Each design direction was developed and detailed, incorporating steam on/off switch, steam pressure regulation, state indication, air vents, and material choices. All three concepts varied in these features to ensure distinct identities. Concept overviews are shown in Figure 12.8.

Concept 1 features the cleanest geometry, with a smooth flowing base and balanced material use. It employs a push button for steam activation, with a coloured LED ring around the button to indicate state and readiness. A slider on top allows adjustment of the boiler pressure.

Concept 2 is bolder, with stronger chamfers but minimal detailing. It uses a wooden lever to open the steam valve, with no separate feature for pressure control, pressure can be modulated by limiting the lever's angle. A small indicator light turns red while the boiler is building pressure.

Concept 3 stands out in terms of character and originality, using an elevated design and a steel extrusion connecting the boiler and water reservoir. A rotary knob on each side controls the steam valve, and a front-facing slider adjusts boiler pressure. A text indicator at the top displays boiler readiness by toggling a 'not ready' to 'ready' LED.

12.7 Killing two darlings to move forward

Despite progress, two of the three directions didn't feel aligned with SteamUp's evolving design vision (see Chapter 11). Input from peers, graduation committee and SteamUp's team confirmed that only Concept 3 truly pushed boundaries. This led to taking a step back and restart part of the design process, focussing more on pushing the boundaries within the drawn design field. A decision that ultimately led to more confident design work results.

Figure 12.8: Concept 1, 2 and 3 at a given time during the form-giving process.



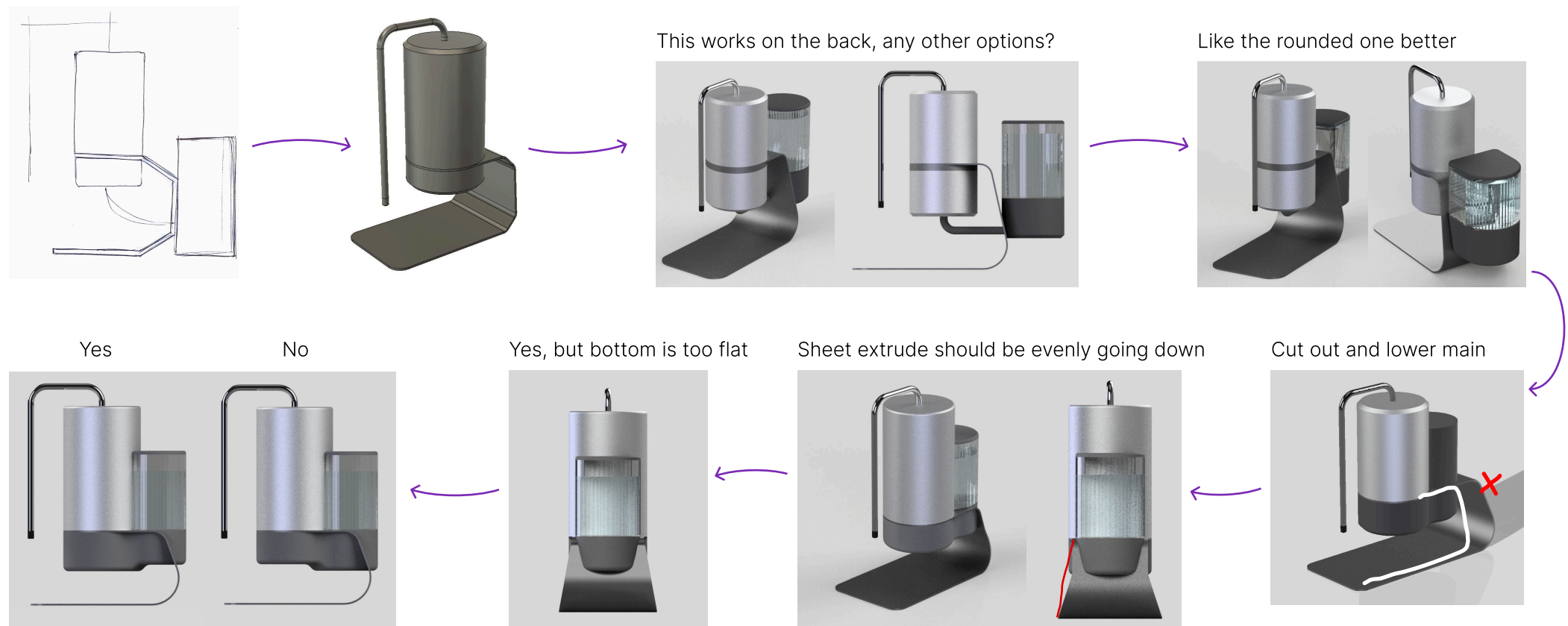
12.8 Rebuilding with confidence

The previous steps discussed in subchapters 2, 3, 5, and 6 were repeated at a higher pace, with the added requirement of using a sheet-formed plate in the design. A feature preferred in the previous concepts. Designs were selected based on intuition and personal direction rather than any formal methods. Each concept evolved through small, documented iterations, showing visible improvements in form language. Figure 12.9 presents a summary of this process, while Appendix C12 includes the detailed progression. This phase resulted in several designs that met the defined design space requirements.

12.9 Consolidating the final concept set

A final review of the concept form-giving process was conducted through meetings with Arthur de Graaf (startup coach) and Laurens Kolks (form-giving professor at TU Delft). Surprisingly, two previously discarded designs were reintroduced as valid options for alternate target groups. While they may not suit the design goal of SteamUp's beachhead market, they remain strong concepts that represent different areas of the market. Together, they contribute to a broader perspective of the design space, resulting in a well-rounded set of options. Ultimately, Concepts 1 and 2 stem from the original set, Concept 3 is a revised version, and Concept 4 is a new direction chosen during the second round. These four concepts are presentation and evaluated in Chapters 13 - 15.

Figure 12.9: Summary of the second form-giving round, with increased pace and better reasoning, due to designers experience growth.



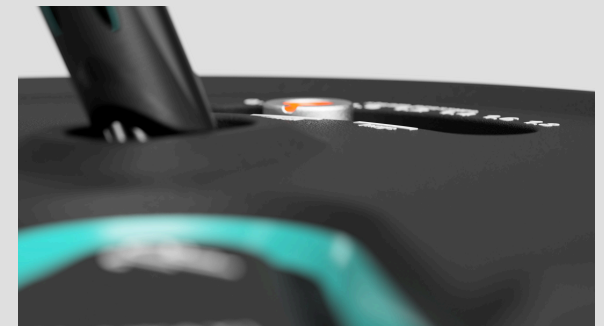
Towers by SteamUp

Concept 1 - Towering above in steam precision

Towers is defined by its sculptural balance and grounded character. With a base that softly flows into the cylindrical forms above, the design feels solid, compact, and intuitively composed. Its tower-like posture creates a clear vertical orientation, establishing a sense of order on the counter.

Steam is released via a push button, with boiler state indication integrated into a button surrounding LED. Green means ready to steam, red means heating up and orange means steam is coming out. A subtle slider adjusts pressure, located at the top just behind the steam wand. The composition limits variation in colour and material finishes, though the revealed boiler offers room for subtle contrast. This creates a natural balance, pairing a plastic-looking main body with a metal-finished boiler embodiment.

Towers should fit a broad audience seeking a refined product that fits seamlessly into modern kitchens. Removing the exposed boiler extrusion could further simplify the product, making it even less visually present in everyday kitchens.



Presso by SteamUp

Concept 2 - From pressure to perfection

Presso brings boldness to the boiler, pairing a confident central form with soft, curved surrounding embodiment. The wooden steam lever rises from the smooth curve, providing a satisfying and natural pull. The design balances strength with approachability, grounded in the tradition of analogue control.

Steam is activated with a solid wooden lever, while a minimal indicator light signals readiness. Steam output is intuitively adjusted by the lever's angle, the further it's pulled, the more steam is released. Ventilation detailing wraps around the base of the boiler, adding a sense of controlled aggression. The shape naturally defines two material zones, opening up opportunities for striking yet balanced combinations.

Presso should appeal to users who value intuitive interaction and visual strength. It blends modern aesthetics with retro familiarity, offering a clear identity that stands out while remaining warm and approachable.



Diver by SteamUp

Concept 3 - Submerge into perfect steaming

Diver is a concept built around balance and contrast. The design is elevated by a stainless-steel extrusion that flows seamlessly along the body, giving the product a posing stance. The cylindrical boiler takes centre stage, paired with a grounded water reservoir in matching proportions.

A rotary knob on each side controls the steam valve, while a front-facing slider adjusts boiler pressure. A text indicator at the top displays boiler readiness by toggling between 'not ready' and 'ready' using LEDs. The split between boiler and water reservoir creates opportunities for material variation, as does the feature-holding ring on the boiler embodiment.

Diver suits users who value character and craftsmanship in the kitchen, ideal for those who see steaming machines as both a function and a form of expression. It invites interaction, tells a visual story, and reflects SteamUp's ambition to elevate home coffee equipment beyond convention.



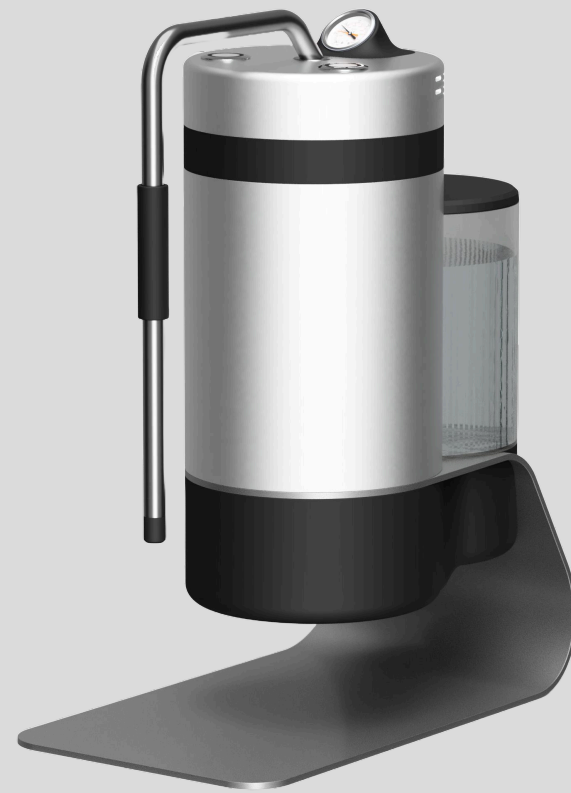
Duck by SteamUp

Concept 4 - Not your average duck in the pond

Duck is balanced in character and design, minimalistic yet expressive. It introduces a soft but bold stance that makes it approachable on the counter. Despite its humour, Duck doesn't compromise on performance, it proves that steam tools can be both serious and fun.

The body floats above the counter and is crowned with a dual-function analogue pressure gauge, displaying and setting the steam pressure. Steam is activated using a push button for instant steam control. Besides elevation, the stainless-steel extrusion allows customisation in materials between the lower and upper embodiment parts. The bottom plate collects any milk or steam droplets.

Duck is designed for users who value character and craftsmanship in the kitchen. Among the four concepts, it fits SteamUp's estimated beachhead market most closely, challenging design conventions while maintaining recognisable, intuitive controls.



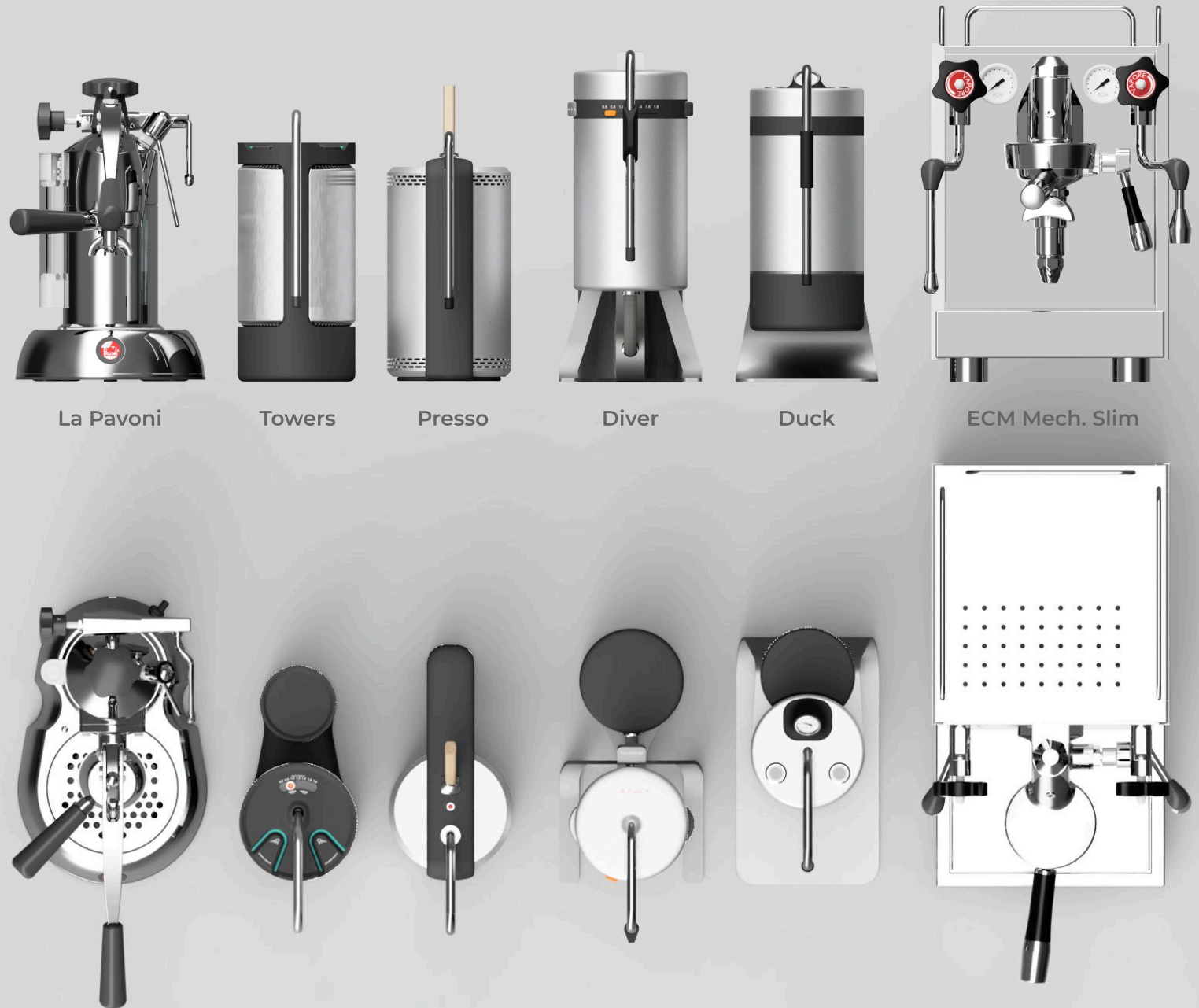
Concepts Side by Side

Does size really matter? Let's put it to scale.

A dimensional comparison of the four concepts reveals differences in scale and proportion. All concepts are shown alongside two espresso machines, the La Pavoni and ECM Mechanika Slim VI, chosen as representative devices for the envisioned SteamUp pairing setup.

Concepts 1 and 2 maintain the most compact form factors, staying well below the height of both espresso machines and occupying a relatively small footprint on the counter. Concepts 3 and 4, while visually taller due to their elevated designs, achieve the proposed height decrease range of 6–14 cm compared to the tested SteamUp prototype (see Chapter 11). This boundary is visually confirmed, as both remain below the ECM machine, which was used as the maximum height benchmark.

If required, elevation can be reduced to further minimise height without compromising overall design intent. In terms of width and depth, all concepts conform to the dimensional constraints outlined in Chapter 11, ensuring suitability for standard home kitchen setups.



14 Concept choice

Choosing between four design directions demands more than preference, it requires alignment with the main project drivers and strategic goals set out in Chapters 10 and 11. While all concepts were developed to be visually appealing, aesthetic taste is inherently subjective. Preferences vary, and each concept has probability to succeed in a specific portion of the market. However, the purpose of this phase is to select the concept best suited to SteamUp's predicted beachhead market: early adopters who seek high-performance milk frothing together with an unique design.

14.1 Concepts evaluation

To evaluate which concept best suits SteamUp's intended direction, five core design drivers were defined. These emerged from the brand's strategic vision and the projects main drivers.

The first driver centres on the expression of the boiler. As a defining feature of SteamUp's steaming technology, the cylindrical boiler sets the product apart. All four concepts succeed in this to varying degrees. Concepts 1 and 2 highlight the boiler more directly, using outlining and surface changes to separate it from the rest of the body. Concepts 3 and 4 achieve a more integrated expression, embedding the cylinder into the base shape, resulting in a calmer and more refined appearance.

Secondly, the product must communicate power and quality. SteamUp's barista-grade performance should be reflected in a form that conveys control and reliability, using visual weighted and grounding elements to enhance perceived performance. Concept 2's narrow central profile may compromise the perceived stability of the design but Concepts 3 and 4 it's levitation could compromise this factor as well. Concept 1 is the most grounded out of all.

A third consideration is the sense of calmness and flow. Coffee preparation is a daily ritual, and the design should support that atmosphere: soft, composed and deliberate. Visually, this means smooth transitions, restrained details and balanced proportions. Of the four, Concept 4 stands out. It achieves a gentle but expressive stance that feels natural on the counter. Concept 3 exceeds on visual flow but introduces more visual complexity due to its split-body configuration. While Concepts 1 and 2 offer a more compact approach the more aggressive boiler visualisation limits calmness.

In terms of ecosystem fit, the product must harmonise with the broader home coffee setup. SteamUp is designed to sit beside grinders and espresso machines but aligns more closely with grinders in terms of size and variety. Grinders are diverse in form and finish, giving more freedom to explore. None of the concepts directly mirror existing grinder designs, but all fall within a relevant design spectrum. None of the concepts align with the general chrome and boxy espresso machines, which could be a problem for some potential customers.

Finally, the product must establish distinctiveness and identity. As SteamUp's first product, it sets the tone for the brand, requiring a design that feels recognisable, future-forward, and unafraid to push visual boundaries. This is where the greatest differences between the concepts emerge. Concepts 1 and 2 are geometrically minimal, making them strong contenders for a wider market, but they fall short in delivering the bold character needed to capture attention in a niche market. In hindsight, this was the underlying reason for setting them aside earlier in the process. Concepts 3 and 4 offer stronger visual identities and communicate the transition from water to steam with expressive elevated forms. Concept 3 stands out in novelty but risks being too unconventional for first-time launch. Concept 4, in contrast, offers distinction with restraint, memorable yet approachable, and strikes a careful balance between standing out and fitting into modern home kitchens.

14.2 Concept choice

After reflecting on all five drivers, Concept 4 emerges as the best fit for SteamUp's beachhead market. It expresses the boiler, communicates power, feels calm and ritual-friendly, allows for material refinement, and introduces a recognisable identity. It stands on its own but leaves room for evolution, making it the best foundation for the brand's first launch.

Concepts 1 and 2 should not be discarded entirely. With their simpler forms and broader appeal, they may play a valuable role in expanding the product family later. Concept 3 remains a strong contender for a future "statement" edition, showcasing SteamUp's design ambition for more niche audiences, or maybe for expansion to cafés?

15 Concept choice validation

An experienced designer with a proven track record can often rely on intuition when developing new products, confident their work will resonate with the target audience. As filmmaker Denis Villeneuve said about Dune, “Frankly, I think that I made this movie for me.” With an established reputation, he could design for himself, trusting others would connect with it. For this project, that level of credibility does not yet exist, making validation essential to ensure the proposed form direction suits the intended target group.

15.1 Validation goal and research method

The goal is to validate whether the beachhead market finds the product visually appealing. Ideally, this happens by selling the product to a significant portion of that market. But at this stage, that isn't feasible. As an alternative, an online form is used to gather early feedback. While in-person sessions with potential customers provide deeper insights, they take a lot of time. Since the main goal is to support the concept choice, a form is considered sufficient.

The form also offers the benefit of anonymity, which reduces biased responses from people who may hesitate to give honest feedback. The validation goal is twofold: most participants should choose the same concept as selected in Chapter 15, and at least 40% should rate it 8 out of 10, or higher. If these conditions are met, the design is considered strong enough to move into the embodiment phase.

15.2 Participant selection

To support meaningful design validation, at least 30 respondents within the beachhead market are targeted. Precisely defining who qualifies as part of this market is challenging, so several questions are included to assess coffee setup and desired milk output. This information enables post-analysis segmentation to better align feedback with the intended user group. The form was distributed primarily via WhatsApp, using both direct and indirect personal networks. Emphasis was placed on sharing the form through intermediaries rather than by the researcher. This approach encourages more neutral and honest responses, reducing potential bias caused by respondents being overly polite due to personal connection.

15.3 Form setup

The form was built on Typeform (Appendix C15) and is fully anonymous.

It starts with basic questions about participants current and ideal home setup, to ease them into the topic and support later segmentation. Next, they receive a short explanation of the project and are asked to give honest feedback on the form-giving results. A series of A/B comparisons follows, where participants choose between two designs. This continues until the same concept is selected three times in a row, showing clear preference over all other concepts.

They then see an overview of their chosen concept and should explain why they selected it. Afterwards, all four concepts are shown again, and they are asked to pick their favourite, confirming or altering their choice. With all concepts now familiar, participants rate each on a 1–10 scale. This standard range helps signal perceived quality clearly. Finally, they answer what they would change about their favourite concept to make it a 10, revealing honest critiques and areas for improvement.

15.4 Results

A total of 41 respondents completed the form. While it is not yet possible to confirm which participants fall within the defined beachhead market, pending the results of Wouter's research. All respondents can be considered coffee hobbyists, making the sample size (n=41) suitable for initial validation. Table 15.1 shows an overview of the results, showing that both validation goals are met.

Table 15.1: Goals of picked concept 4 and 8+ percentage are achieved.

	Towers C1	Presso C2	Diver C3	Duck C4
<i># picked</i>	5	10	4	22
<i>% picked</i>	12%	24%	10%	54%
<i># rated 8+</i>	7	8	8	22
<i>% rated 8+</i>	17%	20%	20%	54%
<i># of picked rated 8+</i>	3	6	3	18
<i>% of picked rated 8+</i>	60%	75%	75%	82%

First, Concept 4 (Duck), the intended direction, is selected by the majority (22 out of 41, or 54%). Concept 2 also performs unexpectedly well, selected by 24% of participants. Follow-up analysis shows this is primarily due to the lever feature and coloured material palette, indicating that surface-level styling, apart from core form, drives appeal.

Second, the aim of having at least 40% of participants rate Concept 4 an 8 or higher is achieved. In total, 54% of respondents give it this rating. Notably, this includes four participants who selected another concept as their favourite but still gave Concept 4 an 8+. Conversely, four respondents who chose Concept 4 as their favourite rated it below an 8. When isolating responses from those who selected Concept 4 as their top choice, the 8+ satisfaction rate increases to 82%.

Qualitative feedback reveals several themes. Many respondents prefer clean, minimal forms, though the floating designs of Concepts 3 and 4 are positively received for their uniqueness. This reveals a slight contradiction: the elevation is non-standard in coffee appliance design, yet it is perceived as simple and refined. One quote on concept 4 summarises this sentiment: "Unique design but not too futuristic or prominent, which would make it look nice with an espresso machine."

Three participants express preference for boxier designs that align more closely with traditional espresso machines. This highlights a potential limitation of SteamUp's cylindrical form language for some users. Material preferences also vary. Some respondents appreciate wood detailing, while others dislike it. Overall, darker accents and stainless steel are generally favoured, although preferences for a coloured version were also noted.

15.5 Conclusion

The results clearly support the choice for Concept 4, with both validation goals comfortably met. However, the feedback also highlights a wide range of preferences regarding materials and colours. While darker tones such as grey and black are generally favoured, several participants expressed appreciation for other finishes, including full black, chrome, wood accents, and more colourful versions. Offering a range of variants could help satisfy these diverse preferences and strengthen the product's appeal.

Notably, features from Concept 2, especially the wooden lever and bold red materialisation, received strong positive reactions. One participant even noted to switch preference based solely on these aspects. This

suggests that integrating similar elements into Concept 4 could further enhance its appeal. Though promising, this idea would benefit from further validation. Overall, Concept 4 emerges as the right direction to continue into the next development phase, with meaningful opportunities for refinement and variation.

15.6 Limitations

While the validation results are promising, the research contains several assumptions and potential biases. The goals are achieved, but broader conclusions require caution.

Concept presentation posed a challenge. An early attempt using uniform sketches failed, as minor differences in colour and material still influenced decisions. Final renders were created with the best-fitting features and finishes per concept, based on the designers preferences. Alternative configurations were shown to suggest flexibility. Still, some participants focused heavily on single elements, such as "the red colour", raising questions about how form was judged.

Typeform's limitations also played a role. While A/B positions could be rotated, the question order could not. All participants started with a comparison between Concepts 2 and 4, which ended up being the most picked. Whether this influenced the outcome is unclear.

Some participants were not unknown to the researcher. While efforts were made to minimise bias, such as indirect distribution, social connection may still have played a role in ratings.

Lastly, relative scoring may have skewed results. Concepts were rated in comparison, not isolation, raising the possibility that individual scores were influenced by surrounding designs.

DELIVER

This section transitions from visual concept development to the final embodiment of the SteamUp product and its path toward market readiness. Chapter 16 presents the complete product design, visually refined, functionally compact, and technically resolved. Chapter 17 builds on this by examining how sustainability and repairability were integrated into the design. Chapter 18 concludes with a bottom-up cost analysis and explores SteamUp's production feasibility, emphasizing how pricing, batch size, and design decisions shape the startup's path to launch.

Deliver - Embodiment

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16 The design embodiment

This chapter presents the final embodiment of the Duck by SteamUp milk frother, combining functional, visual, and technical design into one cohesive product. Building on earlier research and prototyping, the result is a home-use machine that delivers professional steam performance in a compact, well-resolved form. Each design choice, from material use to interaction flow, reflects a balance between usability, aesthetics, and engineering. The following sections describe the product's design intent, visual identity, usage flow, and key technical decisions.

16.1 Duck by SteamUp overview

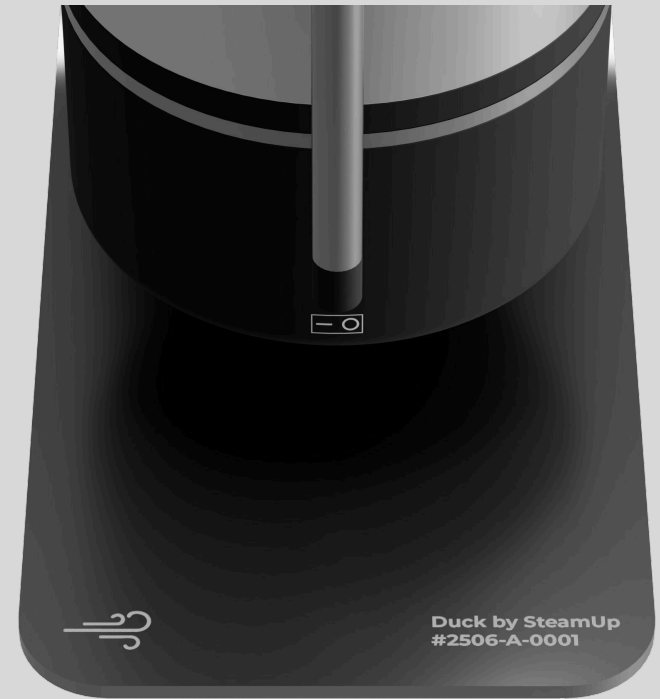
SteamUp is a premium milk frother designed to bring café-quality steaming into the home. Unlike traditional espresso machines, which treat milk frothing as secondary, SteamUp places it at the core. The result is a purpose-built device that enhances the home barista experience through both performance and visual expression. Internally, a boiler delivers consistent, high-pressure steam, typically reserved for professional-grade equipment. Externally, the compact footprint fits neatly in modern kitchens, with a distinctive presence that adds character without overwhelming the space.

User research (Chapters 08 and 09) shows that coffee enthusiasts value innovation, but also appreciate the tactile familiarity of traditional espresso gear. SteamUp embraces this by using analogue cues and simple controls. There are no digital screens; instead, boiler pressure is shown via an analogue gauge, and steam output is adjusted using a rotating ring. Dual on/off switches, one on each side, support both left- and right-handed users. Workflow and usability are discussed later in this chapter.

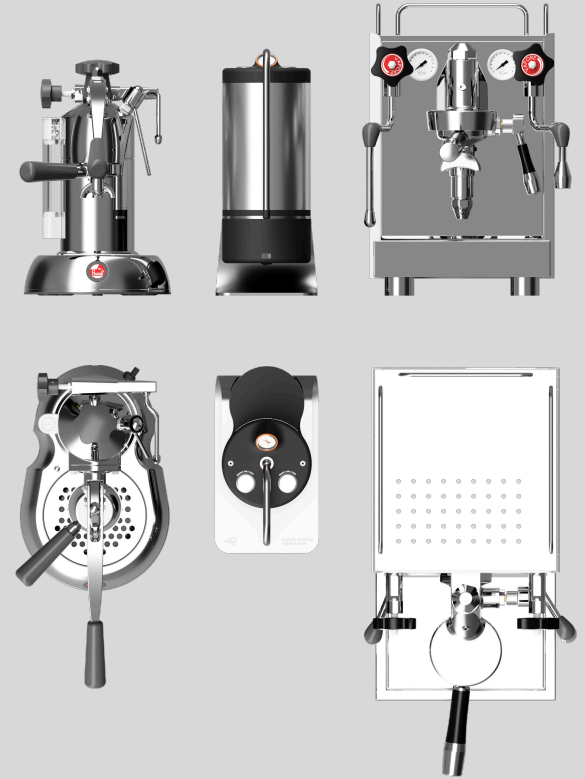
Visually, the product is defined by a cylindrical form that reflects the internal boiler, a key part of both the technology and design intent. The metal finish of the central section highlights this feature while underscoring the product's premium nature. As visualised in Chapter 12.3, soft curves and clean proportions express calmness, while the steam reveals its power. The elevated base adds depth and elegance to the grounded form. This floating stance reinforces recognition and brand identity, making SteamUp visually memorable.



Please just take a moment to enjoy its beauty, before moving on...



Please just take a moment to enjoy its beauty, before moving on...



16.2 Materials and visual identity

SteamUp aims to feel premium while remaining within a reasonable price range. As discussed in Chapter 12, a field study at Kookpunt, a premium kitchen store in Rotterdam, confirmed that coherent material combinations and noticeable weight contribute significantly to a product's perceived quality. To support this, the product's base is constructed from a 4 mm thick bent stainless-steel sheet. This material choice provides not only physical stability but also substantial weight, ensuring that the product remains grounded and cannot easily tip over. The stainless steel has a dark grey, semi-gloss finish that fits the overall dark and premium look and feel of the device.

The central cylindrical volume, which visually references the internal boiler, is made from aluminium. This material is significantly lighter than steel, which is essential because the full weight of the product rests on the bent sheet metal base. Using aluminium in this section helps minimise bending stress. Additionally, aluminium is more cost-effective and easier to machine than stainless steel. A coated finish is applied to visually match the stainless-steel base and maintain a cohesive look.

The black plastic components, visible in the Figures on the previous page, are made from a PC-ABS blend and used in areas requiring tactile interaction and curvy geometry. This material offers the surface versatility of ABS and the thermal resistance of PC. The mould finish is

SPI B1, resulting in a matte, lightly textured surface. Except for the base module, which uses three threaded inserts, all parts are designed for simplified moulds to reduce production costs. Although plastic is a practical and efficient choice, alternative materials such as Zamak with a powder-coated finish could be explored to enhance the perceived quality of future iterations.

The rear water reservoir is produced from clear polycarbonate (PC), allowing users to see the water level easily. The steam wand consists of a metal pipe and a nozzle made from PEEK, a high-performance plastic chosen for its ability to stay cool during use and reduce milk residue build-up.

To widen its appeal, SteamUp is designed to support variations in colour and material finish. The plastic elements can be produced in different colours, while metal components can be powder coated, surface treated or cut from various stainless-steel finishes. While these options allow for visual flexibility, they do increase production complexity and cost. Survey results discussed in Chapter 16 confirmed that the default version, featuring black plastics combined with stainless steel, is the most well-received. This configuration is expected to appeal to the broadest segment of the market, while coloured or wood-accented variations, may attract niche audiences without compromising the brand identity. In the Figure below a few different combinations are shown, highlighting the different possibilities with the design.



16.3 Using the Duck by SteamUp

The interaction flow of SteamUp is designed to be intuitive and minimal, based on user insights gathered in Chapter 08. While the current sequence reflects those learnings, it will require further testing to validate usability, see Figure 16.2 for an usage overview.

The process begins by switching on the main power, located on the underside of the product. Once activated, the LED ring around the steam buttons starts a soft, rotating animation, acting as a loading indicator to show the boiler is heating up. While the system builds pressure, the user can check the pressure gauge and, if desired, adjust the steam level using the control ring around the display, see Figure 18.1. When the boiler reaches operating temperature, the LED turns solid, clearly indicating SteamUp is ready. The user then moves the steam wand into position, places the milk jug underneath, and activates steam mode by pressing the steam button. Frothing begins immediately. Once the milk is ready, another press stops the steam. The wand can then be wiped down for hygiene and readied for the next cycle. For multiple drinks, users can simply repeat the process starting from the pressure check. If the LED lights begin to flicker during use, this indicates the water reservoir is empty. The tank can be refilled easily by sliding it out and topping it up with fresh water.

In addition, SteamUp features a manual descaling mode. By pressing and holding both buttons for five seconds, the device enters descale mode, indicated by alternating flickering lights. In this mode, the boiler stops heating and can be filled or emptied using the left and right buttons respectively. To prevent dry firing, the system first fills the boiler before allowing it to empty.

Figure 16.1: Rotate the orange knob to set the boiler pressure.



Figure 16.2: SteamUp's minimal interface for intuitive steaming.



16.4 Technical design details

A lot of design thinking has gone into the full embodiment of SteamUp. This section outlines a few key technical decisions that shaped the internal architecture and external configuration: specifically, the product's structural strength, temperature management, and the advantages offered by its elevated design.

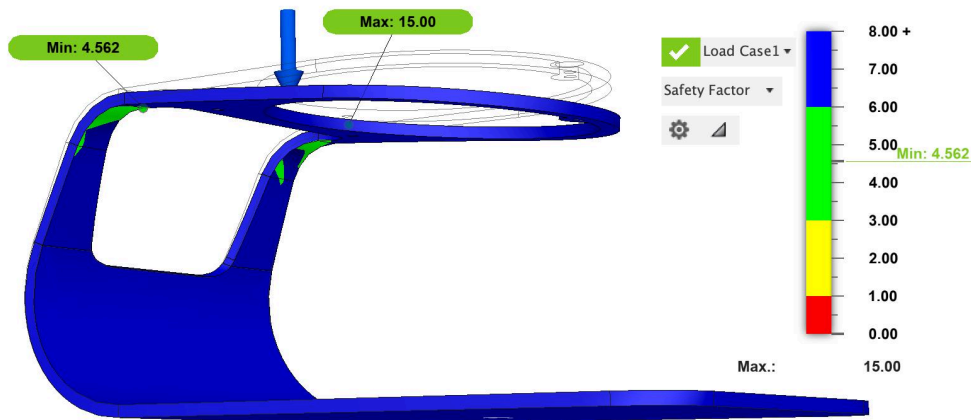
Weight and structural performance

The stainless-steel base plate is a key structural element, carrying the full weight of the product. To ensure durability, a simplified load analysis was carried out. A field test with the existing prototype, including a full water reservoir and boiler, indicated a total weight of 3.4 kg. To allow for tolerances and new component additions, this was rounded up to 4 kg. Using Fusion 360, this 40 N load was applied in a structural simulation of the bent steel plate. The result yielded a minimum safety factor of 4.56, with no signs of deformation or risk. Tests at 60 N (6 kg) still passed the typical safety factor threshold of 3. However, at 80 N (8 kg), the factor dropped to 2.28, indicating the edge of structural reliability. While the current thickness and geometry are considered safe, the embodiment phase should continue monitoring overall product weight in relation to structural integrity. Figure 16.3 visualises the 40 N simulation, which is the most realistic design scenario.

Temperature, airflow, and leakage control

With internal boiler temperatures reaching up to 130°C, thermal management is critical. All plastic components are therefore

Figure 16.3: The current stainless-steel design can easily withstand the estimated load of 40N, based on Fusion 360 load simulation.

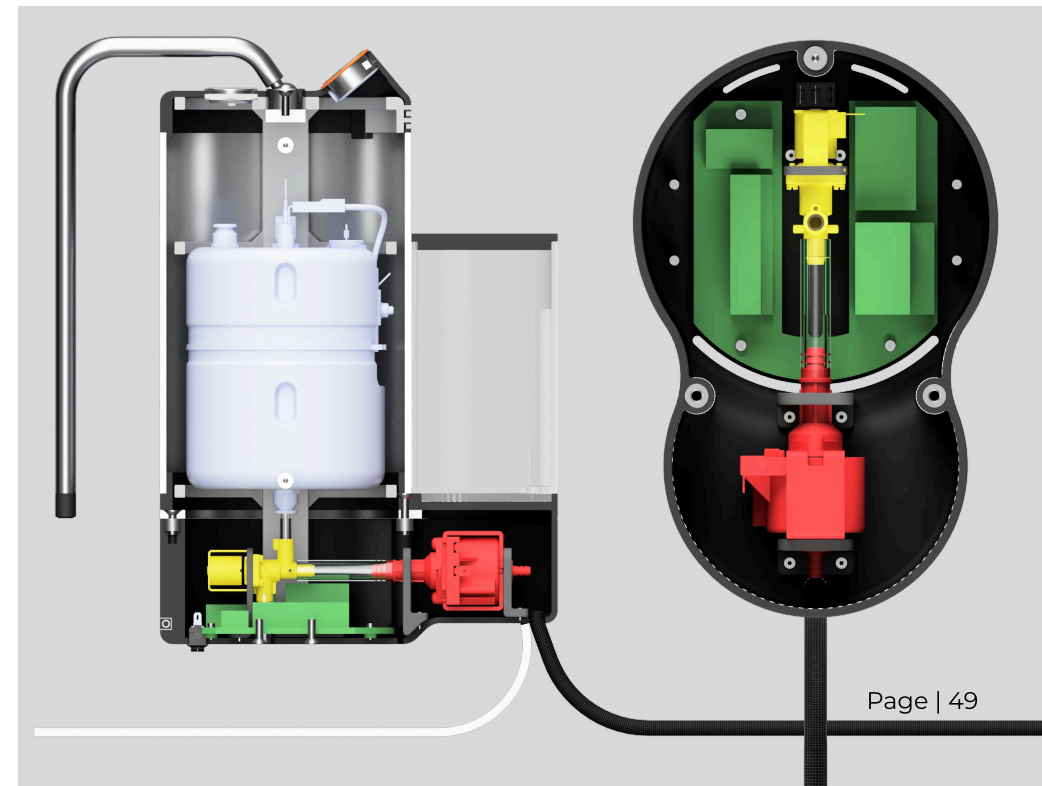


selected for high heat resistance, specifically PC-ABS and/or PC. To support cooling, the body includes vent holes that allow airflow from the bottom through to the top. These vents also serve a secondary purpose: if any leakage occurs internally, they allow water to safely drain away from electronics, see Figure 16.4. In future development, a protective cap over the PCB could be added to further redirect potential leaks and safeguard sensitive components.

Elevation and internal layout benefits

The elevated base began as an aesthetic choice but quickly proved valuable in enabling multiple technical features. First, it creates space for airflow and drainage, as mentioned above. More importantly, it allows for practical descaling and maintenance. The elevation makes it possible to use gravity to empty the boiler, simplifying the design of the descale function. A three-way valve is added for this reason, allowing water to flow either from the pump into the boiler or back out. Additionally, the raised water reservoir position ensures flow remains above the PCB level, reducing the risk of accidental flooding during use or servicing.

Figure 16.4: Optimised internal structure visualised, as well as air ventilation and water drainage slots in the bottom base (right).



17 Sustainability and repair

Sustainability is playing an increasingly vital role in product design education, driven by environmental pressures, regulatory shifts, and growing consumer awareness. Designers are not only expected to reduce the footprint of production and materials, but also to ensure that products can be repaired, upgraded or recycled at the end of their life. As such, repairability and sustainable thinking are no longer side concerns; they are becoming fundamental design challenges.

17.1 Personal vision

As a young product designer, my vision is that we should be more careful with what we make and use. While many current trends focus on reducing consumption, this alone is unlikely to solve the core issue in my opinion. People will always want products that enhance their lives. However, the way these products are designed could be radically improved. For instance, many Apple devices are clearly premium in quality, but only for a limited lifespan. Once the battery degrades or something breaks, repairs become too costly or inaccessible due to glued enclosures and unavailable parts. This approach does not prioritise longevity, but rather recurring customer turnover, one rooted in profit incentives.

17.2 Sustainability through repairable design

Although this thesis does not focus on sustainability or repairability as a primary research goal, these considerations were integrated where possible. A full design-for-repair evaluation falls outside the project's scope, but the following pages present an overview of the product's assembly sequence. All parts are mechanically fastened using bolts and screws, and every assembly step is reversible. This means the product can be disassembled without damage, and individual parts are accessible for servicing. One exception is the electronics base, which uses threaded inserts, making recycling more complex.

From a business and systems perspective, spare part availability will be key in making this repairability meaningful. That should be integrated into both the business model and supply chain strategy. Interestingly, even though this topic wasn't a strong theme in user interviews (Chapters 08 and 09), it is highly relevant in the coffee enthusiast community. Within that space, the ability to clean, tweak or even overhaul your machine is a respected feature, almost a sub-hobby in itself. Many of the most appreciated brands are known for their

repairability and modularity. SteamUp aims to move in that direction, laying the groundwork for products that last longer, and are more serviceable, by design.

Figure 17.1: Overview off the (dis)assembly process.

A. Bottom base assembly

1. On/Off button (black)

Pressed into the base.

2. PCBA (green)

Screwed onto the base.

3. Three-way valve (yellow)

Screwed on with a holding bracket.

4. Pump (red)

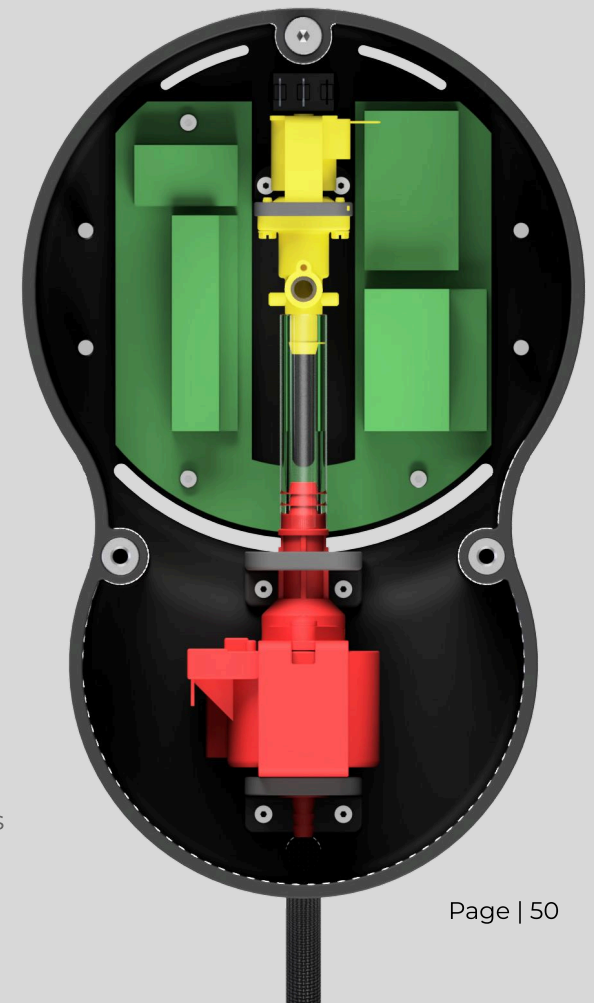
Screwed on with two brackets.

5. Tubing

Add tubing pump (2x) and three-way valve (2x).

6. Cables

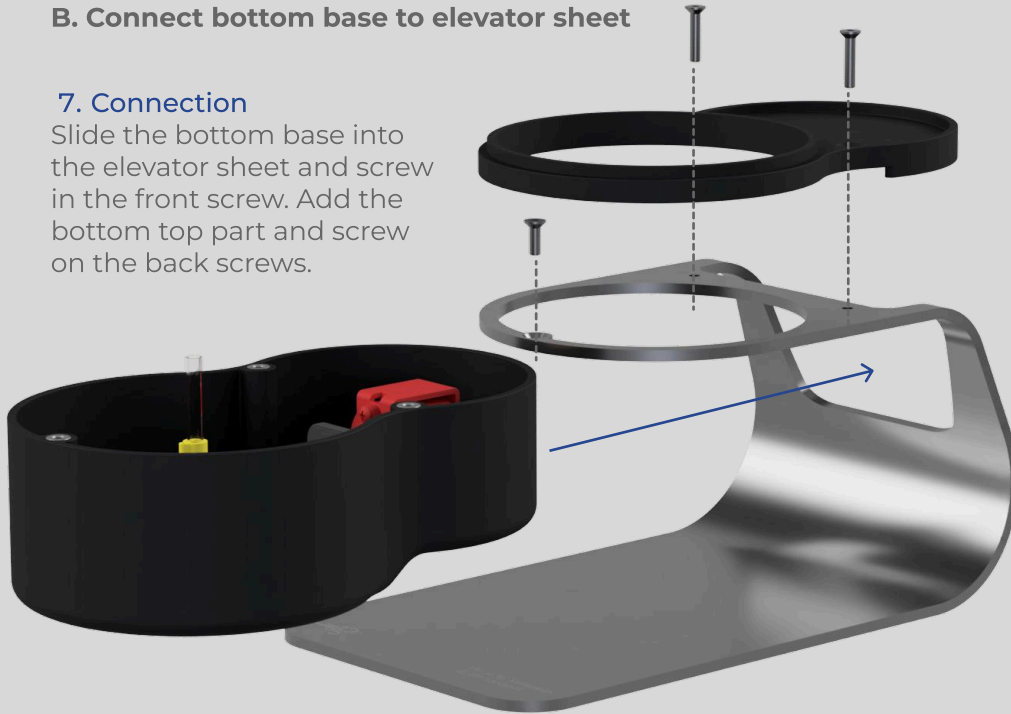
All cables to PCBA and parts are added, as well as cables for other parts.



B. Connect bottom base to elevator sheet

7. Connection

Slide the bottom base into the elevator sheet and screw in the front screw. Add the bottom top part and screw on the back screws.



C. Boiler and steam piping assembly

The boiler and steam piping are assembled outside the main housing and can be removed as a complete unit, making maintenance and repair straightforward for the components most likely to wear or require replacement.

8. Boiler

The boiler is screwed onto the holder using 2 screws.

9. Steam piping (not visualised)

Many components, including piping, couplers, the pressure valve, vacuum valve, and solenoid switch, are preassembled directly onto the boiler unit.



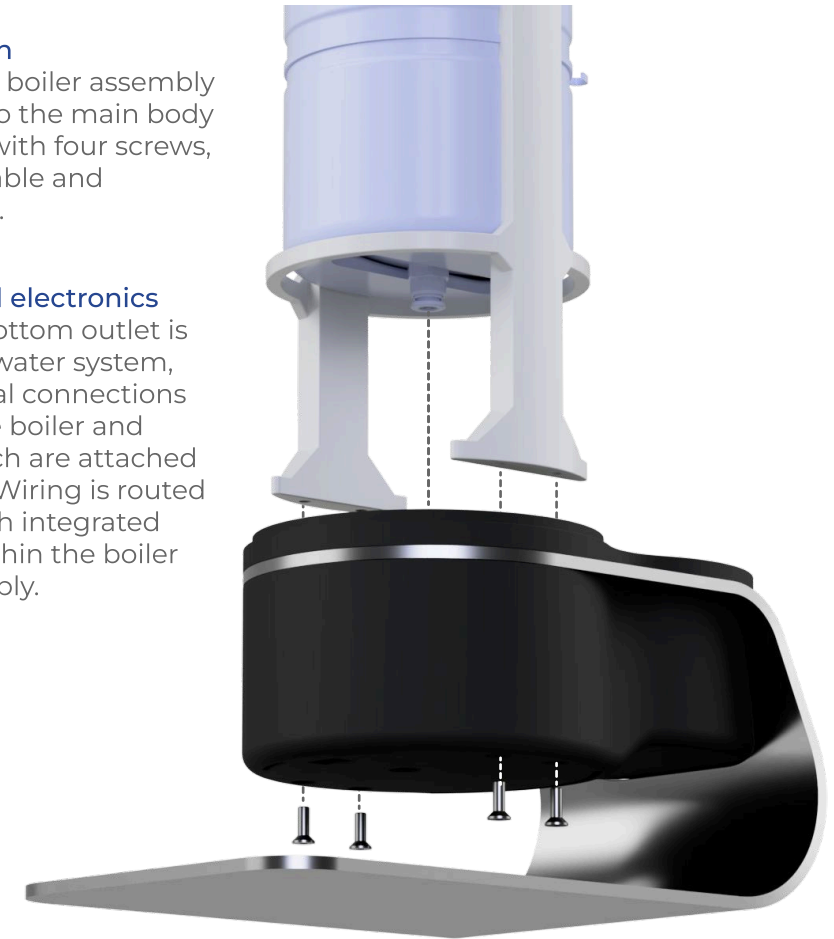
D. Connect boiler system to main assembly

10. Connection

The complete boiler assembly is inserted into the main body and secured with four screws, ensuring a stable and serviceable fit.

11. Tubing and electronics

The boiler's bottom outlet is linked to the water system, while electrical connections from both the boiler and solenoid switch are attached to the PCBA. Wiring is routed neatly through integrated guide rails within the boiler holder assembly.



E. Boiler shell and steam pipe assembly

12. Boiler shell

The aluminium boiler shell slides over the boiler holder and aligns with the bottom base. It is secured in place using four screws, which fasten into the internal boiler bracket. This fixation is critical to ensure that any lifting forces applied to the shell, such as when users pick up the product, are properly distributed through the structure.

13. Steam pipe fixation

The full steam pipe assembly, consisting of the nozzle, metal pipe, teflon tubing, couplers and ball joint, is pre-assembled before installation. It is mounted onto the boiler holder using a coupling screw nut. Finally, the steam tube is connected to complete the circuit.



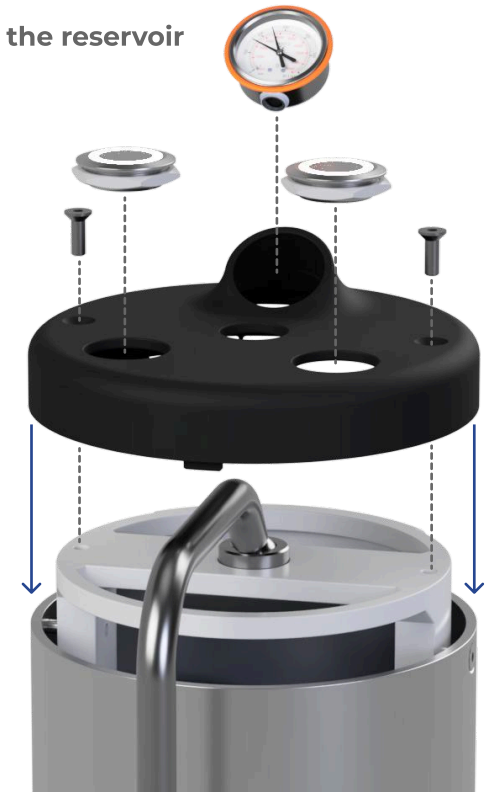
F. Closing the product and adding the reservoir

14. Cap assembly

The cap is assembled separately by mounting the two on/off buttons and inserting the pressure gauge module into position.

15. Closing the product

The cap slides along the steam wand and fits onto the top of the device, a motion verified during earlier prototypes. Before fastening the cap with two screws, the internal wires to the buttons and pressure gauge must be connected.



16. Reservoir

The water reservoir and lid are designed to be removable for easy refilling. The lid clips into the hinge points, while the reservoir slides smoothly into the base.

This completes the full assembly, which is entirely reversible, enabling future repair, part replacement, and responsible end-of-life recycling.



18 Manufacturing cost price estimation

To transition from a functional prototype to a commercially viable product, estimating the cost price is a key step. Cost estimation not only informs the potential retail price and profit margins, but also highlights the impact of design choices, batch sizes, and supply strategies on financial feasibility. This is especially critical for hardware startups, as they often require external investments to initiate production, making financial clarity and realistic projections essential for investor confidence. The chapter concludes with an critical analysis of manufacturing cost and provides early insights on potential pricing strategies.

18.1 The manufacturing cost formula

As defined by Tempelman (2020), the manufacturing cost (MC) of a product consists of five key categories:

$$MC = C_{mc} + C_{ma} + C_{lab} + C_{qp} + C_{inv}$$

C_{mc} = Materials and Components

All purchased and custom-made parts that go into the product, including electronics, mechanical parts, and fasteners.

C_{ma} = Machine and Assembly

Costs related to machine operations and tooling, including any preparatory sub-assembly steps.

C_{lab} = Labour

Manual tasks performed during product assembly, inspection, and packing. Labour cost is influenced by location, labour type, and efficiency.

C_{qp} = Quality and Packaging

Covers both quality control measures (e.g. function testing, final checks) and consumer/transport packaging.

C_{inv} = Investments

One-time expenses for tooling, such as moulds or jigs, amortised over the expected production volume and adjusted for financing costs over time.

The following sections break down each cost component and discuss how production volume affects the overall cost structure.

18.2 The MC breakdown

The MC formula divides manufacturing costs into five distinct categories. However, in practice, quotations often reveal overlapping cost elements. For instance, machine usage and handling for outsourced parts were embedded into supplier pricing. This section outlines the main findings and design decisions related to each of the MC cost components. Although some aspects overlap multiple categories, each is discussed in terms of relevance and influence on the final cost. To maintain clarity, the calculations below focus on a batch size of 500 units, the complete spreadsheet can be found in Appendix C18.

Component costs of fabricated parts

To obtain accurate part pricing, several rounds of quotation requests were submitted to suppliers specialising in injection moulding, sheet metal bending, and aluminium extrusion. Meetings, calls and email exchanges with engineering and sales teams from companies including Xometry, MakerVerse, Fictree and Reurings Precisie Plaatwerk, made up these findings. They validated the manufacturability of the part designs and offered ways to reduce tooling investment, such as combining three injection moulded parts into a single mould. This reduced mould amounts and thus cost. Research into moulding Zamak parts instead of plastic parts resulted in way too expensive prices, nearly doubling its unit price.

An exception is the boiler holder, which has not been finalised. However, based on material choice, aluminium over stainless steel, and simplified geometry. The cost is estimated at approximately 60% of the current sheet metal part.

Fabricated parts cost at 500 units:

- Injection moulded parts (5 parts): €9,47
- Total mould cost: €25.162,00 (spread across 30.000 units)
- Metal parts (2x sheet metal + 1 aluminium extrusion): €19,19

Printed circuit board assembly (PCBA)

A detailed cost estimate was obtained using PCBWay's online calculator, based on the current circuit layout shown in Chapter 05. The quote reflects both the fabrication of the printed circuit board and the

complete surface-mount assembly of all specified components, providing accurate cost data at varying batch sizes. For a batch size of 500 units, PCB fabrication is priced at €0,68 and component assembly at €1,57 per unit (excluding components). This results in a combined electronics cost of €2,25 per unit, which provides a credible benchmark even though the final PCBA design is still under development.

Off the shelf (OTS) components

SteamUp consists of over 80 individual components including pumps, valves, switches, and the boiler. While many of these parts show limited price fluctuation across scales, the boiler represents a major cost driver with significant variance depending on origin. Two boiler sourcing routes were explored. The current supplier in Italy offers a high-quality boiler at €85,00 per unit. Alternatively, a Chinese supplier provided a custom-built boiler, based on specified components, for €40,54 per unit.

Although quality appears comparable, pricing and supply chain considerations may impact the final choice. The cost of OTS components, excluding the boiler, totals €36,06 per unit. This means the boiler alone can double or triple the total cost of bought-in parts depending on the supplier.

At batch size 500 (including PCBA):

- Total component cost excluding boiler: €36,06
- Total component cost with EU boiler: €121,06
- Total component cost with China boiler: €76,60

Labour, assembly, quality control, and packaging

Labour is concentrated in final assembly, quality control, and packaging, as most components are delivered as ready-made subassemblies. To verify key assumptions, an interview was held with Maarten Tromp from AP Nederland. Tromp confirmed the overall setup and reviewed the assembly steps, estimating that the process could be divided across six assembly stations, one quality control and packaging station, and one station for restocking parts. With an average of 2 to 3 minutes per station, the total time per unit ranges between 16 and 24 minutes. For the cost estimate, a conservative duration of 22 minutes per product was used, including overhead. Two labour models were considered: professional production lines at €41 per hour and sheltered workshops at around €13,50 per hour. While the latter is significantly cheaper, it requires roughly twice the time per unit and may lack consistent quality checks. Packaging is estimated at €4,00 per unit, assuming high-end, protective packaging with outer dimensions of 320×380×160 mm.

Labour cost at batch size 500:

- Professional assembly line: €16,91/unit
- Sheltered workshop: €6,44/unit (Note: Sheltered setups may lack quality control.)

Tooling and investment

For hardware startups, tooling often represents one of the most significant early-stage investments. In this case, the cost of injection mould tooling is estimated at €25.162, supporting a projected lifetime output of 30.000 units. While this could theoretically translate to just €0,84 per product, the reality is more complex due to capital depreciation and interest over time.

To explore a more realistic scenario, a simplified depreciation model was applied using a 5% annual interest rate and a modest sales volume of 500 units per year, resulting in a three-year repayment horizon. With these conditions, the effective cost of tooling rises to €19,42 per product. This conservative estimate underscores how heavily tooling costs are influenced by both sales volume and the time required to recover the investment. Faster growth or higher output would reduce this figure, but the example clearly illustrates the risk profile tied to upfront tooling decisions.

18.3 Cost overview and scale effects

One of the most decisive factors in determining a viable cost price is the production batch size. As seen throughout the component, labour, and investment breakdowns, significant cost reductions occur with increasing scale, a well-known effect. Table 18.1 on the next page shows an overview of the main costs per batch size of the SteamUp.

At low batch sizes (e.g. 50x), total manufacturing costs per unit can exceed €700, driven primarily by the disproportionate impact of tooling investments and low supplier discounts. For instance, injection moulded parts cost €46,59 per unit at 50 units but drop to €5,52 at 5.000 units. Similarly, PCBA drops from €6,77 to €1,26. Investment tooling costs alone decrease from over €500 per unit to under €6 at higher volumes. Labour and packaging show modest improvements but are less sensitive to scale.

One of the most significant cost drivers is the boiler unit. Its contribution to the overall product cost is substantial, especially when sourced from the European supplier. At a batch size of 500 units, the EU-sourced boiler accounts for approximately 49% of the total

component cost (€85 of €173.70), while the China-sourced boiler still contributes around 23% (€40.54 of €173.70). With larger batch sizes, this percentage only increases as other part prices decrease way quicker. This demonstrates that the boiler alone can nearly halve the cost difference depending on the sourcing strategy, making it a critical decision point in the product's financial viability.

From batch size 1.000 onwards, most prices begin to stabilise, with diminishing marginal gains. At 5.000 units, total manufacturing cost approaches €111,17 per unit, nearly 85% lower than at 50 units. This shows clearly that achieving market readiness at a competitive price strongly depends on committing to higher volume production.

Table 18.1: Overview cost calculations of all parts of the SteamUp product.

Cost of fabricated parts, electronics and off the shelf components

Amount	Injection moulded	Metal parts	PCBA	OTS Components	Boiler EU	Boiler China	Total cost (China)
50	€ 46,59	€ 25,22	€ 6,77	€ 46,84	€ 95,00	€ 48,04	€ 48,04
100	€ 26,45	€ 23,04	€ 5,11	€ 44,23	€ 90,00	€ 44,04	€ 44,04
500	€ 9,74	€ 19,19	€ 2,25	€ 36,06	€ 85,00	€ 40,54	€ 40,54
1.000	€ 7,43	€ 18,91	€ 1,54	€ 33,99	€ 75,00	€ 39,64	€ 39,64
5.000	€ 5,52	€ 18,69	€ 1,26	€ 33,03	€ 63,00	€ 39,04	€ 39,04

Cost of assembly, packaging and quality check

Amount	Assembly NL	Sheltered NL	China	Packaging	Total cost
50	€ --	€ 6,44	€ --	€ 4,00	€ 48,04
100	€ --	€ 6,44	€ --	€ 4,00	€ 44,04
500	€ 16,91	€ 6,44	€ 1,73	€ 4,00	€ 40,54
1.000	€ 16,41	€ 6,44	€ 1,68	€ 4,00	€ 39,64
5.000	€ 16,07	€ 6,44	€ 1,65	€ 4,00	€ 39,04

Cost of investment

Amount	Mould cost	2 years 5% intrest
total	€ 25.162,00	€ 27.741,11
50	€ 503,24	€ 554,82
100	€ 251,00	€ 277,41
500	€ 50,32	€ 55,48
1.000	€ 25,16	€ 27,74
5.000	€ 5,03	€ 5,55
30.000	€ 0,84	€ 0,92

Manufacturing cost (MC) total

Amount	Total cost
50	€ 738,72
100	€ 430,73
500	€ 173,70
1.000	€ 137,16
5.000	€ 111,17
30.000	€ 106,55

18.4 Understanding pricing thresholds for launch viability

While this chapter focused on manufacturing cost (MC), many additional factors shape the total cost and viability of bringing a product to market. Product design decisions, manufacturing engineering complexity, logistics and warehousing overhead, marketing and sales strategies all contribute significantly. To keep the analysis manageable, a multiplier between 3x and 5x the manufacturing cost is typically used as a rule of thumb to approximate the final retail price. This helps account for those extra expenses while acknowledging the variability between projects.

Applying this to SteamUp reveals that production volumes below 500 units remain financially unviable under the current model, especially with tooling amortisation and premium components like the boiler. For example, the MC at 500 units is approximately €170, which, when multiplied by 3, results in €510, probably too high for a competitive consumer product. This is partly due to under-utilisation of the moulds, which are designed for up to 30,000 units, yet only amortised over two years time to market and of low sales volume.

However, the outlook improves significantly at larger batch sizes. From 1,000 units onwards, production costs decrease sharply, and the MC multiplier falls within a feasible retail pricing range. While this cost analysis was done bottom-up, a top-down perspective on realistic market pricing is equally important. Based on current competitors, who use less advanced heating technology and invest less in design quality, a retail price between €350 and €500 appears both competitive and justifiable. The boiler remains one of the most expensive components, but it also represents a functional and qualitative differentiator in the market, justifying a slightly higher product price.

Ultimately, launching a pilot production of 500 units is still possible, but will require founder-driven assembly, lower-cost tooling, or other creative trade-offs to bridge the early-stage cost gap. Although lower tooling costs are possible, obtaining reliable RFQs for alternative tools proved challenging within the limited timeframe of this study. As volumes grow, SteamUp's design is well positioned for efficient scaling, while maintaining its premium and modular identity.

18.5 Limitations

While the manufacturing cost (MC) analysis provides a solid foundation, several limitations remain. Many supplier RFQs are still pending and may alter key cost components. Additionally, the analysis primarily focuses on mid-scale production, whereas low-scale techniques are not explored enough, yet could offer useful short-term alternatives. Cost factors beyond MC, including logistics, warehousing, distribution, and warranty, are also not included in detail. The boiler, in particular, deserves further study as its specs and price strongly influence overall feasibility. Lastly, the pricing strategy relies on assumed market positioning and competitor benchmarks, which will benefit from further top-down validation and customer testing. All prices in this chapter are excluding shipping, import tax, and VAT, which may significantly affect the final landed cost depending on sourcing regions.

WRAP - UP

This final section brings the project to a close. Chapter 19 answers the main research questions and consolidates the findings of the project. Chapter 20 reflects on the designer's personal development throughout the form-giving journey. Chapter 21 lists all references used in the thesis.

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19 Conclusion

This thesis set out to investigate whether SteamUp could be designed and produced with both a competitive advantage and a feasible cost structure. The goal was to evolve the current prototype into a minimum viable product (MVP), addressing embodiment design, technical performance, and scalable manufacturing. After the analysis phase, it became clear that target users value aesthetic quality nearly as much as milk steaming performance. While the prototype's steam capabilities were already positively received, its form and visual identity were lacking a gap this project aimed to resolve.

SteamUp's core advantage lies in its technical foundation: a professional-grade boiler system, rarely used in this product category due to cost and complexity. This choice offers a tangible edge over competitors relying on simpler, less consistent heating methods. To express this technical strength visually, the product design incorporates rounded forms and metal finishes that evoke the character of a boiler. This leads to the guiding vision: SteamUp is a premium milk frother that blends its technical boiler strength with a distinctive, yet calm design, to create a recognisable identity; where elegant design and power from within meet.

The selected concept, Duck by SteamUp, was favoured for its ability to combine personality with performance, rated 8+ by over 50% of participants. It embraces a minimal yet expressive stance, characterised by soft curves and a compact silhouette that communicates both playfulness and precision. Duck proves that a product doesn't need to be loud to be powerful; it can be humble in form yet confident in presence. While the current design is optimised for the core of the target group, its parts allow for future variation in colours and material finishes, enabling tailored visual identities for different sub-segments.

Cost modelling revealed that the premium boiler is SteamUp's largest cost driver (25% to 50%), but also its strongest differentiator. With a manufacturing cost (MC) of approximately €170 at a 500-unit batch, reaching the original €100 MC target for a €350 retail price is difficult at low volumes. However, this picture improves significantly at higher scales: from 1,000 units onward, the MC multiplier begins to align with the typical retail pricing range of €350–€500. This range was validated through bottom-up cost analysis and is consistent with SteamUp's premium positioning in a market where competitors use less robust heating elements and less refined design.

In answering the central research questions, this thesis shows that SteamUp can be designed with both competitive advantage and a feasible cost structure, provided that sufficient volume is reached. While the original €100/€350 goal may now seem outdated, it remains within reach at reasonable scales. At 500 units, production is possible, but only through early-stage startup strategies like founder-led assembly and simplified tooling. These approaches are not long-term solutions, but they can serve as realistic launch strategies to bridge the gap until full-scale production is viable.

SteamUp is set to advance beyond the prototype phase, blending premium steam performance with elegant design and a seamless user experience.

Future work should prioritise refining the internal architecture and producing a limited number of production-quality units. These units will be essential for collecting structured customer feedback and deriving product engineering insights ahead of any potential pilot run. Special attention should be given to the boiler system; its performance, price point, and long-term durability remain critical factors for both product differentiation and cost viability. Further collaboration with suppliers will help clarify actual manufacturing costs, while top-down pricing research from Wouter's parallel thesis will be key in testing whether the estimated price range aligns with user expectations and willingness to pay.

20 Form-giving reflection and academic contribution

In the Industrial Design Engineering programme at TU Delft, particularly within the Integrated Product Design master's track, students are equipped with tools on technology, user research, and business strategy. However, one of the foundational pillars of product design, semantics and visual form, often receives less explicit focus. During the analysis phase, it became clear that the visual identity of the product played a central yet underdeveloped role. This gap presented an opportunity: to approach form-giving not only as a design task but also as a personal learning objective. This chapter reflects on that journey, what it means to build form from the ground up, what was learned in the process, and how this experience may support future students in developing a stronger visual design voice.

20.1 Initial learnings during the process

When the form-giving phase of this project began, I had no clear starting point. Without a predefined brand identity or visual language to lean on, I found myself navigating unfamiliar territory, guided mostly by instinct, exploration, and trial and error. One of the first useful habits I developed was collecting visual references. By browsing curated image boards and analysing products that felt visually appealing, I began to identify the aesthetic direction that suited SteamUp. These weren't copied directly but served as adjustable templates that grounded my decision-making.

Equally important was getting off-screen. Visiting physical stores helped me observe how form, material, and detail behave in the real world, where reflections, surface textures, and proportions communicate far more than digital renders ever could. These early steps taught me that inspiration comes from interaction and observation, not just from behind a desk. A major breakthrough came when I started discussing my ideas without showing visuals. Explaining the concepts out loud, sharpened my thinking and helped refine the story behind each design. Another turning point was letting go of the idea that every component needed to be custom-built. Using pre-made parts from 3D databases allowed me to shift energy toward refining the overall form, improving both quality and speed.

There were challenging moments too. At one point, I had a few base shapes but no detailing, everything felt static and unconvincing. I now realise I should have explored materials and detailing earlier. Another hesitation was showing my work too late. Sharing unfinished ideas

earlier would've made the process feel more open and help build confidence through dialogue. Next time, I'd involve others sooner and trust that the process, not the polish, is what creates real progress.

20.2 Advice for future design students

Form-giving demands time, especially when starting without a strong personal style or a defined brand identity. One of the biggest lessons was learning not to rush the process. When there are no visual guidelines to rely on, progress may feel slow, but that time is necessary to explore, reflect, and build confidence. Some tasks feel useless when doing them, but later they show their value, for instance visiting Kookpunt. For future students, I recommend documenting every small design change, noting why it was made and what effect it had. This habit not only improves design reasoning but also makes it easier to backtrack when a direction doesn't work out. Trust in your own judgment is essential, but it shouldn't happen in isolation. Share your work often, get feedback early, and talk through ideas before they're finished. It is scary though, so you will need to step outside your comfort zone. The best insights often come from casual conversations, not formal presentations. Form-giving is also about building confidence, so besides the scary work, also do things that make you feel more confident in presenting your work.

20.3 Looking back, shaping forward

I still have a lot to learn, especially when it comes to organic shapes. But I now feel much more confident navigating the form-giving process. I'm proud of the final designs, even though I can see now that Concepts 1 and 2 would have been stronger if I had embraced simplicity instead of forcing uniqueness. One of the most important mindset shifts was understanding the link between form and story. Initially, I started designing with no clear identity or guiding narrative, which made decision-making difficult. Once I defined SteamUp's vision and translated it into design principles, things started falling into place. Design became less about guessing and more about refining.

In hindsight, I also should've spoken to more people earlier on. Once I printed my concepts at A3 and casually talked through them with others, the feedback was more honest and more useful. Form-giving was unfamiliar territory at the start, it has since become a factor in my growth as a designer. The confidence gained here will guide how I handle ambiguity and complexity in future work.

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