Designing Interactive Solutions for Adolescents with Sickle Cell Disease

HCI for I-Tech (202100208)

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April, 2025

1 Introduction

Sickle Cell Disease is a blood disorder that affects the protein, haemoglobin, which is tasked with carrying oxygen in the red blood cells. It is caused by a gene mutation and is an inherited disease. Patients with the disease have red blood cells that "sickle," i.e., they become crescent shaped, resembling a farming tool, the sickle. (*Sickle Cell Disease*, n.d.)This abnormality leads to many difficulties such as an increased risk of infections, and strokes. The disease also causes severely painful episodes called "sickle-cell crisis" or "vaso-occlusive crisis" (*What Is Sickle Cell Disease? | NHLBI, NIH*, 2024). Vaso-occlusive crises are the leading cause of hospital admissions of patients with sickle cell disease and are also associated with an increased risk of mortality (Niraimathi et al., 2015)(Ballas & Lusardi, 2005). As a result, this lifelong disease is managed by treating as well as preventing pain episodes and other complications. In combination with medications to prevent serious symptoms, it is also often recommended that patients undertake precautionary actions to stay as healthy as possible. Patients are often advised to stay hydrated, do moderate exercise, eat well, and maintain good hygiene to prevent infections (Sickle-Cell.com, 2020)(Brent Sickle Cell & Thalassaemia Centre, 2021).

Although sickle cell disease is a lifelong disease, the ages of 12-18 years present a serious challenge due to patients transitioning from childhood to adulthood (Sickle-Cell.com, 2020). Not only are they confronted with the trials of puberty, but they also must face tribulations caused by sickle cell disease and the transitioning from paediatric to adult medicine. The adolescent patients must also adjust with becoming in charge of their care instead of their parents or caregivers. They are at a higher risk of morbidity and mortality during this time (Calhoun et al., 2021). Moreover, the international Sickle Cell World Assessment Survey found that sickle cell disease has a substantial effect on a patient's quality of life due to the impact on their physical and mental health, social life, work, and school. Of the 2145 patients surveyed, a considerable fraction reported that the disease had a "high negative impact" on emotions (60%) and school (51%) (Osunkwo et al., 2020). Taking these aspects under consideration, the following research question was proposed:

"What tangible and interactive solutions can be designed to promote the adoption of healthy habits, such as hydration, moderate exercise, balanced diet, hygiene, and consistent medication use, among adolescents with sickle cell disease for preventive care?"

This project will focus on creating interactive solutions for teens with sickle cell disease by conducting a design study. The results of the study will be analysed and used to create one or more conceptual directions for the proposed design challenge.

2 Background & Related Work

The objective of the empathise phase was to gain understanding of the users, their needs and the problems they encounter (Dam.R. F, 2025). During the empathise phase, a literature review and an expert interview were conducted. The literature review was done to comprehend the disease to be designed for. This included the symptoms, the triggers and current prevention methods. In addition, the literature review was meant to serve as preparation for the expert interview to know what kind of questions would be relevant for the interview. The expert interview was conducted to investigate areas of concern regarding management of the disease and possible design opportunities.

2.1 Methodology

The literature study was conducted with the research questions in mind. The focus points for the research were the nature of the disease itself, disease management and prevention, pain medication administration and existing devices/systems for disease management.

2.2 Results

Sickle Cell Disease is a complex inherited blood disorder that impacts red blood cells, specifically the protein, haemoglobin, that carries oxygen in the red blood cells. Due to a gene mutation, the red blood cells, that are ordinarily disc-shaped and flexible, are rigid and abnormally shaped like a farming tool known as a sickle. Typical red blood cells easily travel through blood vessels, delivering oxygen throughout the body. However, when the cells "sickle", they are unable to bend or move easily which can hinder blood flow and cause significant cascading complications including an increased risk of infections, anaemia, organ damage, and stroke (*What Is Sickle Cell Disease? | NHLBI, NIH*, 2024).

While sickle cell disease is a lasting illness, the ages of 12 – 18 years old present a critical challenge due to the patients transitioning from childhood to adulthood (Sickle-Cell.com, 2020).

The table below shows a summary of the findings from the two research methods.

Theme	**Findings from the Literature Review**	**Findings from the Interview**
Symptoms	Episodes of severe pain (Osunkwo et al., 2021) Chronic fatigue (Ameringer et al., 2014)	Pain episodes
Triggers of Crises	Drastic changes in weather (Piel et al., 2016) Dehydration (Sickle-Cell.com, 2020) Infections (Sickle-Cell.com, 2020) Physical and mental stress (CDC, 2020)	Drastic changes in weather Dehydration Traumatic experiences, psychological stress, too much exercise, lack of sleep
Prevention	Adherence to prescribed medications (CDC, 2020) Stay hydrated (CDC, 2020) Avoid extreme temperatures (CDC, 2020) Balanced meal Manage stress (CDC, 2020) Patient education (CDC, 2020) Microfluidic devices (Adusei & Ofori, 2016) Regular blood transfusions (National Heart, Lung, and Blood Institute, 2020) Medical check-ups (Centers for Disease Control and Prevention, 2020)	Taking prescribed medication, vaccination Drinking water to prevent clots Multiple layers of clothing, warm pools Healthy diet

Table 1: Comparison of Findings from Literature Review and Interview

From the literature review and the expert interview, it can be concluded that the most prominent symptom of the disease is chronic pain. The common triggers from both the interview and the literature study were:

- Weather changes
- Dehydration
- Mental and physical stress
- Infections

The design study showed that there are current preventative measures in use for the chronic pain experienced by the patients of sickle cell namely:

- **Medication -** Can help to reduce the frequency and severity of the pain.

- **Staying hydrated** – Helps reduce the sickling of red blood cells.
- **Staying warm** – Helps relax the muscles, reducing the likelihood of pain episodes.
- **Healthy diet** – Ensures that sickle cell patients have enough energy and nutrients to support overall health.
- **Moderate exercise** – Can help improve circulation.

3 Method

3.1 Defining the Challenge

To effectively identify the design direction, different design methods were evaluated to "Define" the case and to put together all the evidence gathered from the literature review. The goal at hand was to understand the problem space around Sickle Cell Disease (SCD), the daily life of adolescents (aged 14-18) and define a clear actionable Research Question (RQ). The team decided to use 2 design methods (courtesy of d.school toolkit) that would help lay down all the facts and structure the challenges to make an informed design decision. The methods selected were MoSCoW Prioritisation method, moving to a Problem Tree Analysis and subsequently creating a User Persona to address the overarching RQ.

3.2 UX Goals & Usability Goals

It became evident early on in the challenge discussion that the solution must extend more than just a clinical solution to ensure social acceptance and engagement. Adolescents with SCD usually face social stigma, and converging to a solution that is available for a wider audience yet specifically catering to SCD use was deemed ideal. This strategy draws from inclusive design principles, which emphasise products that "work well for everyone", thereby avoiding social signalling that could alienate the user (Nielsen Norman Group, n.d.).

In parallel, Usability goals were defined to guide ideation and assess the practical effectiveness of the developing solution:

Effectiveness: The system should support adolescents with sickle cell disease in consistently monitoring and managing their habits.

Efficiency: Interaction with the system should be quick and effortless, with minimal interruption to daily routines.

Safety: The product must be clearly viewed only as a supporting system, rather than a diagnostic tool.

Utility: It should offer meaningful functions such as reminders and visual feedback to facilitate habit formation.

Learnability: Users should be able to understand and use the product without requiring formal training.

Memorability: The interaction patterns and visual elements should help users ease back into using the system even after periods of non-use.

Satisfaction: The product should be enjoyable to interact with and contribute positively to the user's daily experience.

UX goals were chosen with specific focus on fostering desirable emotional responses. Hence, desirable and undesirable traits were defined (Table 2), that could possibly influence habit initiation, routine cues, learning and stability (Gardner et al., 2012).

Desirable Traits	Undesirable Traits
Easy to use	Annoying
Memorable	Unreliable
Engaging	Patronising
Seamless	Gimmicky
Trustworthy	
Efficient	
Effective	

Table 2: User Experience (UX) Goals

3.3 The MoSCoW Method

The MoSCoW method is a tool which allows the team to prioritise the different features that they will work on. Features are then categorized into “Must have”, “Should have”, “Could have”, or “Would like but won’t get”. The four categories that the approach uses to decide priorities are represented by the (nearly) acronym MoSCoW. The method was selected because of its effectiveness in categorising complex design requirements given the limited design timeline. It operates on the premise that while all project requirements are significant, they should be ranked in order of importance to provide the greatest advantages in the shortest amount of time (Interaction Design Foundation - IxDF, 2015). The features were classified based on this method, as can be seen in (Figure 1).

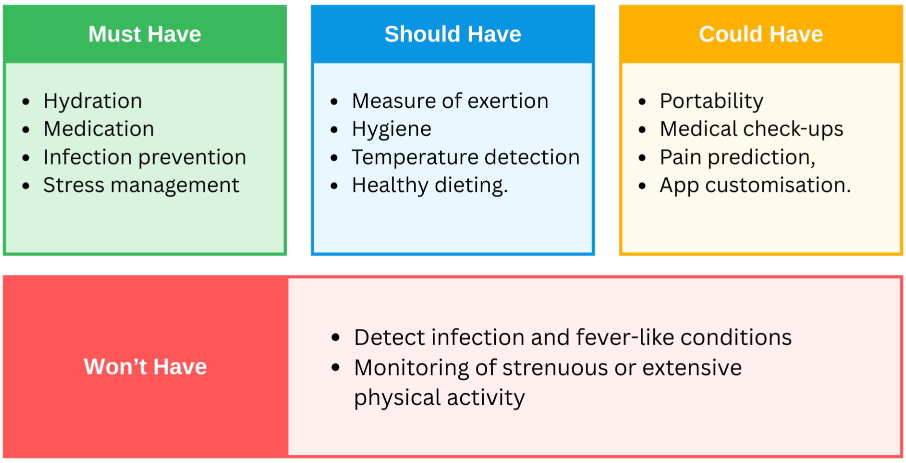

Figure 1: The MoSCoW Prioritisation Exercise

Must Have: Hydration, medication, infection prevention, stress management.
These features are non-negotiable and link directly to symptom triggers

Should Have: Measure of exertion, hygiene, temperature detection, healthy dieting.
Such features improve adherence and long-term outcomes, which are important, yet not critical.

Could Have: Portability, medical check-ups, pain prediction, app customisation.
Nice to have features to improve system intelligence personalization.

Won’t Get: Detect infection, Monitoring of strenuous or extensive physical activity, considered unsafe or impractical.
Acts as an acknowledgement of design constraints, and safety boundaries.

At this stage, the challenge still seemed too broad. The MoSCoW aided in prioritizing needs, narrow scope and focus only on essential daily habits. The analysis helped translate prophylactic measures to tangible user-friendly solution, and also clarified that over-designing can be avoided. However, the method fell short in explaining why such “needs” emerged or how they were interconnected. To address this, a Problem Tree analysis was planned to map the causal relationships between triggers, the symptoms and daily life.

3.4 The Problem Tree

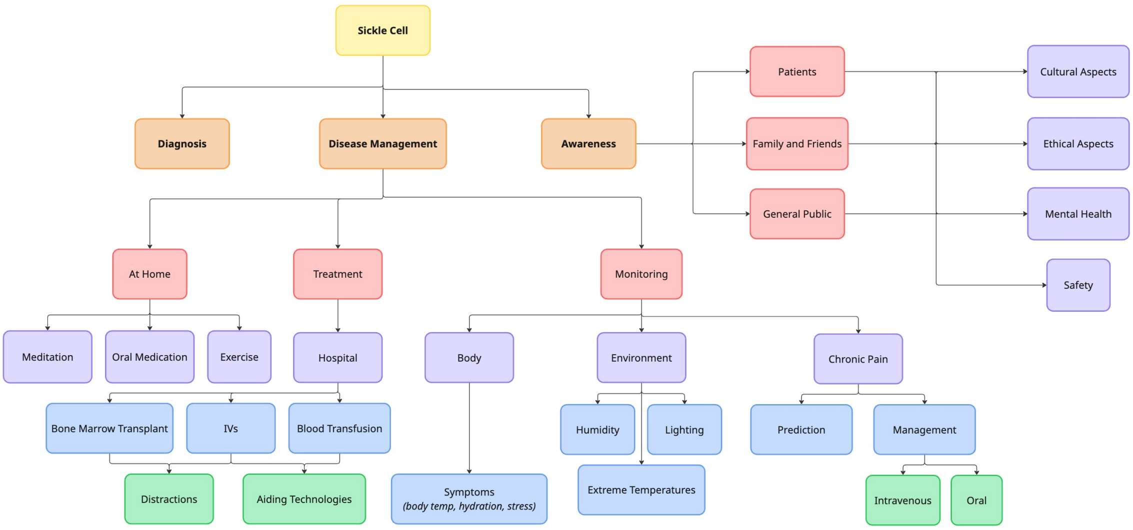

Figure 2: The Problem Tree Exercise

The Problem Tree (Figure 2) is a tool to clarify the hierarchy of problems addressed by the team within a design project; it represents high level problems or related sublevel problems. The design process progressed from the MoSCoW method to a Problem Tree analysis, to better structure the root causes, core problems, and their consequences. While MoSCoW presented a flat hierarchy of features, the Problem Tree enabled a more holistic framing of the issue, and the context where different actors, triggers and symptoms are linked. This phase was initiated by mapping out the broader context of Sickle Cell Disease under the following core themes:

- **Awareness**: Targeting awareness among patients, families, and the general public.
- **Disease Management**: Split into home-care, treatment at hospital and monitoring (body, environment & chronic pain).
- **Diagnosis**: This theme was not given priority since the essence of this project was 'Prevention and Homecare'. By doing this, the team steered away from a more technical and medical solution, which was not the focus.

By analysing the findings from the MoSCoW prioritisation alongside the causal relationships in the Problem Tree, **five habits** were recognised as essential to managing adolescent sickle cell disease:

- Hydration
- Infection prevention
- Moderate exercise
- Medication adherence
- Healthy dieting

These habits were either prioritised directly in the MoSCoW Method (e.g., hydration, medication as "Must Haves") or linked indirectly through other outcomes in the Problem Tree (e.g., diet and exercise aiding pain management and stress reduction). The Problem Tree revealed that these habits target key triggers such as dehydration, extreme temperatures, and infections, while providing adolescents with practical routines to manage their condition more effectively. Consequently, these five habits were selected as thematic pillars for the design study, to allow generation of concepts that balance novelty with practical behavioural change and preventive care.

3.5 User Persona

To better understand the needs of our users, a persona named Noah was created: a 14-year-old living with sickle cell disease. His story reflects common challenges faced by teens, such as balancing health with school, wanting more independence, and dealing with fatigue and social pressure. Noah's frustrations aided in defining the value of subtle, supportive solutions that fit naturally into daily life. The persona also helped evaluate and understand the most relevant habits to address. More details about Noah's persona and scenario can be found in Appendix B.

4 Design Study

4.1 Framework

When designing for specific user groups, it is important to collaborate with the users through co-design sessions and field studies. However, due to the limitations of designing closely to sickle cell users, the team decided to involve other designers in the design study instead. The aim of the study aim was to generate at least 5 different concepts, each specifically targeting a healthy habit (frequent hydration; medication administration; infection control and prevention; healthy dieting; moderate exercise) recommended for people with sickle cell disease.

4.2 C-Sketch

The chosen method for the study was **collaborative sketching**, shortly known as C-Sketch. This method is an extension of the 6-3-5 method that involves 6 designers developing 3 concepts through 5 stages. During the activity the participants were free to add to, modify or delete from the other designers' ideas. However, instead of describing ideas through text in the 6-3-5 method, during a C-Sketch activity designers focus on creating graphical representations (Shah et al., 2001). This method was the preferred option as the outcomes are proved to be more effective over discussions or written texts focused sessions, as sketches can spark more design ideas even if misinterpreted (Shah et al., 2001).

4.3 Organisation

Participants: For the design study, 5 master-level students from the University of Twente were needed to participate. To diversify the group as a mean of uncovering new ideas from different perspectives, participants with different study backgrounds were chosen: 2 Interaction Technology students; 1 Industrial Design Engineering student (with a Mechanical Engineering background); 1 Embedded Systems student; and 1 Communications Science student.

Materials: PPT presentation, video about sickle cell, sketching paper (size A3) including guiding materials (Figure 3), sketching tools (markers, pens), post-it notes, snacks and drinks.

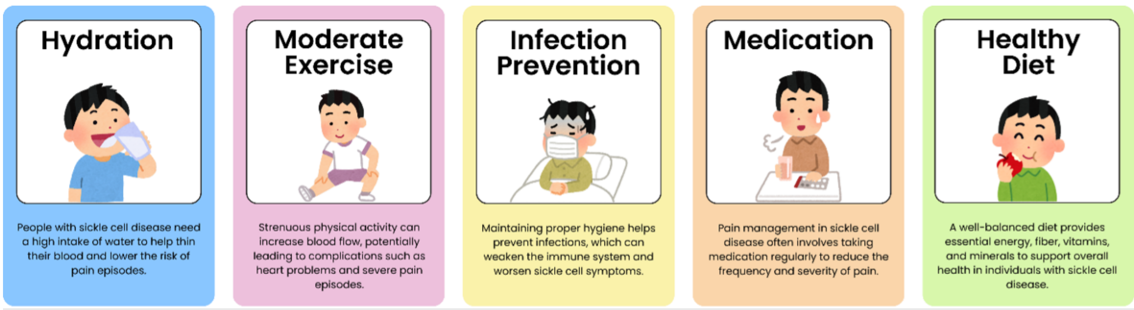

Figure 3: Guiding cards used during the design study, each representing a healthy habit.

Roles: To ensure an organised and productive session, roles were assigned to each researcher (Daniel – facilitator; Daniela – assistant; Elna – note taker; Anushka – timekeeper; Adarsh – photo/videographer).

Ethics: No personal information of the participants was disclosed to be used in the study. The only information used for further ideation and analysis were the sketch results. Each student was sent a consent form in advance, which they could sign at the beginning of the activity. The template for the consent form can be found in Appendix C.

4.4 Planning

The allocated time for the activity was around 1 hour and 30 minutes, starting at 10:45 until lunchtime. The room "Play" in DesignLab was booked for hosting the activity, that is equipped with a round table, chairs and a screen. Additionally, a schedule was made to organize the activity (Table 3).

4.5 Design Activity

The design study was hosted on March 26, 2025, in the room "Play" at DesignLab, University of Twente, as planned. It started at 10:50 and concluded at 12:35. Around 10 students were invited to be part of the study, from which 5 agreed to participate. All the participants were present during the study and agreed to sign the consent forms. The facilitator then introduced the design challenge (Figure 4) through a PPT presentation and shared a video about sickle cell disease, after which he encouraged the icebreaker activity. All the participants were enthusiastic and bonded quickly, successfully concluding the activity. The C-Sketch activity (Figure 4) followed, split into two shorter sessions, lasting 15 minutes and 20 minutes respectively, with a 10-minute break in between. It was noticed that as the activity progressed, the participants had more ideas and inspiration drawn from the previous sketches.

Figure 4: Photographs taken during the C-Sketch activity

At the end of the C-Sketch activity, participants handed in the sketches, which were photographed and shared on the screen for the discussion section of the study. During the discussion, the participants explained their ideas and shared more suggestions, which led to a productive discussion session (Figure 5).

Figure 5: Photographs taken during the discussion

Duration	Activity	Method	Aim	Description	Recording	Materials
5 mins	Welcoming & Documentation	–	Welcoming the participants and getting the consent forms signed	Welcoming participants in the room, offering them a seat, snacks/drinks and consent forms	–	Consent forms, pens, drinks and snacks
10 mins	Introduction	–	Familiarizing the participants with the challenge and aim of the study	The facilitator gives an introduction presentation and shows a video about sickle cell disease, explaining the scope of the design study, the expectations and methods	Notes, photo and video recording	Screen, PPT presentation, sickle cell video
10 mins	Icebreaker	Truth or Lie	Creating a more comfortable environment	Participants say their name, study, and one fact. Others guess if it's true or a lie.	–	–
15 mins	Design Activity	C-Sketch	Generating ideas and concepts based on the habit cards provided	2 rounds: 5 mins each, sketches passed to next participants	Notes, photo and video recording	Paper, markers, pens, post-it notes
10 mins	Break	–	Resting, eating and refreshing mind	–	–	Snacks and drinks
20 mins	Design Activity	C-Sketch	Generating ideas and concepts based on the habit cards provided	3 rounds: 5 mins each, sketches passed to next participants	Notes, photo and video recording	Paper, markers, pens, post-it notes
15 mins	Discussion	Open discussion	Understanding and comparing ideas, discussing the feasibility	Discussing results by habit, projecting sketches on the screen	Notes, photo and video recording	Screen, sketches
5 mins	Closing	–	Thanking for the contribution	Concluding the activity and thanking the participants, asking for feedback	–	Snacks and drinks

Table 3: Design study activity schedule and description

5 Results

The aforementioned habits became the basis for the design round, resulting in a variety of ideas. The subsections hereunder highlight some of the interesting outcomes from the design study, illustrated in Figure 6. The full C-Sketch outputs for each habit can be seen in more detail in Appendix D.1. Reflection regarding the discussion held at the end of this same study and some of the constraints and challenges faced are also presented. Finally, a final subchapter highlights how these ideas were thematically coded.

5.1 Design Study Outcomes

Participants generated layered sketches that evolved collaboratively over multiple rounds. Their designs encompassed a range of tangible and digital solutions addressing behavioural reinforcement, sensory interaction, and technological augmentation. A few key examples across the five habits are described in this section. Cutouts of the most interesting ideas can also be seen in Appendix D.1.

Hydration One particular idea was a Product-Service System (PSS) integrating a water bottle, smartwatch, and mobile phone to provide hydration reminders, goal tracking, and insights. A second design worth mentioning explored the relationship between hydration and access to clean restrooms by including a self-cleaning toilet to mitigate any hesitations regarding hygiene. Another participant proposed a speculative idea inspired by *Dune*, the movie series, whereby moisture secreted from the body would be recycled back through the nose. This later prompted a reflection on extreme (and visible) solutions and stigma.

Moderate Exercise Most ideas focused on motivation gained through community as well as gamified exercise. One concept featured a smartwatch and app system that allowed users to monitor their heart rate and receive alerts when it exceeded safe limits. The app also allowed sharing experiences and progress with peers, promoting social accountability. Other participants suggested lower-strain activities like yoga or tai chi. Group classes and a sense of inclusion were highlighted as ways to prevent isolation while maintaining healthy routines. An idea like *Strava*, the running app, but for sickle cell patients was also suggested as it fosters a common understanding.

Infection Prevention A spectrum of proposals was sketched, including ultraviolet (UV)/black light tools to visualise bacteria on surfaces, as well as a portable water bottle that sterilises the water using similar technology. There was also a concept for a device with environmental sensors to detect air quality and another to disinfect other devices such as a phone or smartwatch. A mirror that provides visual feedback on whether handwashing was done correctly was proposed. One speculative idea took inspiration from blood-glucose finger-prick devices, but instead to check antibody levels so as to gauge the level of immunity before entering potentially risky environments.

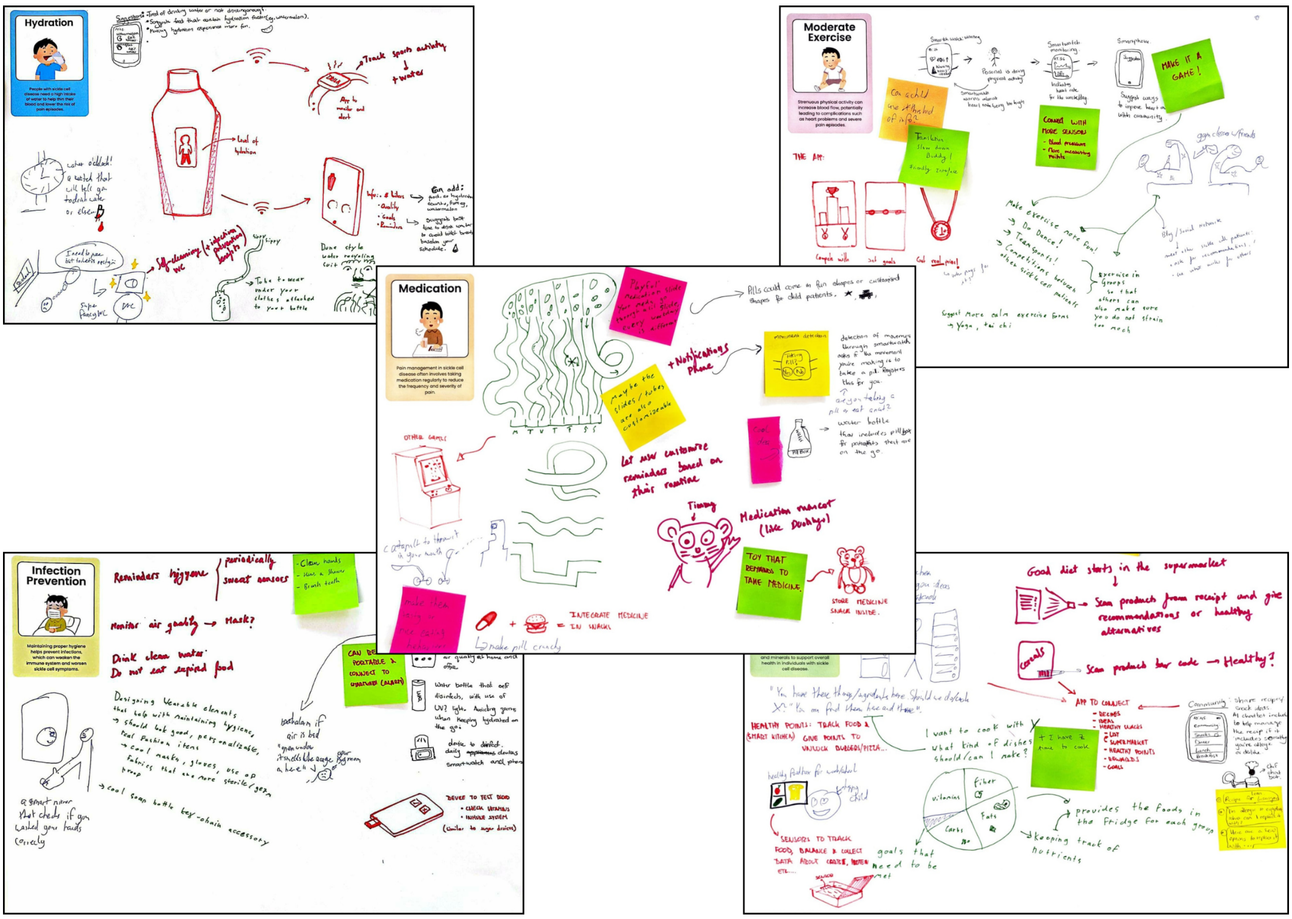

Figure 6: C-Sketch outputs for each habit

Medication Most ideas for this habit revolved around gamification and anthropomorphism. Concepts included an arcade-style pill dispenser where tubes are manually activated to dispense medication in a playful way. Another sketch was inspired from *Duolingo* and included a toy or a mascot to appeal to the target group, storing pills and snacks and reminds the user to take their medicine. A smartwatch interface that detected gestures analogous to taking a pill, and logs the result, was proposed. There was also interest in customising the shape of pills or integrating medication into food to reduce the psychological barrier of taking the medicine. A concept of a water bottle housing a pill box at the bottom was also suggested.

Healthy Diet This habit generated the most complex and multi-layered ideas. Sketches proposed a smart kitchen system with voice-to-text input, embedded artificial intelligence (AI), and inventory tracking that suggests meals based on current ingredients and user health data. A gamified system offered reward points based on healthy choices, with community features for recipe sharing and challenges, with a smart chat bot for help. A smart lunchbox was imagined to monitor meal content and nutritional intake throughout the day. Barcode scanners at grocery stores could suggest better alternatives or recipes suited to the user's condition.

5.2 Thematic Coding

Following the design session, results were analysed and the process of coding them into themes was started. This was done by means of a Miro board which can also be found in Appendix D.2. The **inductive thematic coding** method was deliberately chosen. This choice allowed the themes to emerge naturally from the results of the study, rather than being constrained by pre-conceived categories. The themes were derived through affinity mapping and cross-comparison of features across concepts. The final themes are outlined below, with select sub-themes. Table 4 and Figure 7 illustrate the themes and sub-themes, and their relationships between them, highlighting inter-dependencies. A more in-depth explanation of each link between themes and sub-themes can also be found in Appendix D.3.

Theme	**Description**	**Example Concepts**
Gamification	Use of game mechanics to increase engagement.	Reward systems, arcade dispensers, interactive goals
— *Competition*	Sub-theme: driving motivation through peer comparison and contests.	Leaderboards, challenges, fitness goals
Community	Leveraging social networks and shared experiences.	Peer challenges, recipe sharing, group workouts
— *Competition*	Sub-theme: fostering motivation via group or peer dynamics.	Exercise in groups, competitive goal tracking
Smartification	Embedding intelligence and sensors into everyday objects.	Smart bottles, AI fridges, biometric devices
— *Sensing*	Sub-theme: context-aware or physiological sensing.	Sweat sensors, UV detection, heart rate monitors
Anthropomorphism	Giving human-like traits to tech to increase relatability and compliance.	Mascots, toys, playful interfaces
Cognitive Offload	Shifting mental effort to the system.	Automated tracking, reminders, AI meal planning

Table 4: Themes, sub-themes, and associated concept examples

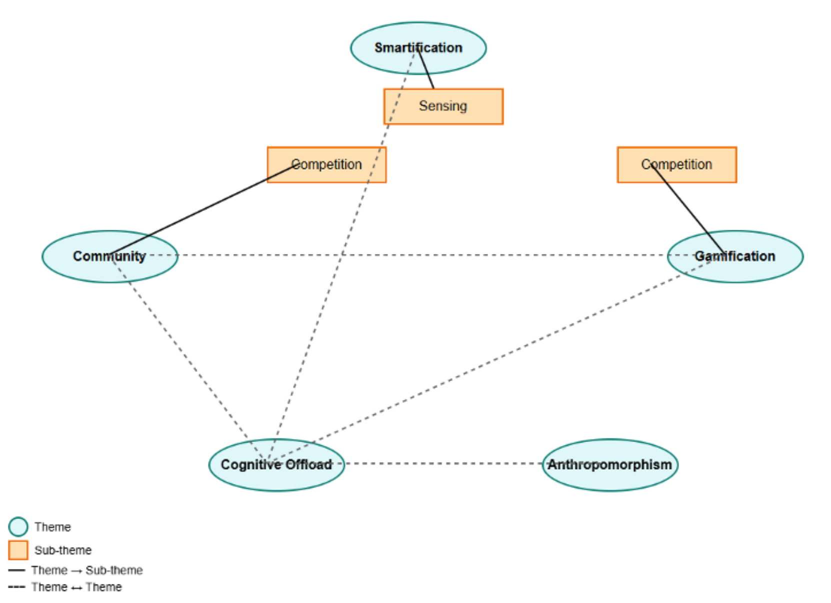

Figure 7: Thematic coding relationship diagram

5.3 Synthesis of Insights

The themes formulated show a focus on solutions that are playful, supportive, and context-aware. Gamification was the most prominent motivator, especially when tied to community interaction. Smartification, especially through sensing, supported monitoring unobtrusively, while anthropomorphism and cognitive offload aided in the formation of positive habits.

These findings provided a foundation for the next stage of development, where the most promising features from each theme will be considered, and possibly utilised and combined into new or adapted concept proposals.

5.4 Concepts Proposed

Based on the findings from the thematic coding of the design study results, three ideas emerged which tackled various habits and their regulation (Figure 8 and Appendix E). The following section discusses the initial designs, the concepts behind them and the final solution that was chosen.

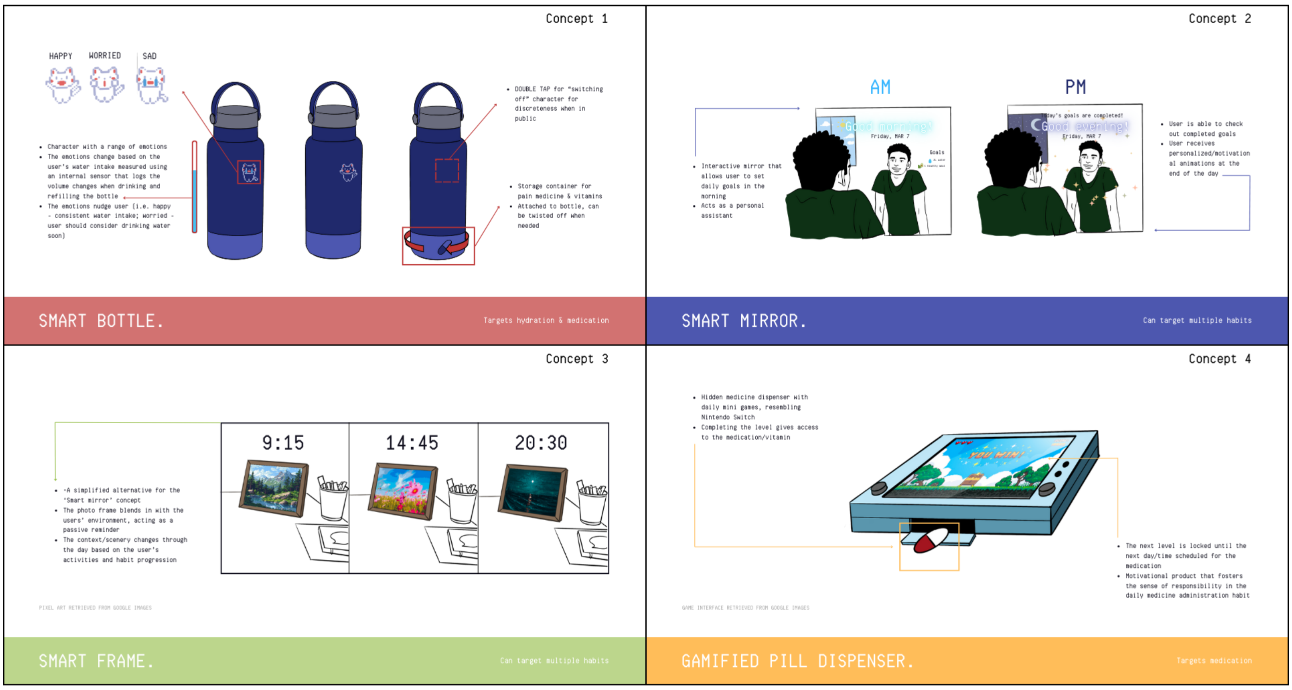

Figure 8: Conceptual directions

1. Smart Bottle Based on the results of the design study, as well as the need for making hydration feel less tedious, the concept of a smart bottle was developed. The bottle would have sensors that detect the water levels remaining in the bottle to assess the user's water intake for the day. It would also have a storage section at the bottom for the user's medication, so that they can have it on the go and handy with the water. The design, therefore, aims to design for the habits of hydration and medication.
The smart feature of the bottle would be incorporated in the form of a screen which would depict a virtual friend. The friend could also serve as a mascot for the bottle, similarly to *Duo*, the owl mascot of the language learning app *Duolingo*. The friend would then act as a guide for depicting how hydrated a user is, i.e., depending on how well hydrated the user is, the mascot's mood changes. As a result, the mascot's mood would nudge the user to drink more water. For a more in-depth analysis of the users' water intake, an accompanying app could also be created that could connect to the bottle as needed. As such, the themes of anthropomorphism, smartification and cognitive offload are applied here to create an appropriate solution.

2. Smart Mirror/Frame The concept of a smart mirror aims to keep track of whether a habit was completed for the day or not. In the morning, the users would set their habit goals or tasks for the day using the smart mirror and its screen. This would ideally be done as part of the users' morning routines. In the evening, the users can then log if they completed the tasks or have a look at the remaining ones. Ultimately, the mirror would display the progress through visually appealing images such as blooming flowers, pulses of colour, or congratulatory messages, depending on their personal preference. This would help the users reflect on their day and remind them to complete any unfinished tasks. Here, the themes of smartification and cognitive offload are applied to help aid the users. However, the concept of a smart mirror may feel overwhelming or distracting for users in their day-to-day life.
Thus, the idea was simplified to a smart frame, which the users can keep on their desks. Its small form factor would allow for a more discrete user experience without taking away any of the necessary functionalities.

3. Gamified Pill Dispenser As suggested by the name, a gamified pill dispenser would target the habit of medication for the users. It would be a simple box with a screen on it and a lockable storage compartment on the inside for medication. The screen would have daily games which lead a character, that the users control, through challenges in a quest. Winning daily games would allow the users to then open the pill box and take the medicine. Moreover, when the medication is dispensed, the users' character would undergo an upgrade, allowing the users to move forward in the game's quest. In this concept, the themes of gamification and smartification are applied to make an otherwise tiresome task more engaging.

5.5 Final Solution

In the end, a combination of the concepts of the smart bottle and the smart frame were integrated to create the final solution (Figure 9) . The smart bottle, with its embedded sensors, would allow the users to measure their water intake as they go about their day. The bottle would have a screen which would depict a virtual avatar, Finneas, who is a friendly fish that accompanies the users throughout the day. With his changing moods and human-like facial expressions, the fish would remind the users to keep drinking water. The smart frame would serve as a fish tank and home for Finneas, the fish avatar. In the beginning of the day, the frame would depict a barren tank for the fish, with barely any water in the tank. As the users drink more water through the day, the smart frame would subsequently add more water and more environmental details to the tank. Once the users head home, Finneas, who would be with them on their bottles during the day, would appear on the frame instead. As the users continue using the products, more details, such as castles and vegetation, would be added to the smart frame to create a livelier atmosphere for Finneas.

It is clear here that the themes of smartification, gamification and anthropomorphism were synthesised to create a feasible solution. The embedding of sensors in the bottle as well as the interactive display of the frame transform the respective objects into smart devices, and as such apply the theme of smartification. Similarly, the fish avatar, Finneas, allows for the themes of gamification and anthropomorphism to shine through. Finneas and his fish tank in the smart frame would incentivise the users to be well hydrated. This approach is similar to the design of the *Sugargotchi*, a digital pet created to promote dental health in children by encouraging behaviour change through similar themes. Like Finneas, the *Sugargotchi* reflects the user's health through emotional expressions and visual feedback, fostering an emotional bond that motivates positive habits (Gray et al., 2020). Finneas, with his friendly disposition and expressive personality, would get sad if a user is not hydrated enough and his tank would remain barren and have scarcely any water in it. Only the consistent drinking of the user would enable the tank to fill up and for Finneas to be happy and thriving. The focus here is not solely about the volume drank by the user over a daily period, but rather the number of times, which aids in the uptake of the positive habit.

The final solution solely focuses on the habit of hydration. This was an intentional decision as any solution that aimed to tackle all the selected habits became too cumbersome and overwhelming as a product. The chosen solution hones in on one habit which has a big impact on the presence of symptoms. It aims to provide a simple and efficient system with an engaging experience to create more stimulation to an often-overlooked activity. In the future, more products could be designed to target the remaining habits and create an ecosystem of smart devices, all together tasked with aiding in the management of the disease.

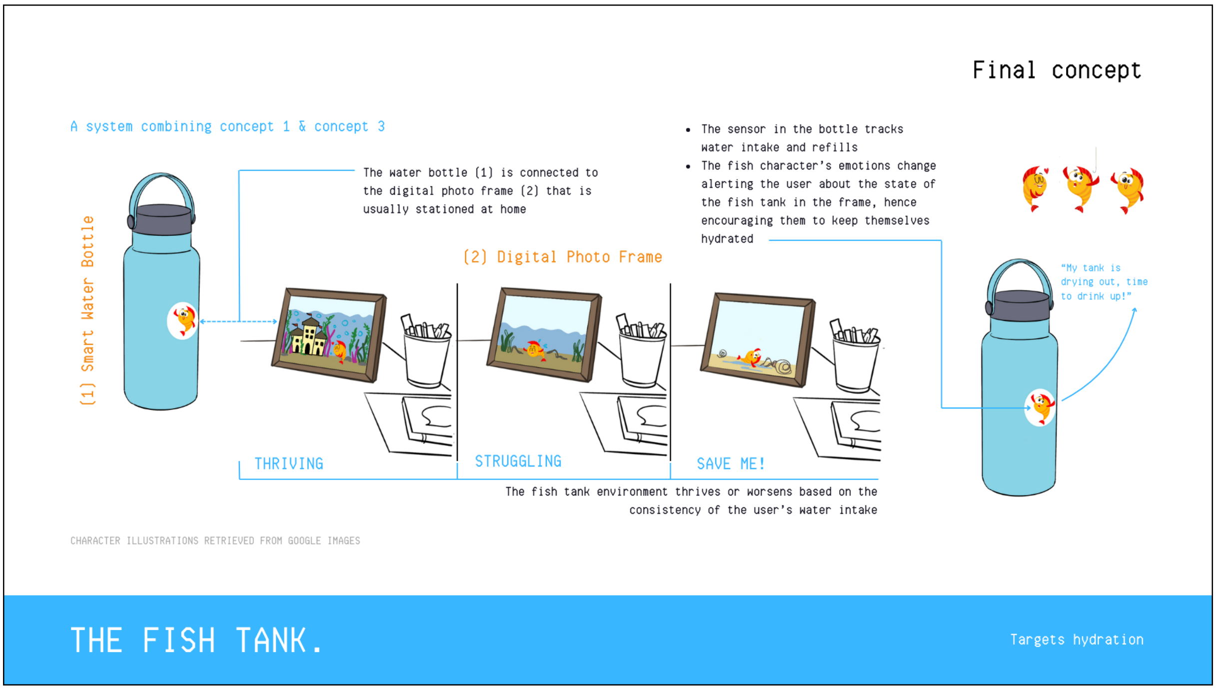

Figure 9: The final concept

6 Evaluation

An evaluation plan to test the final product was designed; referring back to the UX and UI goals, the use context and the target user of the product.

6.1 Case-based evaluation

To test the usability of the final system two cases were used to compare to a control. A case-based evaluation was used to test whether the full product system increases water intake compared to the current solution of a water bottle. In addition, it would help determine if there is a difference in water intake between the smart bottle and the combination of the smart bottle and the smart frame.

Cases The control is defined as an everyday water bottle to drink water. Case 1 will be defined as the smart water bottle. Participants will use the smart water bottle during the evaluation phase. Case 2 is defined as the smart water bottle in combination with the smart frame.

6.2 Evaluation research questions

Research Questions The following research questions were used to determine the usability and the user experience of the two study cases:

1. Is there a difference in water intake between the two cases?
   This will be measured by recording the number of bottles consumed.
2. Is there a difference in user experience between the control and the two use cases?
   This will be measured using a User Experience Questionnaire (UEQ), video recordings and observations.
3. Is there a difference in system usability between the two use cases?
   This will be measured using a System Usability Scale (SUS) and number of errors made during testing.

Materials: Questionnaires, diaries, recording device, notepad, water bottles, smart bottles and smart frames.

6.3 Participants

The goal is to have a variety of ages and genders in the participant pool. The study will make use of 24 participants, 12 male and 12 female. The participants should be aged between 12 and 18. Participants will be recruited through emails to parents in healthcare institutions. At least one parent should be present for ALL participants. Participants should fill in an informed consent form together with their guardians as well as any questionnaires.

6.4 Procedure

Duration: 9 weeks

During the first two weeks of the evaluation, all participants should receive a water bottle and a diary. Using the provided diary, they will record the number of bottles of water consumed during the period. After two weeks, the participants hand in their diaries. The usability of the system will be tested in the next two weeks. The participants will be tasked with setting up the system and interpreting the different possible fish animations. During these tests, recordings and observations will be taken to take note of any errors in interpretation. The participants are then divided into two groups for the different use cases during the next two weeks of the evaluation. Both groups should have the same gender and age distribution.

Case 1 participants will be given the smart bottle. Case 2 participants will be given the smart bottle and frame. The sensors in the bottles will be used to keep count of water intake. Both groups will take the products home. During the last week of the evaluation, the participants from both groups will fill in the System Usablity Scale (SUS) and User Experience Questionnare (UEQ) forms provided (see Appendix F). Results from the questionnaires are used for evaluation of the cases.

6.5 Expected results

1. Diary entries of water intake;
2. Questionnaires;
3. Video recordings and observation notes.

The number of errors made in animation interpretation and setting up system will be used to evaluate usability. Comparison using the number of bottles, the usability score and the UX score will be used to determine if the final product makes a difference in water intake. The video recording and observation notes taken will be used to determine the emotional response to the animations on the bottle and frame.

6.6 Limitations

Due to the age range of the participants, video recordings cannot be used in their day-to-day life without supervision. Emotional response of the product can only be tested in a controlled environment. Manual entry of water intake can skew the results due to human error such as forgetting to enter data.

7 Discussion

7.1 Design Study: Reflections

At the end of the sketching activity, a discussion was held to perhaps clarify some of the ideas as well as to gain more insight into the perspective of the participants on the ideas sketched by themselves or the other participants. Most of the discussion revolved around feasibility in implementation.

For **hydration** a concern was raised regarding the personalised water bottle, which might make adolescents feel singled out due to their medical condition. This prompted a conversation around whether such assistive products should be designed to be discreet. Regarding **moderate exercise**, enthusiasm was shown with respect to community-centred, social and competitive elements in most ideas, while concern was also expressed regarding overexertion. Hence, suggestions for safe, guided activities were identified to be of utmost value. For **infection prevention**, some participants questioned whether a hyper-sterile environment might be counterproductive or socially isolating. There was also discussion around the appropriateness and usability of tools like blood-test devices for teenagers. For **medication**, participants raised questions whether the incorporation of toys and games would result in long-term effectiveness. Integrating medication into food or drinks prompted ethical questions about autonomy and consent. For **healthy diet**, most participants appreciated the smart kitchen idea, while others noted it could reduce conscious decision-making. On the other hand, some felt that smart features might empower users to become more autonomous, especially when leveraging it to learn healthy habits.

7.2 Design Constraints and Challenges

While the study produced many creative outputs, several limitations and challenges were noted. Designing for 12 — 18-year-olds presented difficulties in finding a balance between autonomy and guidance. Some solutions leaned too heavily into adult intervention whilst others were perhaps overly simplistic for teens. Although participants were encouraged to ideally think of interfaces which were tangible, many ideas defaulted to app-based solutions. This reflected the norm, and highlighted the challenge to avoid burdening the user with additional applications which do not fit into their daily life. Although participants were prompted to try to incorporate the five senses, this was sometimes a challenge to be reflected in the ideas. Some relied on abstract or symbolic gestures rather than sensory experiences. Given the varying background of the participants, some prioritised imaginative ideas (ex: *Dune*-inspired hydration) while others focused on suggesting concepts which were technically feasible. Finally, some participants expressed that they faced challenges to sketch their ideas and therefore used mostly text.

8 Conclusion

Future efforts could explore expanding the hydration-focused solution into a modular ecosystem addressing all key habits. Additional research can focus on longitudinal studies to assess behaviour change over extended periods and across various demographic groups. Moreover, co-designing with actual adolescents who have sickle cell disease could bring forth more nuanced, user-driven insights.

This project shows how interaction design can offer real support to adolescents living with chronic conditions. The solutions which emerged, and particularly the final concept, manages to combine empathy and practical function in a way that feels both accessible and meaningful to its intended users. With its grounding in user-centered design and insights drawn from collaborative ideation, the concept presents a solid base for future development. The assignment was deemed successful in its goal, particularly in reinforcing the theme of prevention and homecare. Much of the project centred around the first three stages of d.school's five-stage design thinking process (empathise, define, and ideate). Empathy proved to be a valuable and influential phase, enabling the team to deeply understand the users' daily challenges and tailor the design accordingly. However, the latter stages of prototype and test would benefit from more dedicated effort in the next phases in the process of fully-realising the concept. This work was underpinned by the broader aim of exploring the interaction between humans and computers in ways that help embed thoughtful, intuitive systems into the lives of those who need them most. As it stands, the project adds to ongoing discussions about how digital tools can contribute to more equitable and engaging healthcare experiences.

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Appendices

A Design Process Timeline

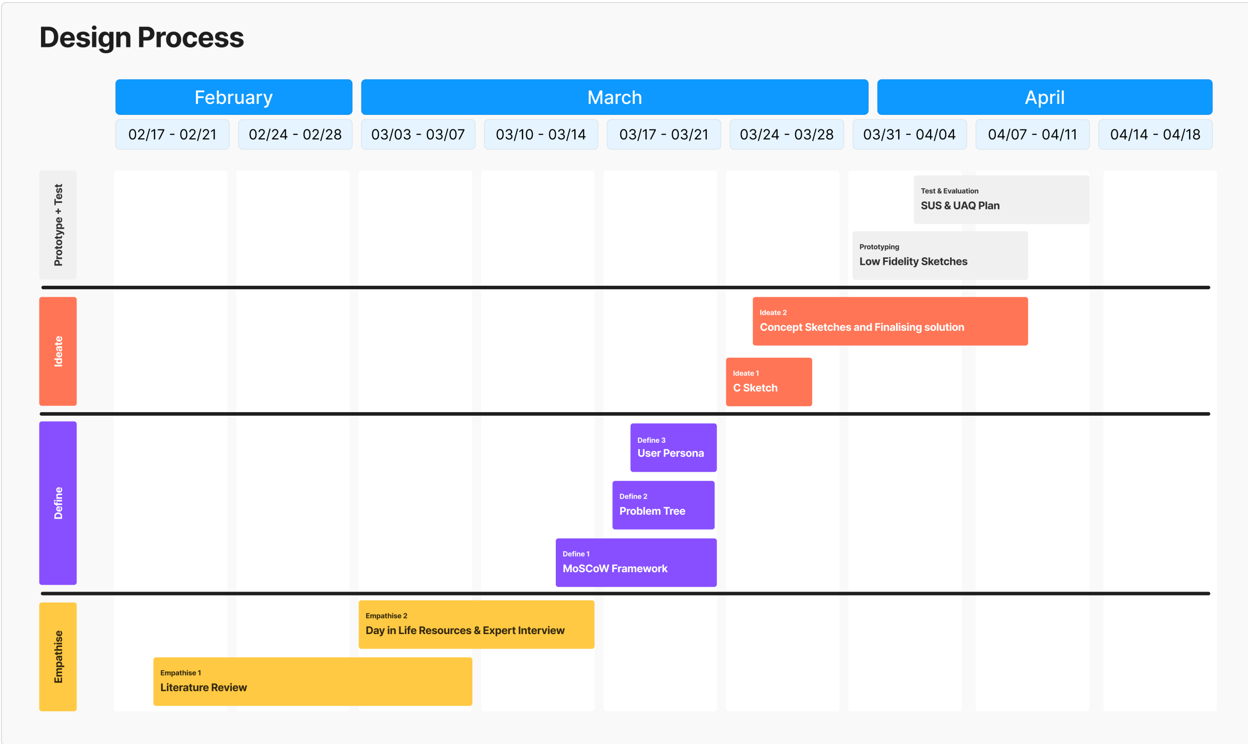


Figure 10: An overview of the design process timeline

B User Persona

Noah Jansen

Age: 14 years old

Occupation: Middle school student (VWO[1] year 2 student)

About:
Noah is a 14-year-old boy living with sickle cell disease. Born and raised in Rotterdam, he has a Dutch father and a Surinamese mother. Despite the challenges of managing his health, Noah is determined to live a normal life and dreams of being a doctor so he can help people going through similar struggles.

Likes 👌

- Playing on his Nintendo Switch, usually when he's recovering from a pain episode
- Playing as the school football team's regular goalkeeper cause a lot of his friends are in the team
- Studying biology to understand his body better

Dislikes ❌

- Cold weather (triggers pain episodes)
- Sitting out of games due to health concerns
- Hospital stays and missing school/friends
- His parents controlling his life too much and treating him like a little kid

Pain points + Frustrations

🔴 Having days where he's totally fine and others where he's exhausted for no reason
🔴 Missing out on fun things because of random pain episodes
🔴 People acting like he's "lazy" when he's actually just exhausted
🔴 Drinking way too much water just to avoid getting sick

Needs + Expectations

✅ More flexibility at school when he's feeling unwell
✅ Friends who don't make a big deal when he needs to sit things out
✅ More breaks during sports practice without feeling like a "quitter"
✅ Less nagging from his parents about his health and condition

[1] Pre-university educational track in the Netherlands, as part of secondary education *(voortgezet onderwijs)* – lasts 6 years

Figure 11: The User Persona

C Consent Form

Consent Form: Participation in Design Project

Introduction

You are invited to participate in a design project as part of the course *Introduction to Human-Computer Interaction (202100208)*. Before agreeing to participate, please carefully review the following information. If you have any questions, feel free to ask the research team.

Purpose of the Study

The purpose of this project is to collect and analyse creative input for use in design-related research and development within the scope of *Introduction to Human-Computer Interaction*.

Voluntary Participation

Your participation in this study is completely voluntary. You may refuse to participate or withdraw at any time without providing a reason and without any negative consequences.

Use of Information

By signing this consent form, you agree that any creative information you share will be utilised as part of the design project. This information may be incorporated into reports, presentations, academic discussions, or other related coursework. Your contributions will be acknowledged appropriately when applicable.

Confidentiality

No personal details will be collected as part of this project. Any creative contributions you provide will remain anonymous and will not be linked to you personally.

Photo Consent

As part of this project, photographs may be taken for documentation and research purposes. All identifiable faces in these photographs will be blurred out to protect anonymity.

Data Retention and Future Use

The information collected will be retained for the duration of the project and may be stored for future academic reference unless you request its removal.

Contact Information

If you have any questions regarding this project or your participation, please contact the course instructor or the research team.

Consent Statement

I have read and understood the above information regarding the design project for *Introduction to Human-Computer Interaction (202100208)*. I understand that my participation is voluntary, and I agree to the terms stated in this consent form.

Participant's Name:	____________________	**Researcher's Name:**	Daniela Iamandii
Email:	____________________	**Email:**	d.iamandii@student.utwente.nl
Signature:	____________________	**Signature:**	____________________
Date:	____________________	**Date:**	____________________

Figure 12: Consent Form used in the Design Study

D Design Study Outcomes

D.1 Concept Sketches by Habit

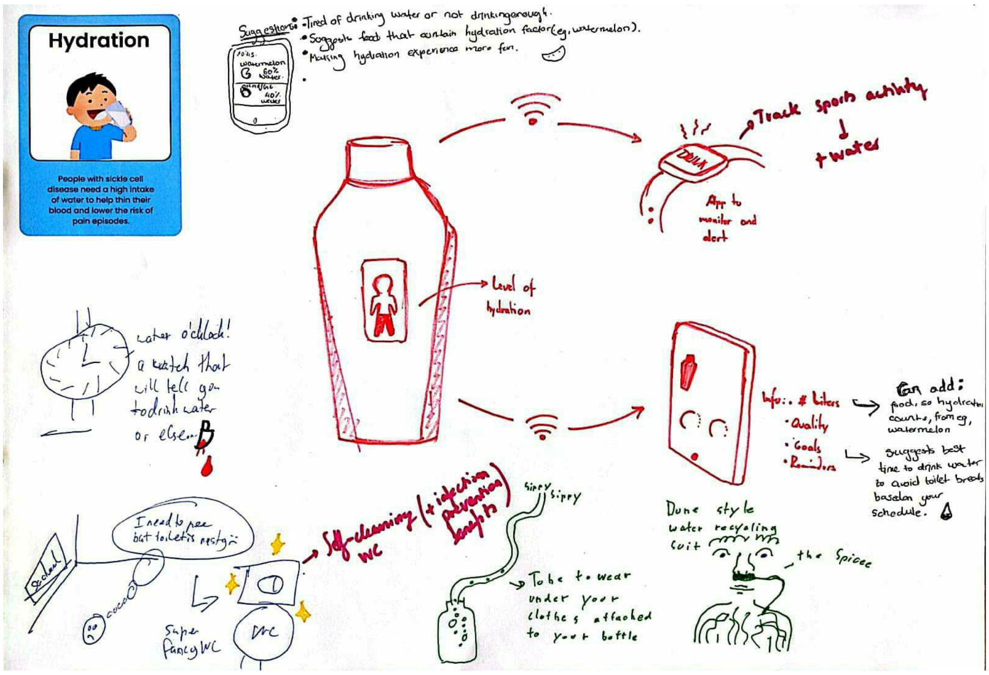


Figure 13: Hydration-related concept sketches

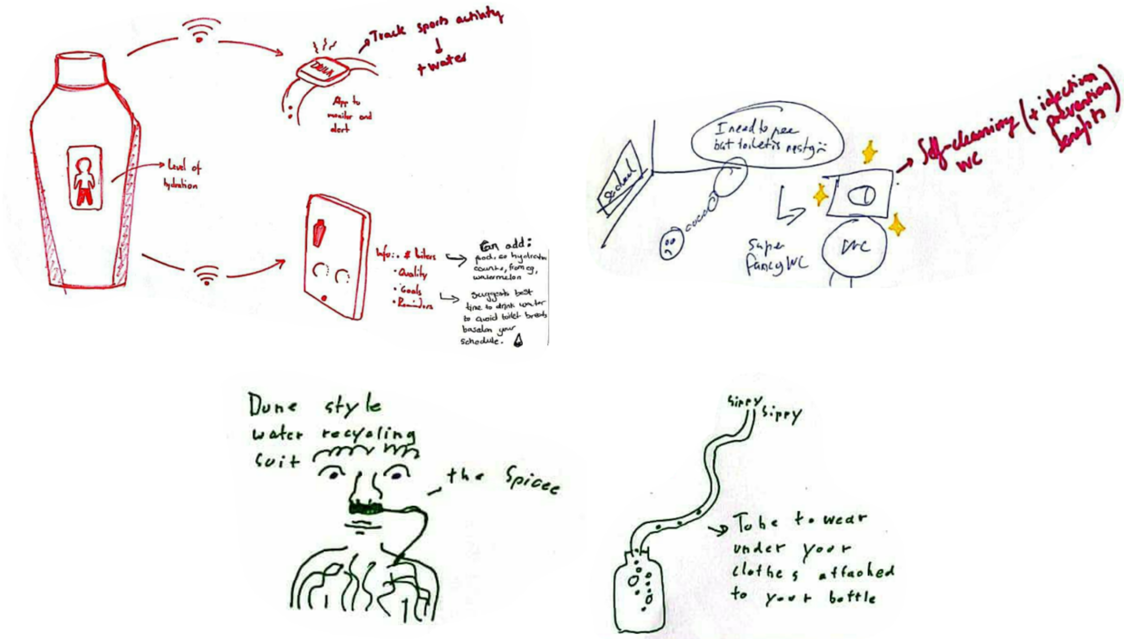


Figure 14: Standout ideas: hydration-related

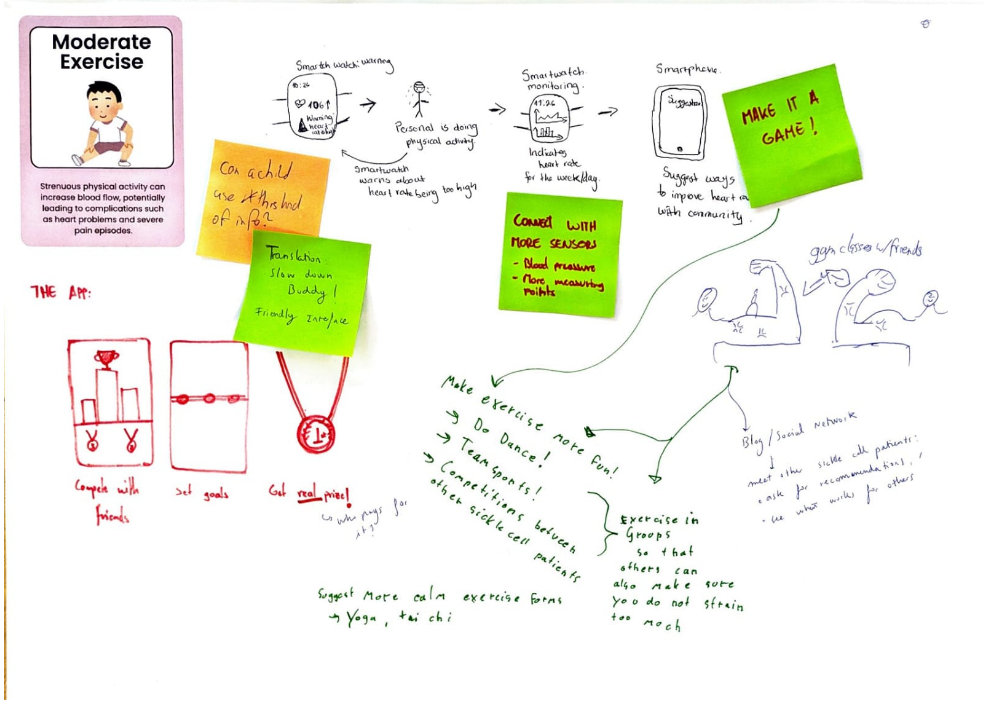


Figure 15: Moderate exercise concept sketches

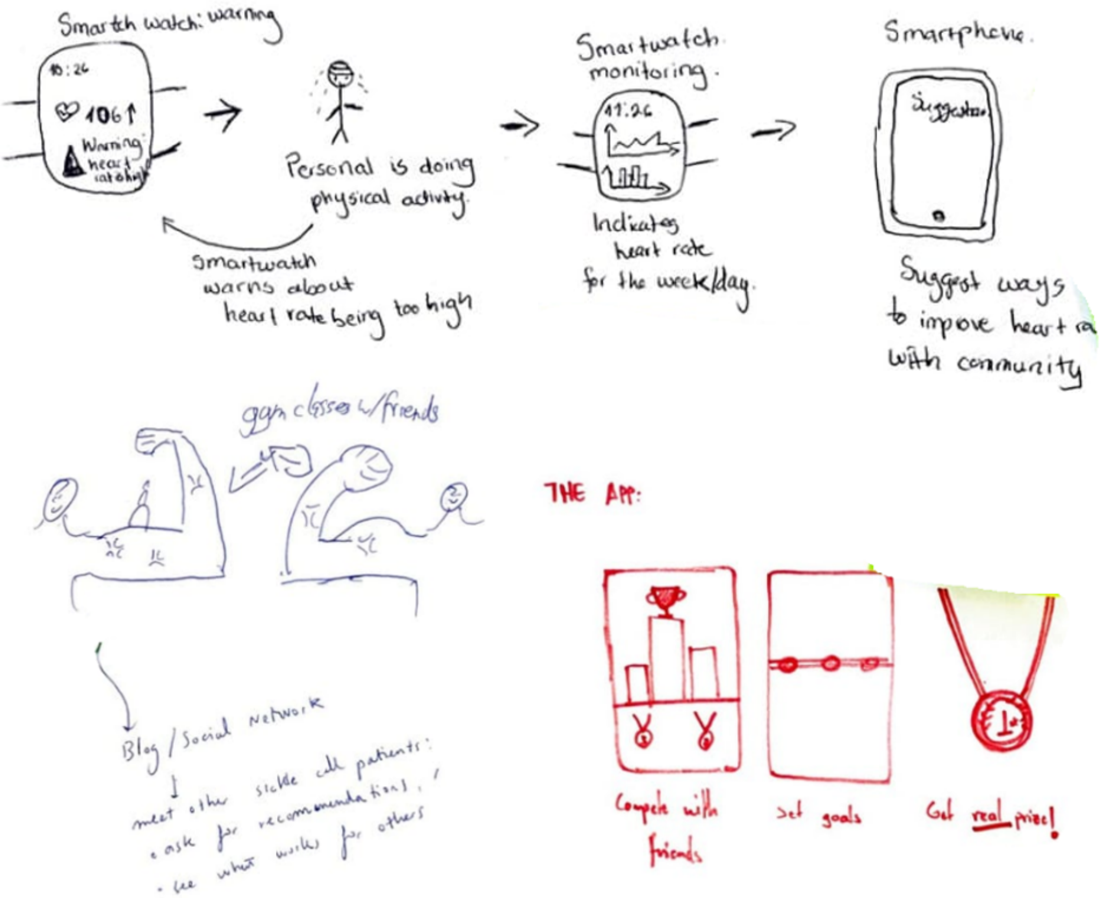


Figure 16: Standout ideas: moderate exercise

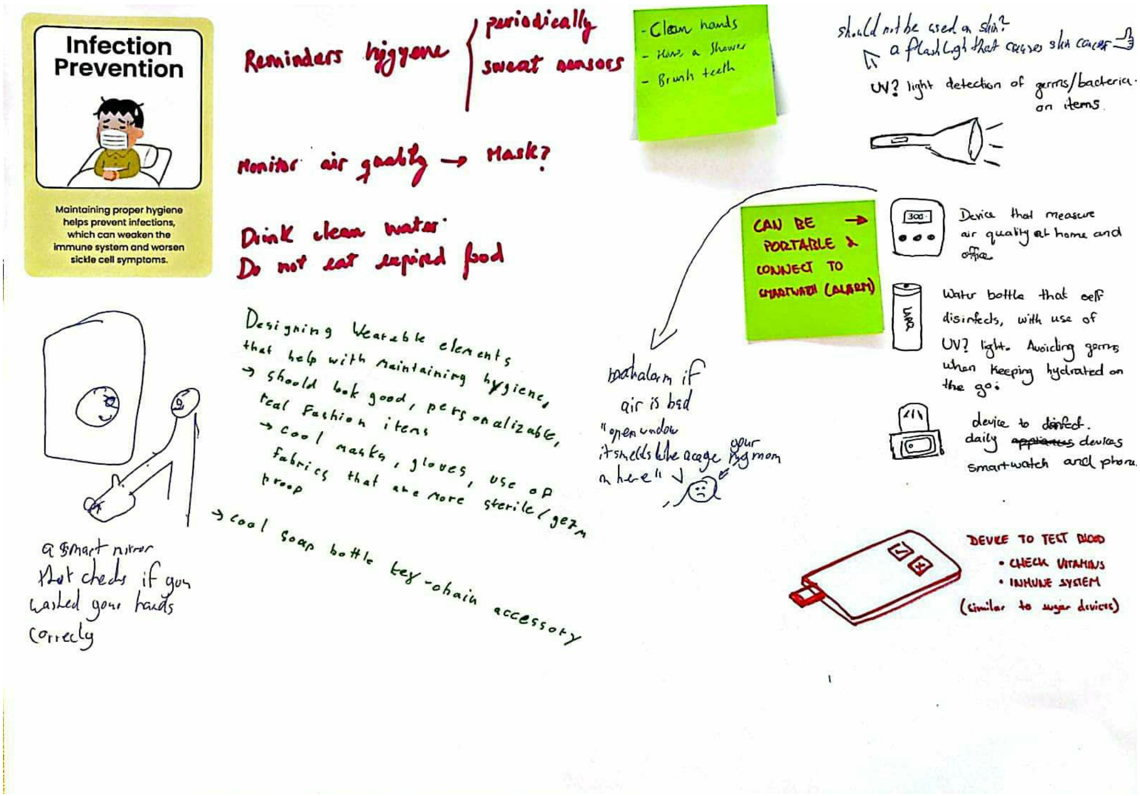


Figure 17: Infection prevention concept sketches

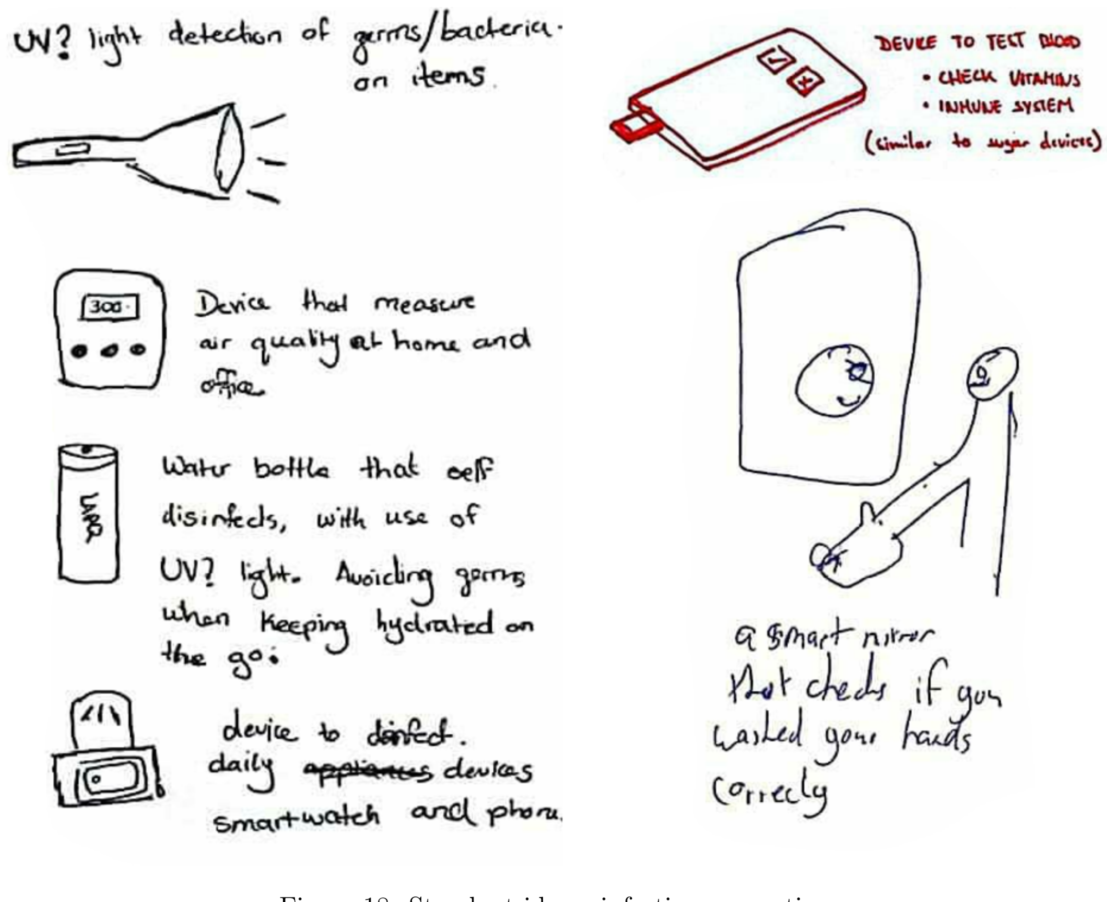


Figure 18: Standout ideas: infection prevention

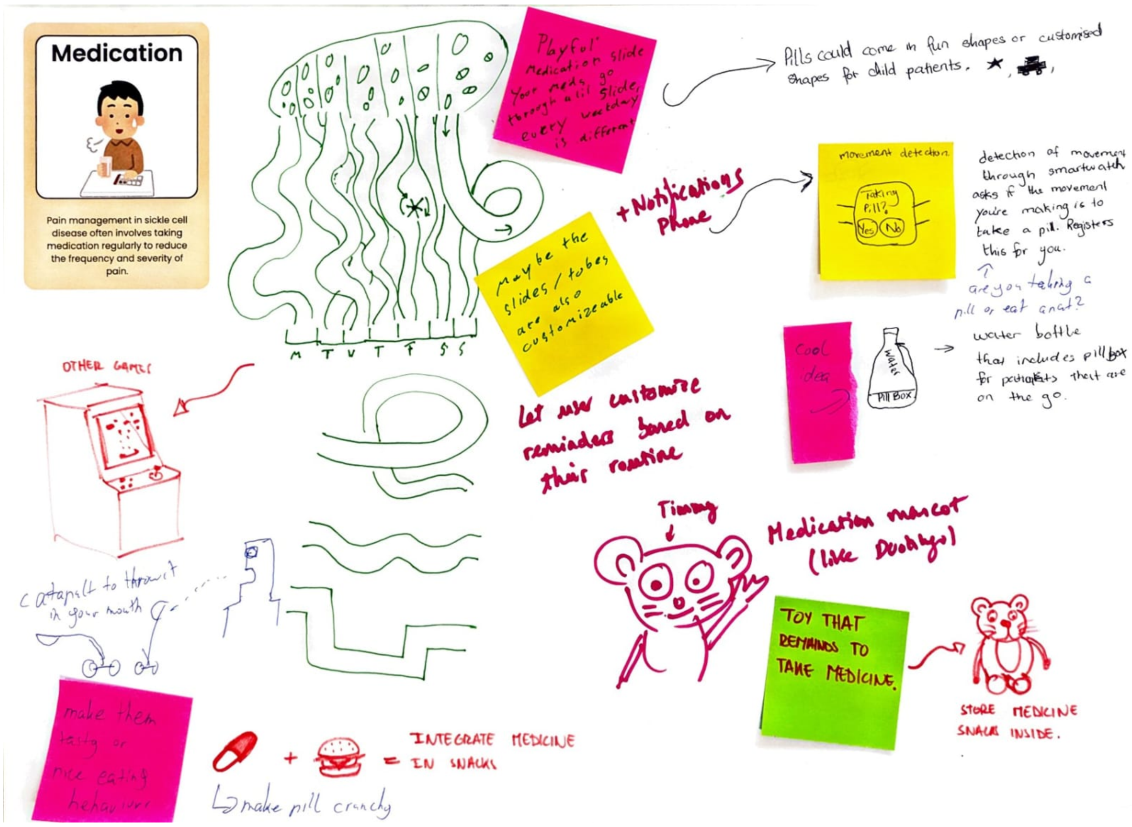


Figure 19: Medication-related concept sketches

Figure 20: Standout ideas: medication-related

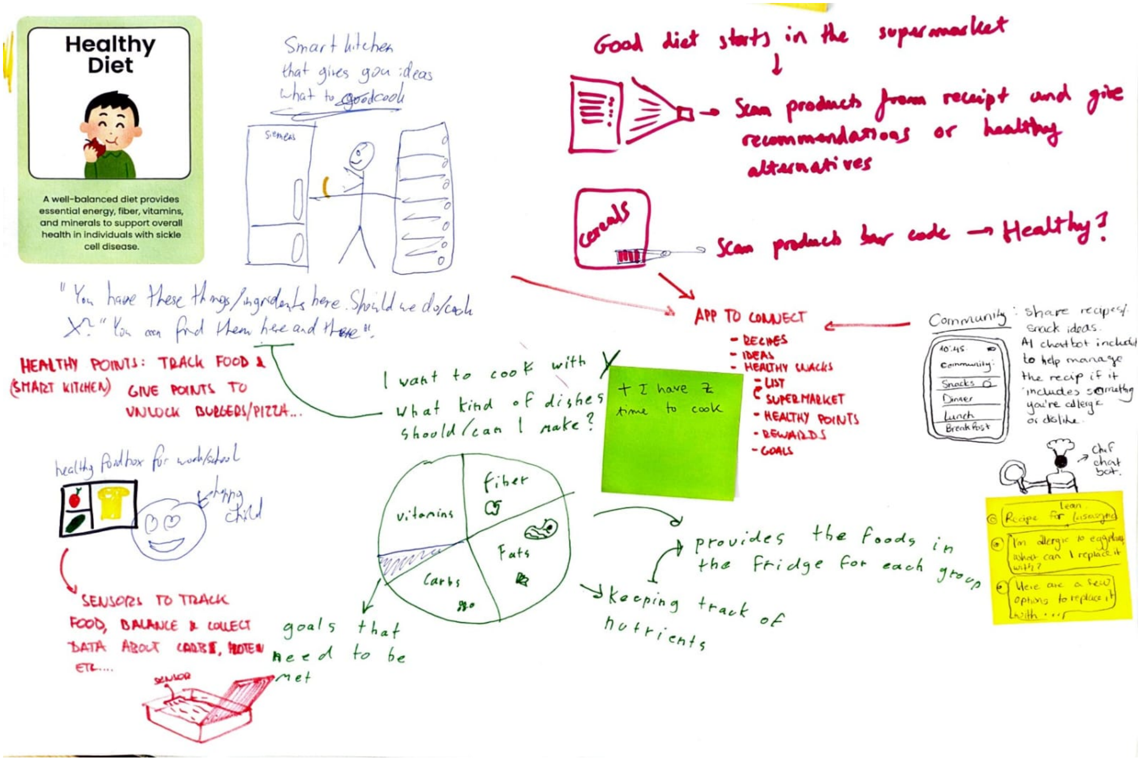


Figure 21: Healthy diet concept sketches

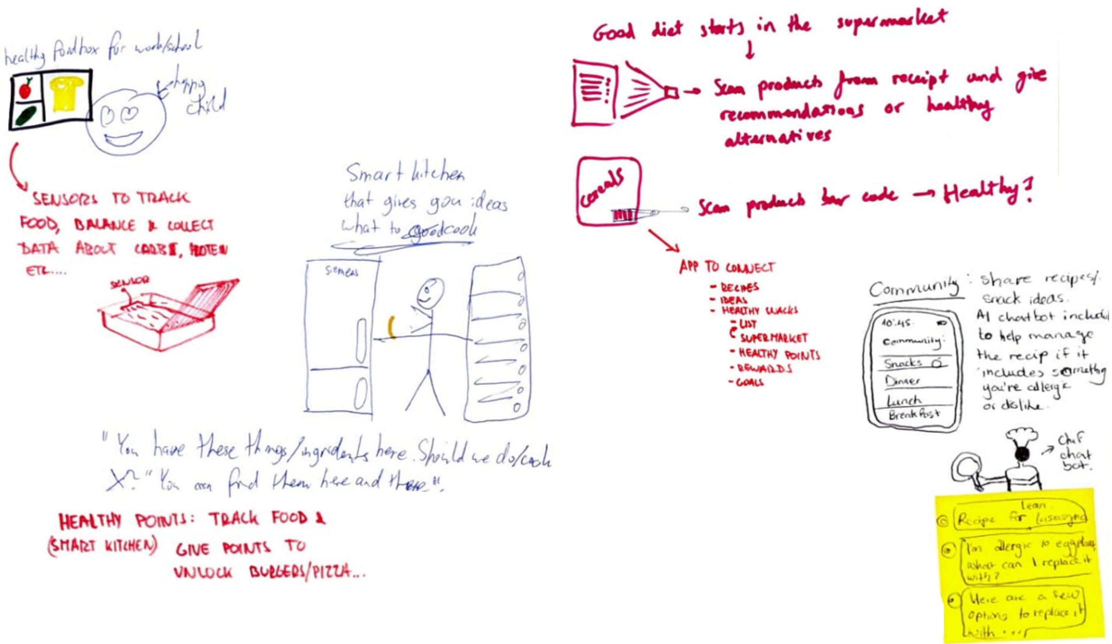


Figure 22: Standout ideas: healthy diet

D.2 Miro Board Overview

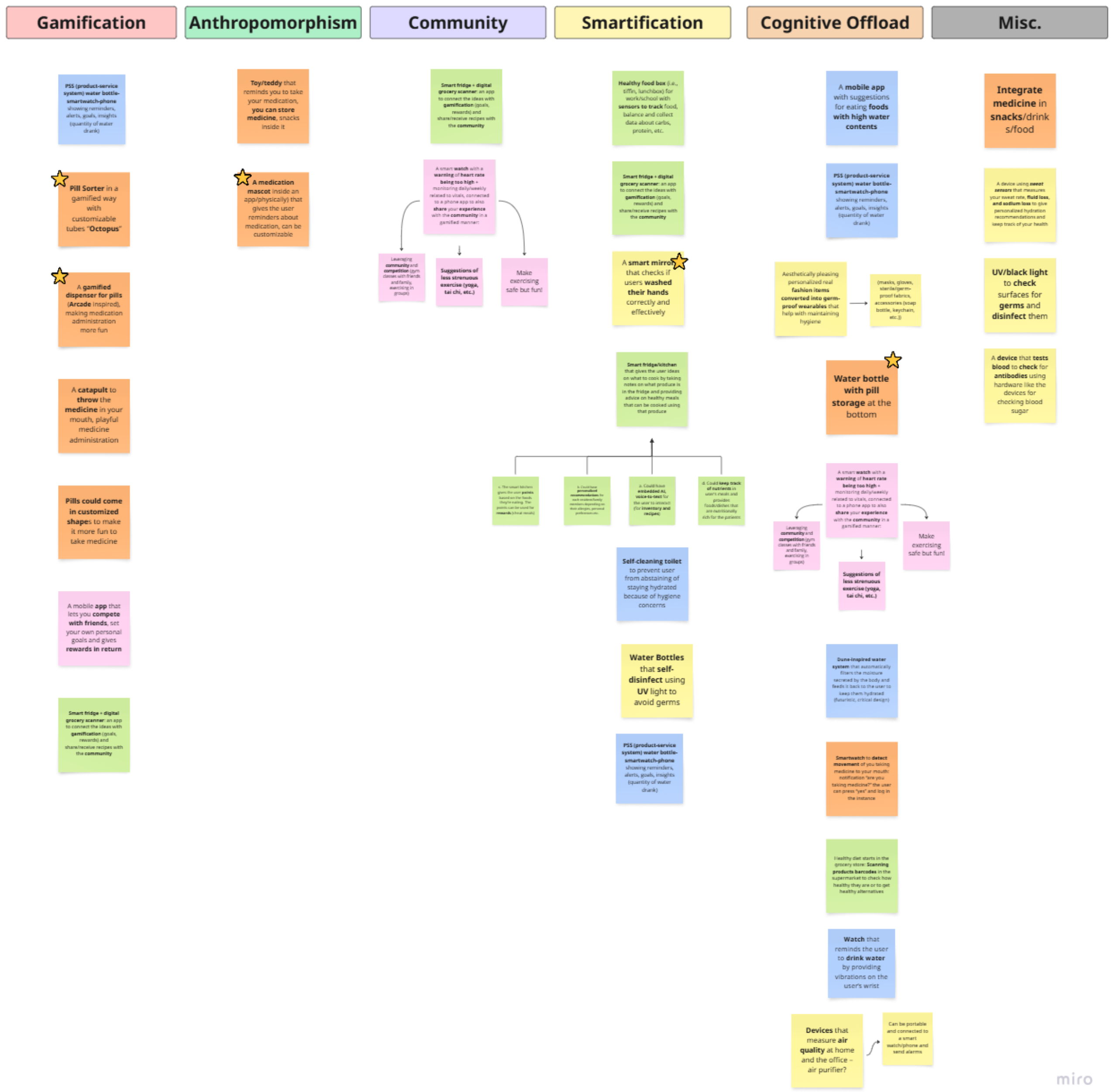


Figure 23: Miro board used for affinity mapping and concept grouping

D.3 Thematic Coding Relationship Diagram Explanation

Solid Lines: Theme → Sub-theme These show hierarchical inclusion, where a sub-theme directly derives from and supports the parent theme:

- **Gamification → Competition**
  Many ideas used competitive mechanics (e.g., rewards, leaderboards) to enhance motivation.
- **Community → Competition**
  Competition here emerges socially — e.g., challenges between peers or shared progress tracking.
- **Smartification → Sensing**
  Smartification depends on devices collecting real-time data — hydration levels, air quality, etc.

Dashed Lines: Relationships Between Themes These indicate functional or conceptual synergy:

- **Gamification – Community**
  Gamified elements were often social in nature (e.g., challenges, leaderboards).
- **Gamification – Cognitive Offload**
  Game mechanics reduce mental effort (e.g., reminders, rewards), easing habit adherence.
- **Community – Cognitive Offload**
  Social structures externalize responsibility (e.g., group nudges, shared accountability).
- **Smartification – Cognitive Offload**
  Smart tools automate decisions (e.g., hydration tracking, meal suggestions).
- **Anthropomorphism – Cognitive Offload**
  Human-like features (e.g., mascots) make systems more intuitive and emotionally engaging.
- **Smartification – Community**
  Smart devices (e.g., fitness apps) support social interaction and shared progress.

E Concept Sketches

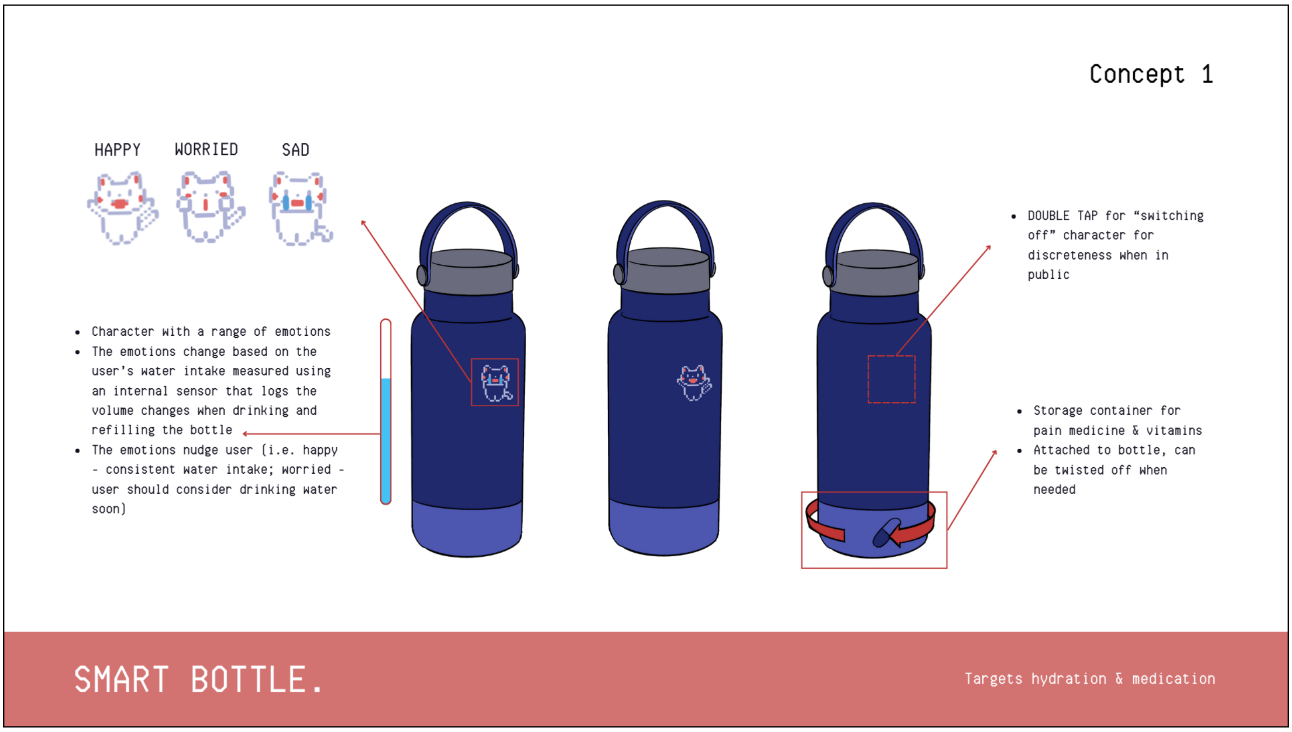


Figure 24: The Smart Bottle

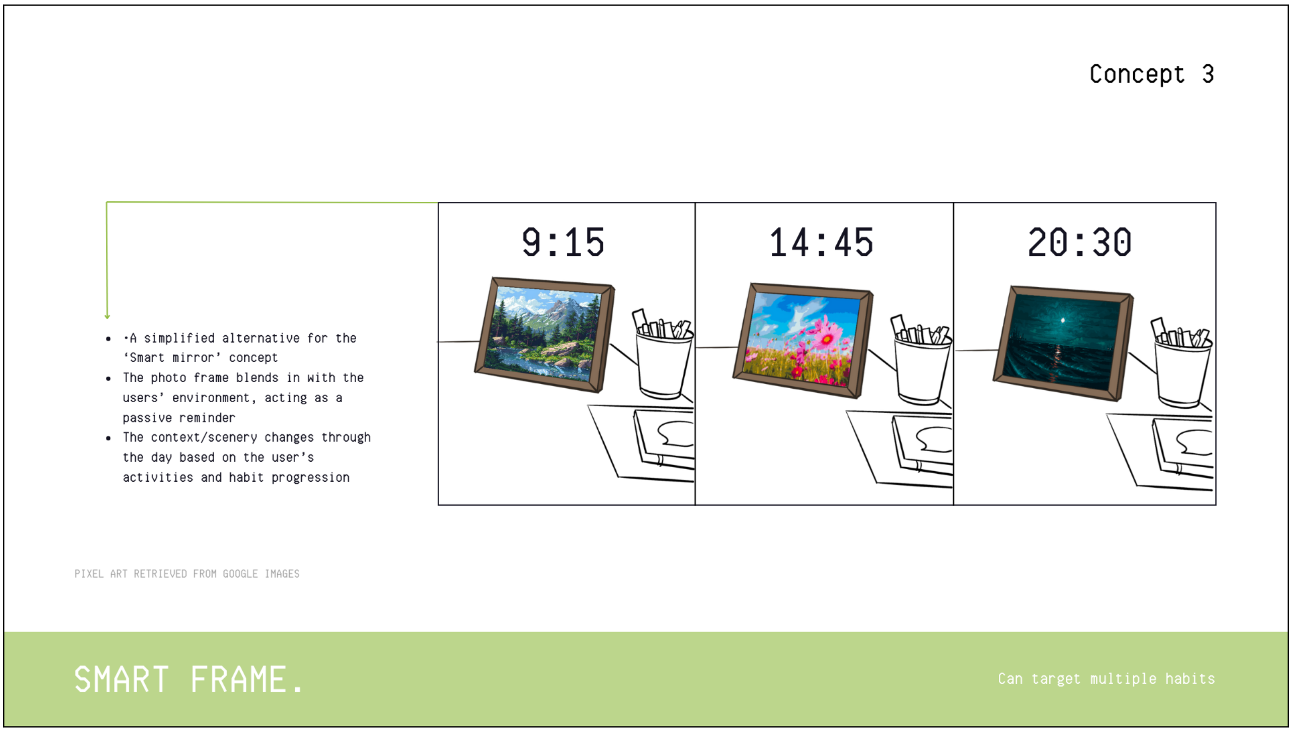


Figure 25: The Smart Frame

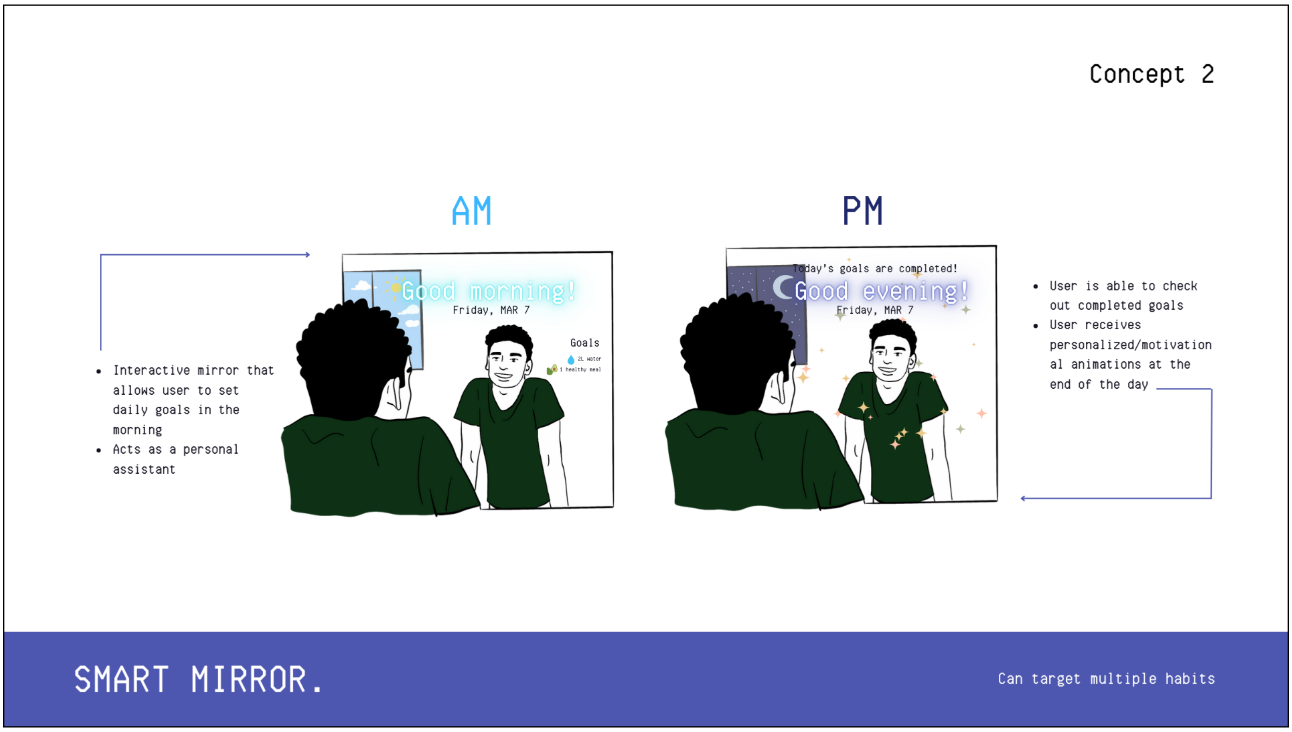


Figure 26: The Smart Mirror

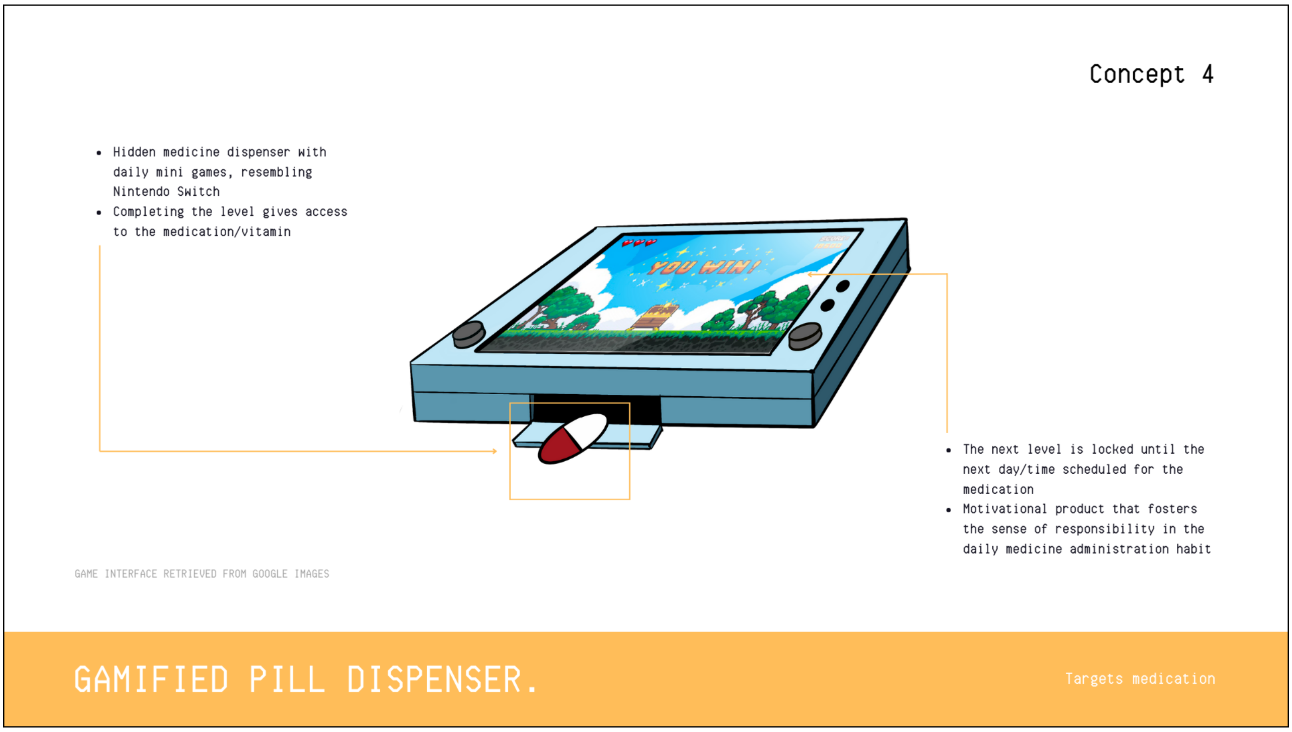
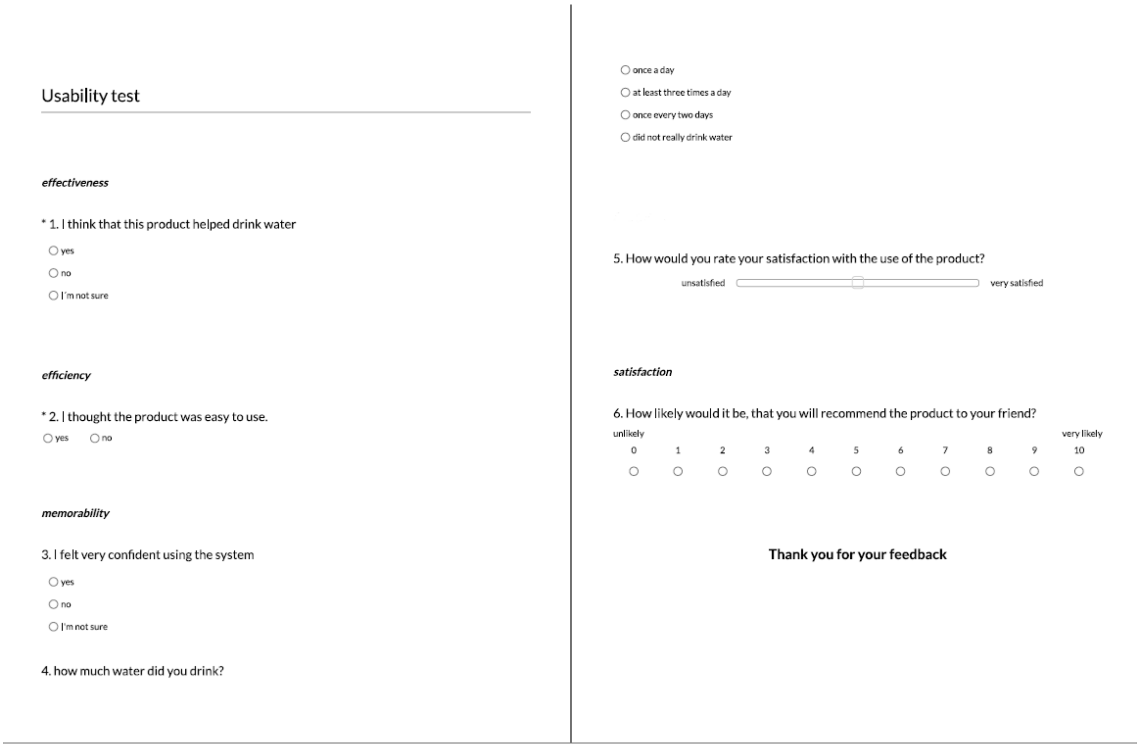


Figure 27: The Gamified Pill Dispenser

F Evaluation Materials

F.1 System Usability Scale (SUS) sample


Usability test

effectiveness

* 1. I think that this product helped drink water

- yes
- no
- I´m not sure

efficiency

* 2. I thought the product was easy to use.

- yes
- no

memorability

3. I felt very confident using the system

- yes
- no
- I'm not sure

4. how much water did you drink?

- once a day
- at least three times a day
- once every two days
- did not really drink water

5. How would you rate your satisfaction with the use of the product?

unsatisfied — very satisfied

satisfaction

6. How likely would it be, that you will recommend the product to your friend?

unlikely 0 1 2 3 4 5 6 7 8 9 10 very likely

Thank you for your feedback

Figure 28: System Usability Scale used to evaluate perceived usability of the prototypes

F.2 User Experience Questionnaire (UEQ) sample

	1	2	3	4	5	
annoying	○	○	○	○	○	enjoyable
easy to learn	○	○	○	○	○	difficult to learn
memorable	○	○	○	○	○	forgettable
attractive	○	○	○	○	○	unattractive
impractical	○	○	○	○	○	practical
boring	○	○	○	○	○	fun
motivating	○	○	○	○	○	demotivating
difficult	○	○	○	○	○	easy
inefficient	○	○	○	○	○	efficient
not interesting	○	○	○	○	○	interesting
unpredictable	○	○	○	○	○	predictable
inventive	○	○	○	○	○	ordinary
obstructive	○	○	○	○	○	supportive
unlikable	○	○	○	○	○	pleasing
clear	○	○	○	○	○	confusing
friendly	○	○	○	○	○	unfriendly

Figure 29: User Experience Questionnaire used to assess user experience across cases