

# Team Project: Automatic Flushing Toilets

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**Abstract**—This project aims to improve the overall experience of using automatic flushing toilets for selected types of users. Surveys and participant observation are conducted and executed throughout the process of needfinding. Regarding data inventory and requirements, design alternatives are prototyped after the execution of brainstorming. Then, qualitative and predictive evaluations are performed on prototypes. Another iteration of the design life cycle will be planned according to the feedback from survey results and cognitive walkthrough.

## 1 INTRODUCTION

If you, like most human beings, have ever been inside a restroom, you may have found yourself face-to-face with an automatic flushing toilet. In the last several decades, the automatic flushing toilet has become a staple in both commercial and residential restrooms across the world. John T. Barrett invented the automatic flushing toilet in 1986(1), and since then, over 27 million of the free-spirited thrones can be found in the United States alone(2). They were marketed as a cleaner, more hygienic, and less wasteful alternative to their traditional, manually-operated counterparts. The essential function of the automatic flushing toilet is to remove the human input from the flushing process. Users can expect the toilet to detect when they are finished with their essential business using motion sensors, and flush itself. This technology, like all emerging technologies, has grown throughout its lifespan. Modern self-flushing toilets rely on an infrared sensor that detects when a user departs from the toilet, at which point the flushing mechanism is triggered(3). There may still room for improvement in areas of the automatic flushing toilet realm. The goal of this

work is to understand where those areas lie and to introduce innovative enhancements to the most important device in each one of our lives.

### 1.1 Problem space & user types

Despite individual differences in socioeconomic status, users may interact with automatic flushing toilets in either **commercial** places or **residential** places, or both places. Therefore, the problem usually **takes place** in locations such as restaurants, shopping malls, offices, homes, and hotels. No matter the **context** of accessing automatic flushing toilets in commercial or residential places, the user experience of a restroom is characterized not only by users' **explicit needs** such as **cleanliness**, **comfort**, **accessibility**, and **privacy**, but also by users' **implicit needs** such as **efficiency**, **simplicity**, and **ease of use**. Features of the interface of automatic flushing toilets aim at fulfilling these needs in order to enhance users' overall satisfaction.

The table shown below describes our targeting types of users in this project.

*Table 1*—Outline of our targeting user types. Types of users who may have problems with the interface of automatic flushing toilets.

User Types	Demographics	Expertise Level	Motivation
Senior Citizens	Aged 65+, diverse socioeconomic backgrounds.	Limited to moderate expertise in technology.	Prioritizing simplicity, ease of use, and accessibility in restroom facilities
Adults	Aged 21+, diverse socioeconomic backgrounds.	Moderate to high familiarity with technology.	Seeking comfort and hygienic restroom experience, value time efficiency.
Children	Aged 5-12, diverse backgrounds	Limited technology exposure with potential unfamiliarity.	Requiring a supportive and engaging restroom experience

## 2 NEEDFIND PLANNING

We selected two methods for needfinding: **participant observation** and **surveys**.

## 2.1 Participant observation

**What will you do?** As the participant, I will use automatic flushing toilets from both commercial and residential places such as restaurants, shopping malls, hotels, and my home. First, each day I will pick one place to go and observe my interaction with different automatic flushing toilets. Next, I will pay attention to needed physical behaviors, functional challenges, and hygiene concerns. I will ask about the installation times of the different flushing toilets I observed, comparing the effects of different time spans on the design as well as the user experience. Then, I will write down my overall thoughts and feedback regarding my experience.

**What steps will you follow?**

1. Visiting automatic flushing toilets in various locations
2. Observing different designs of flushing toilets
3. Using flushing toilets
4. Documenting my thoughts and feedback

**What data will you gather?** First, I will gather and report my basic demographic information as one of the targeting user types from *Introduction 1.1: Problem space & user types*. Next, I will gather types of locations visited, characteristics of restrooms, and specific observations on the design of automatic flushing toilets. Then, I will gather my user feedback regarding my overall experience, needs, and challenges.

### 2.1.1 Data inventory

**Who are the users? What are their ages, genders, levels of expertise?** I am the user in participant observation. I am a 23 years old male and have moderate to high familiarity with technology. I belong to the “Adult” type of user from *Introduction 1.1: Problem space & user types*.

**Where are the users? What is the environment?** I live in Anaheim, California. The environment varies from place to place such as restaurants, shopping malls, and hotels.

**What is the context of the task?** The context of the task is either public restroom or private restroom environments that are installed with various kinds of automatic flushing toilets.

**What are their goals? What are they trying to accomplish?** My goal is to have a comfortable and hygienic restroom experience. I am trying to use the automatic flushing toilets as efficiently as possible.

**What do they need? What are the physical objects? What information do they need?** I need efficient user experience, a comfortable and odor-free atmosphere, and minimal body touchpoints for hygiene. Physical objects may or may not include: toilet seat paper cover, touchless sensors, flush buttons, and other reachable controls. I need information such as cleanliness of the seat, feedback on successful flushing, etc.

#### ***2.1.2 Potential biases & solutions***

In the role of the user myself, I may potentially encounter **observer bias** because it is easy for me to discover buttons, sensors, or controls and understand how to use automatic flushing toilets efficiently. To mitigate my observer bias, I need to pay extra attention to the interface of the automatic flushing toilet during observations. I also need to avoid making assumptions based on previous experiences. My memory towards the user experience of automatic flushing toilets may be unreliable and forgetful. Therefore, in order to avoid **recall bias**, I need to take notes or record my thoughts and feedback immediately after restroom use to minimize reliance on memory. Moreover, as I am the only participant who voluntarily agrees to participate in the participant observation, I will inevitably have **voluntary response bias**. Therefore, I need to keep in mind that I need to gather more feedback from surveys, which is the next needfinding plan.

## **2.2 Surveys**

**What will you ask?** To view all survey questions for each participant, please view *Appendix 11.1: The survey questions for needfinding*.

**Who will you send the survey to?** I will create and publish the survey via PeerSurvey. I will share my survey links to friends & family, classmates on Ed discussion, and classmates on Discord. Additionally, I will ask them to share my links to more people around them.

### **2.2.1 Data inventory**

**Who are the users? What are their ages, genders, levels of expertise?** Users are participants who completed and submitted the survey. They could be any type of user from *Introduction 1.1: Problem space & user types*. To be more specific, ages of users may vary from 12 to 65, genders of users would be all genders, and levels of expertise of users may vary from novice to advanced.

**Where are the users? What is the environment?** Users are participants who engaged in the online survey, thus they are from everywhere in the earth that can access the survey link with stable internet connections. The environment varies from place to place such as restaurants, shopping malls, hotels, homes, and other places that they will specify in the survey.

**What is the context of the task?** The context of the tasks may vary depending on where each participant takes the survey, what devices they use to take the survey, and when they take the survey.

**What are their goals? What are they trying to accomplish?** Their goals are to have comfortable and hygienic user experiences from using automatic flushing toilets. Regarding *Appendix 11.1: The survey questions for needfinding*, each participant will be asked what they prioritize more among simplicity, ease of use, accessibility, comfort, supportiveness, efficiency, and feedback.

**What do they need? What are the physical objects? What information do they need?** Potential participants who receive the survey link need to have a stable internet connection for their phone, tablet, laptop, desktop, or other devices in order to access the survey and participate in the survey.

**What are their tasks? What are they doing physically, cognitively, socially?** They will accomplish the survey task by answering 10 questions in total, where 8

questions are multiple-choice questions and 2 questions are free response questions. **Physically**, they will tap on the survey link and answer each question in the survey by tapping on choices or typing on the keyboard through their phone or tablet. If they participate in the survey through a desktop or laptop, they will use a mouse and keyboard to answer each question in the survey. **Cognitively**, they will need to understand each question and provide their honest response or feedback to each question. Most importantly, they need to recall their memory regarding their previous experience of using automatic flushing toilets, and come up with some thoughts, concerns, and suggestions of the current interface of automatic flushing toilets. **Socially**, we ensure their user privacy and their feedback information remains anonymous.

### ***2.2.2 Potential biases & solutions***

First, **social desirability bias** could potentially happen in the survey because participants may provide their thoughts and concerns regarding the interface of automatic flushing toilets in a way that portrays them favorably. **However**, by designing survey questions that focus more on general experiences rather than specific personal experience, the social desirability bias could be mitigated. Also, no question appears in the survey that is asking sensitive information, and all questions assure anonymity. Second, **voluntary response bias** could potentially happen in the survey because only individuals who are willing to participate with strong opinions might respond to the survey. **However**, I will diversify survey distribution to not only my friends & family, my classmates on Ed discussion, or my classmates on Discord from the other course, but also I will ask all of them to share the survey link further to their circles of people. **Therefore**, voluntary response bias will be under control in this needfinding plan. Third, **recall bias** will happen inevitably because participants need to recall their memory regarding their previous experience of using automatic flushing toilets, and come up with some thoughts, concerns, and suggestions of the current interface of automatic flushing toilets. **Therefore**, I will also keep in mind that this bias might still exist.

### 3 NEEDFINDING EXECUTION

#### 3.1 Execution of participant observation

##### 3.1.1 Raw results

The table shown below reports my observations, experiences, and additional thoughts from 4 locations.

*Table 2*—Raw reports. Observations, experiences, and additional thoughts in using automatic flushing toilets from different places.

Locations	Observations	Experiences	Additional thoughts
LA Fitness Signature Club	Have <b>one</b> sensor and <b>two</b> control buttons to trigger flushing. <b>No</b> additional features. The seat looks not that clean.	The sensor worked but it flushed multiple times before and after use. Open design of the seat leaves an <b>odor</b> .	Automatic flushing function was <b>too sensitive</b> .
Asia Buffet Restaurant	Have <b>one</b> sensor and <b>one</b> manual control to trigger flushing. The seat needs a paper cover.	Automatic flushing from the sensor is effective, but <b>delayed</b> . Open design of the seat leaves an <b>odor</b> .	Automatic flushing function <b>delayed</b> , lack of <b>time efficiency</b> .
The Cove Hotel	Only have an infrared sensor behind to trigger flushing. Fully <b>touchless</b> . The seat looks really clean.	Automatic flushing from the sensor is <b>sensitive</b> . Warm seat with hidden design of heat function. Open design of the seat leaves an <b>odor</b> .	Automatic flushing function <b>working</b> well. <b>Cleanliness</b> atmosphere achieved.
South Coast Plaza Shopping mall	Have <b>one</b> sensor and <b>one</b> control to trigger flushing. <b>No</b> additional features. The seat needs a paper cover.	The sensor did <b>not</b> work and I had to press the button to flush. Open design of the seat leaves an <b>odor</b> .	Automatic flushing function <b>failed</b> .

##### 3.1.2 Summary of takeaways

Based on my report of participant observation, the design of automatic flushing toilets need to ensure the **reliability** of automatic flushing function to avoid malfunctions such as delayed flushing, early flushing, too many flushing, and no flushing. The current design of automatic flushing toilets in common places all leaves the seat open **without** a lid to fully close, which is because the **placement** of the infrared sensor is designed on the back. However, toilets with lids would improve **discretion** and **odorlessness**, which are highly valued in both public

and private restrooms. The **touchless** experience of automatic flushing toilets are good in general. The current interface of automatic flushing toilets all remain **clear** and **straightforward** design. Advanced features for redesign can be potentially positive but need to obtain its **simplicity**. Additionally, **Consistency** in design across various locations is observed. The automatic flush toilet at South Coast Plaza shopping mall has experienced prolonged use without timely maintenance, leading to the failure of its automatic flush function. While the flush function is functional in the LA Fitness Signature Club and the Asian Buffet Restaurant, there are design flaws that make the flush either overly sensitive or delayed, creating a suboptimal user experience. At the Cove Hotel, where the automatic flushing toilets were installed most recently, the primary function works well, and users can distinctly feel the cleanliness of the seats. From a temporal perspective, it is evident that the design and functionality of automatic flushing toilets have improved over time. However, the focus now shifts to optimizing the operation of the automatic flush function and refining the design to ensure not only a flawless flush but also a clean and odor-free environment.

### ***3.1.3 Report of handling biases***

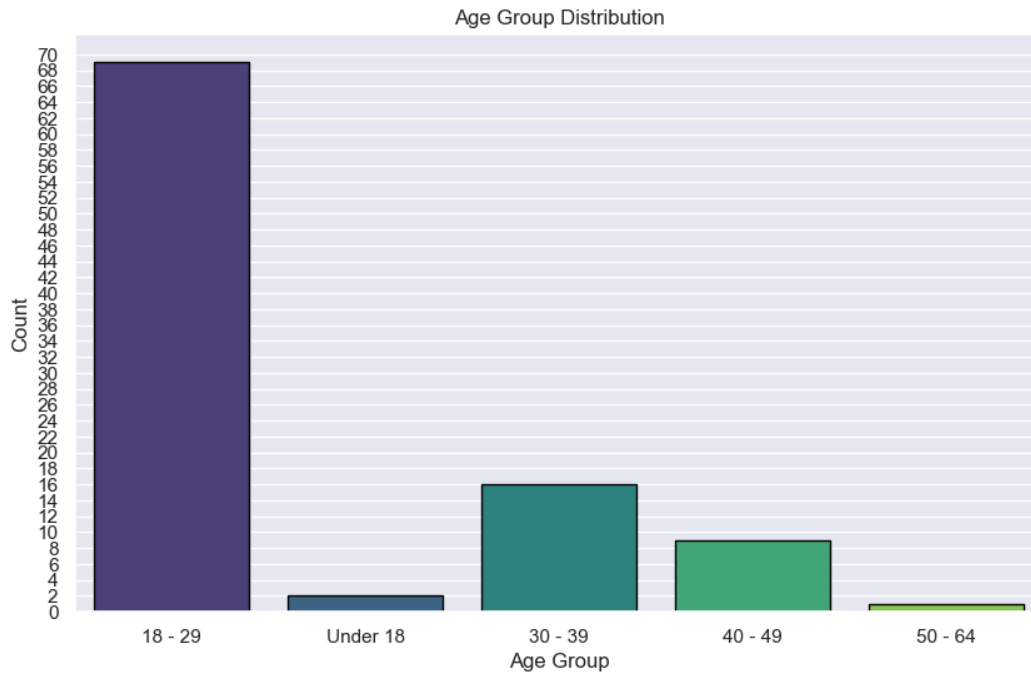
**Observer bias** was handled by actively playing the role of novice user and consciously avoiding assumptions based on previous experiences. Also, due to the nature of the current design of automatic flushing toilets, there were no additional features or functions to be discovered. **Recall bias** was handled by taking immediate notes of thoughts and feedback on my phone during each restroom use to ensure accuracy and minimize reliance on memory. **Voluntary response** bias was acknowledged because of the limitation of being the **only** participant. Diverse feedback from survey results will be heavily considered to counteract this bias.



## 3.2 Execution of surveys

### 3.2.1 Raw results

I collected survey responses from **97** participants via PeerSurvey. For viewing the rest of statistical graphs that are made from raw data and raw data itself, please check *Appendix 11.2: The preprocessed data and collected survey responses*.



*Figure 1*—Age distribution. **Majority** of participants from the survey fall in the **18-29** age group.

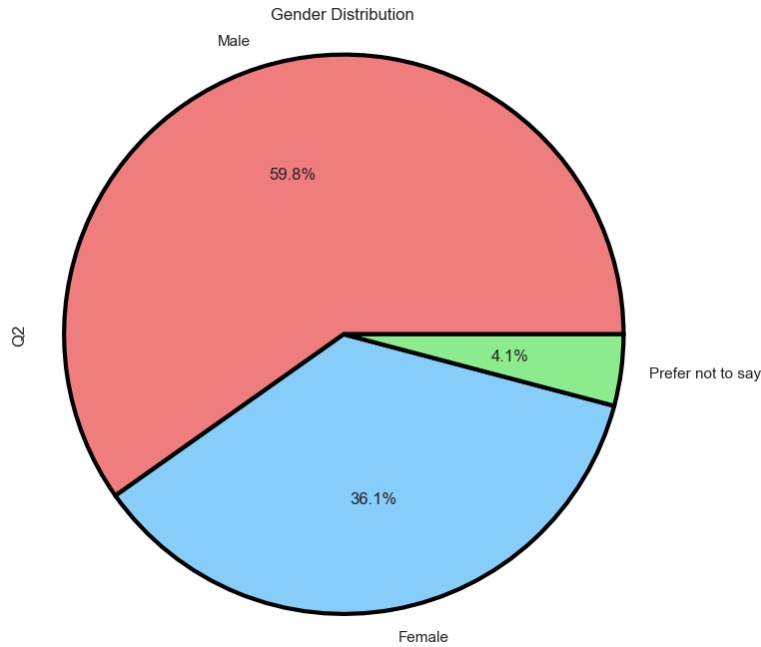


Figure 2—Gender distribution. Almost **two-third** of participants are male.

### 3.2.2 Summary of takeaways

Regarding figures above and *Appendix 11.2: The collected survey responses*, one can interpret that many participants expressed their strong **needs for reliability, comfort, ease of use, and simplicity**. Some participants mentioned that toilets don't always flush **on time**, requiring manual **intervention** such as pressing the button, while others complained that automatic flushing toilets flush **too soon** when they slightly move or grab more toilet paper. Some also expressed concerns about the toilet sensor being **too sensitive**, leading to unintentional flushes that may cause **water splash**. Some participants pointed out the need for manual control over the automatic flushing process, addressing the problem of **reliability** in the design of automatic flushing toilets. A few participants expressed the desire for a new “**delay**” option to **prevent flushing or water splash** while still in use. A few participants highlighted the **difficulty** in understanding the infrared **sensor's working condition** and shared concerns about wastage of water and hidden cameras. One participant mentioned the challenge of interpreting labels in a foreign language, emphasizing the

importance of **universal design**. Participants who have **children** talked about the benefit of automatic flushing is to **conveniently** help kids who **forget** to flush, but others expressed concerns about **scaring** children due to **unexpected loud flushing sounds**. Suggestions for **quieter** flush options for kids are also noted. Despite the various concerns raised, some participants expressed overall appreciation of the current interface design and technology. They found automatic flushing toilets very convenient, providing a hands-free experience and better hygiene.

### **3.2.3 Report of handling biases**

Social desirability bias is handled in the survey such that it assured participants of anonymity to encourage honest responses and avoided asking sensitive or judgmental questions in the survey. Voluntary response bias is handled in the survey because participants are from different platforms and social circles. However, due to the nature of the survey, potential inaccuracies of participants' memories of their past experiences are inevitable. Therefore, the existence of recall bias is acknowledged.

## **4 DATA INVENTORY AND REQUIREMENT DEFINITIONS**

Based on *Needfinding execution 3.1: Execution of participant observation* and *Needfinding execution 3.2: Execution of surveys*, the data inventory and the requirements are defined below.

### **4.1 Data inventory**

**Who are the users? What are their ages, genders, levels of expertise?** Data is gathered from 97 survey participants and my own participant observation (Xiangsheng Gu). Users are primarily young adults aged from 18 to 29, with a diverse range including older adults and potential users with children. Genders of users are all genders. Users have varied technological expertise, ranging from novice to advanced.

**Where are the users? What is the environment?** Besides me (mentioned in *Needfinding planning 2.2.1: Data inventory*), users are from everywhere on earth

that can access the survey link with stable internet connections. The environment where users use automatic flushing toilets are restrooms from: restaurants, shopping malls, offices, homes, hotels, parks, retail stores, airports, and school facilities.

**What is the context of the task? What else is competing for users' attention?**

The context of the task are public and private restrooms with installed automatic flushing toilets for users to use. While engaging with the interface of automatic flushing toilets, users may have distractions from other interfaces such as phones, or time constraints depending on various environments and context.

**What are their goals? What are they trying to accomplish?** Users' goals are about having discreet, odor-free, comfortable, and hygienic restroom experience, while minimizing unexpected or faulty flushing. Users are trying to accomplish the use of automatic flushing toilets as efficiently as possible.

**What do they need? What are the physical objects? What information do they need?** Users need enhanced reliability in the redesigned interface of automatic flushing toilets to control or minimize malfunctions of flushing. Users need new features to improve discretion and odorlessness. The overall touchless experience and simplicity in the design of automatic flushing toilets need to be obtained. Physical objects include: toilet lid, toilet seat cover, touchless infrared sensors, functional buttons, and other reachable controls. Users may need information such as cleanliness of the seat, feedback on upcoming flushing, control options for additional features , etc.

**What are their tasks? What are they doing physically, cognitively, socially?**  
**What are the subtasks? How do they accomplish those tasks?**

1. Physical task: approach, use, and exit
  - a. use the toilet.
  - b. interact with features from the interface of the toilet
  - c. exit the restroom.
2. Cognitive task: understand the interface
  - a. assess the interface of the toilet to understand its functionalities.

- b. identify the presence of any buttons, sensors, or controls.
- 3. Social consideration: ensure privacy
  - a. ensuring privacy and respect for others using the restroom
  - b. looking for features that contribute to a discreet and odorless experience

## **4.2 Requirements**

### **4.2.1 *Ease of use***

While keeping the experience touchless, the overall redesign of automatic flushing toilets should remain a clear and straightforward interface for all possible actions.

### **4.2.2 *Comfort***

Providing users a more comfortable experience by including new features that enhance discretion, mitigate bad odor after use, and minimize the loud sounds of flushing.

### **4.2.3 *Reliability***

Ensuring a consistent and reliable automatic flushing with solutions to address user concerns about malfunctioning situations, and to prevent multiple flushing while still in use.

### **4.2.4 *Simplicity***

Prioritizing simplicity in the design of advanced new features with universal design principles for symbols, language, labels, or instructions.

### **4.2.5 *Evaluation metrics for Success***

The redesigned interface should be evaluated based on improvements in ease of use, comfort, reliability, simplicity, and overall user satisfaction. Successfulness can be measured through a combination of assessing how easy for users to understand and using the new features, gathering agreements of improvements that focus on comfortability from users, collecting ratings of the reliability from

prototypes, and analyzing feedback from users to evaluate user satisfaction over simplicity.

## 5 DESIGN ALTERNATIVES

### 5.1 Brainstorming plan

#### 5.1.1 *Plan outline*

Our **goal** is to generate 20 design alternatives from individual brainstorming sessions and the group brainstorming session. For **individual brainstorming**, each of us will perform a brainstorming session prior to the group brainstorming session during week 14 within an hour. First, each of us will write down the core problem: “improve the user experience of using automatic flushing toilets”. Next, each of us will consider brainstorming non-traditional interaction methods such as voice control, motion detection, or weight detection. Then, each of us will aim at generating 3 ~ 5 ideas. Each of us will take a 5-minute break every 15 minutes during the brainstorming process. Last, we will not only focus on the redesign of the interface when the user performs the main task, but also aim towards the redesign of each subtask before and after using toilets. Here are **rules** to follow:

1. Writing down any ideas that come to mind.
2. Generating at least 3 ideas individually.
3. Adding free thoughts on top of/ around each idea.
4. No explaining or justifying any ideas.
5. Revisiting the core problem if one needs to take a break.

For **group brainstorming**, we will hold a 60 minutes group meeting via Discord voice channel over the weekend of week 14 to collaborate and bring ideas from each of our respective individual brainstorming sessions. We expect the preparation time will take 5 minutes, the brainstorming session will take 45 minutes, and the review & record phase will take 10 minutes. We will first designate one of the group members to be the recorder for the session, and then we will begin to list ideas, either from our individual sessions or during our group session via Discord:

1. Interactive construction: Each idea can serve as a springboard for another idea, and participants should build their own ideas on the ideas of others.
2. Defined, consistent roles: One team member shall volunteer to record the entire proceedings of the meeting to make sure that there is consistency in annotative style.
3. Annotation & Volume of Ideas: No matter what is said during the brainstorming session, all ideas shall be recorded by the designated team member. Members are encouraged to vocalize as many ideas as possible, to ensure an adequate quantity of potential ideas.
4. Discussion without Criticism: team members are encouraged to ask qualifying questions if they need more explanation of an idea. This shall be done in a manner that does not evaluate or criticize.

#### **5.1.2 Execution results**

1. Instead of an infrared sensor, a built-in weight scale inside the toilet seat triggers flushing if the weight remains zero for 10 seconds.
2. If the pressure sensor detects weight constantly, it will prevent toilets from flushing.
3. Touchless lid will open automatically if its sensor detects a human approaching and it can fully close the toilet after flushing, providing enhanced discretion and minimizing exposure to unpleasant odors.
4. The height of the toilet will adjust automatically if its sensor detects children approaching.
5. An additional smaller size seat can be installed inside the regular seat of the toilet for enhanced child safety.
6. If the sensor detects the user is a child, the flushing mode will switch to quiet multiple flush after use.
7. Everytime after flushing, the integrated ice maker will release mini ice cubes into the water for odor absorption.
8. A seat warmer for toilet seats for comfort during winter.
9. Voice activated bidet for improved touchless experience.
10. A foot pedal to replace the traditional button for manual flushing in case of malfunctions of automatic flushing.

11. Integrated time reminder to prevent legs numb and to promote health, as well as shorten the use cycle of public toilets.
12. Subtle fragrance to release underneath toilet seats in order to neutralize odor after use.
13. A built-in air purifier that can absorb odor and release fresh air for a comfortable cooling atmosphere.
14. A built-in sanitizer to automatically clean the toilets overnight or during off hours.
15. If sensors detect a human approaching at night, it will turn on soft night lights for a more comfortable user experience.
16. Self-diagnose system identifies malfunctions and automatically reports issues in order to get people to fix the toilets on time.
17. Self-diagnose system allows smartphone connectivity to notify users for maintenance and better hygiene.
18. Toilets can project green/ red lights onto the floor to indicate whether the stall is occupied or not.
19. An integrated plunger will automatically plunge toilets if clogs are detected.
20. Automatic toilet paper replenishment system to prevent the situation of running out of toilet paper, coupled with a monitoring system to prevent the malicious removal of large quantities of toilet paper.

## 5.2 Selection criteria

### 5.2.1 Referencing

According to *section 4: Data inventory and requirements*, we looked for two ideas that promoted the most **user comfort, reliability, simplicity, ease of use, and touchless experience** during the interaction of automatic flushing toilets.

### 5.2.2 Rules & explanations

Design alternatives that include design principles and heuristics of comfort, simplicity, and ease of use are considered more important. Ideas that consist of touchless experience and enhance functional reliability were favored.



Additionally, ideas with high similarity were combined for a better redesigning solution. With consideration of these rules, 2 ideas are selected to move forward to prototyping:

1. The redesigned automatic flushing toilet will have a **foot pedal** to replace manual flushing buttons. If there is a malfunction of automatic flushing, users can simply pedal the foot pedal to flush the toilets.
2. Instead of using infrared sensors, the redesigned automatic flushing toilet will have a **built-in weight scale** inside the toilet seat that prevents toilets from flushing too early (or too often), as long as weight above 5 pounds is **constantly** detected during use. The built-in weight scale will trigger **one-time** flushing if the weight remains zero for 10 seconds after use.

**The first** idea not only ensures a **touchless** experience but also provides a manual flushing option, addressing users' concerns about the **reliability** of the automatic flushing function. The foot pedal is **simple**, straightforward, and **easy to use**, contributing to principles of ease of use and simplicity of the interface.

**The second** idea not only enhances **simplicity** and **ease of use** by introducing a more direct and intuitive method for initiating the flushing process, but also contributes to improving user **comfort** by preventing early or frequent flushing and addressing concerns about unexpected toilet operation. The integrated weight scale aligns with the requirement of **touchless** experience, and it eliminates the need for infrared sensors.

### 5.2.3 Connections

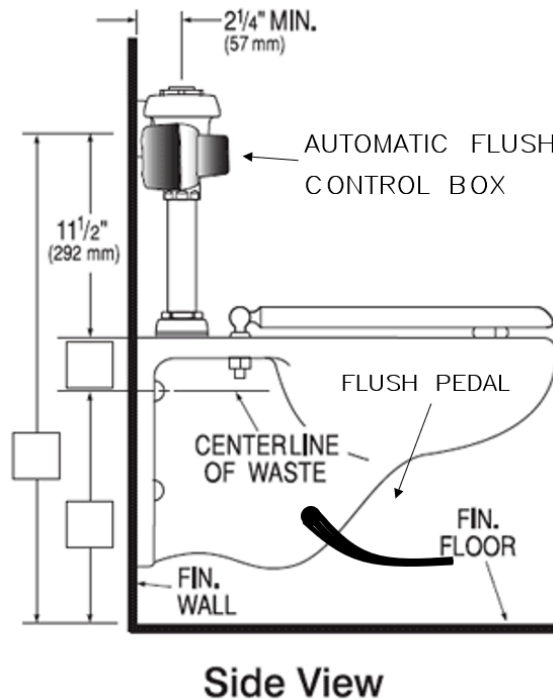
Based on *section 4: Data inventory and requirements*, these 2 ideas are not only adaptable to both commercial and residential restroom settings, but also more suitable for users of all ages and technological expertise levels. They meet the requirement of maintaining the touchless experience while providing a comfortable, simple, easy, and reliable function of flushing. Therefore, these two design alternatives promote all design principles and heuristics mentioned in requirements. Moreover, they both maintained a touchless experience and

removed the existence of infrared sensors, addressing users' needs of hygiene and discretion.

## 6 PROTOTYPING

### 6.1 Foot pedal for manual flushing

#### 6.1.1 Paper Prototype and Description



*Figure 3*—A side-view paper prototype drawing of a foot pedal design implementation.

Because most self-flushing toilets have a button or hand-activated lever to trigger a flush manually, users may be hesitant to touch these interfaces with their bare fingers. A pedal that is mounted to the base of the toilet as shown in Figure 10 would allow users to instead activate a flush using their foot. The pedal will have a pressure sensor that triggers an electronic impulse in the automatic flushing control box and triggers the flush action. To activate the pedal, users simply need to use their toe to push down gently on the pedal arm until the flushing sequence is activated.

### **6.1.2 Evaluation**

This prototype meets several of the needs identified in the data inventory. Firstly, survey participants expressed an interest in having reliable safeguards against malfunctioning flushing devices in the toilet. This manual flushing option maintains the ability to override the automatic flushing sequence by manually triggering a flush. Users also emphasized an interest in making the touchless experience more hygienic. This design prototype gives users the ability to flush manually while maintaining a hygienic, hands-free experience.

This prototype would be a valuable update for users of all demographics, but will be most impactful to users who expressed an interest in improving the hygienic qualities of the toilet. Any time a user feels the need to flush manually, they now have the ability to do so without having to use their hands.

## **6.2 Integrated weight scale to trigger flushing**

### **6.2.1 Paper prototype and its explanation of design**



*Figure 4*—A paper prototype of a redesigned toilet with built-in weight scale that triggers flushing.

As users approach, sit on the toilet, and use it, the built-in digital weight scale detects the current users' weight and can display the number in pounds on the screen. The weight scale constantly monitors the weight on the toilet seat, because it is programmed to prevent flushing. After users finish using the toilets and leave the toilet, the weight drops to zero and if the weight remains zero for 10 seconds long, indicating that the user has left for sure, the built-in weight scale executes a one-time flushing to ensure cleanliness for the next user.

### **6.2.2 Evaluation**

This prototype does **not** have features for **odor control**. However, it adhered to **ease of use** and **simplicity** design principles by utilizing a straightforward mechanism of pressure sensing. The integrated digital weight scale continuously monitors weight on the toilet seat, which improves user **comfort** as promised. One-time flushing will be triggered if the weight remains zero for 10 seconds after use, ensuring users a touchless experience while eliminating the need for an infrared sensor or manual flushing buttons. Regarding the data inventory, this prototype caters to users of **varied ages** and technological **expertise**, offering a straightforward and **intuitive** interaction. The overall design is simple and **applicable** across various **environments**, meeting the needs of users in different **locations**. Overall, it successfully addressed user **goals** and **needs** of having a comfortable, hygienic, and efficient restroom experience.

## **7 EVALUATION PLANNING**

For **each** prototype, a **qualitative evaluation** plan is established for assessing whether users consider our design alternative to be effective and address their needs. We use surveys to collect demographics and interests of respondents as it pertains to their opinions surrounding self-flushing toilets. This will help us understand if the targeted user groups (those that care about failsafe flushing mechanisms and those that care about hygiene) find the design effective. Additionally, a cognitive walkthrough will be conducted and used to perform a **predictive evaluation** on **both** prototypes.

## 7.1 Qualitative evaluation planning of the first prototype

The first prototype, which was introduced in *Prototyping 6.1: Foot pedal for manual flushing*, will be qualitatively evaluated via a survey administered to a random pool of volunteers. The goal is to understand at an early stage of the prototyping process whether users find the design to be **useful**, **efficient**, and **optimal**. This step of evaluation is conducted with the intent of informing an iterative design process.

### 7.1.1 Procedural information

Survey questions will be created on the PeerSurvey platform and distributed to classmates from CS6750, family members of group members, friends, and encouraged them to spread the survey to more people. As most people would be considered users of self-flushing toilets, the goal is to have a larger, more diverse, and respondent pool.

### 7.1.2 Content

The survey will display a wireframe prototype of the design alternative shown in figure 10 **without** usage instructions followed by questions 1-7 in *Appendix 11.3: The survey questions for evaluation 7.1*. Then, usage instructions from *Prototyping 6.1: Foot pedal for manual flushing* will be provided with figure 12 and the remaining questions in *Appendix 11.3: The survey questions for evaluation 7.1* will be asked.

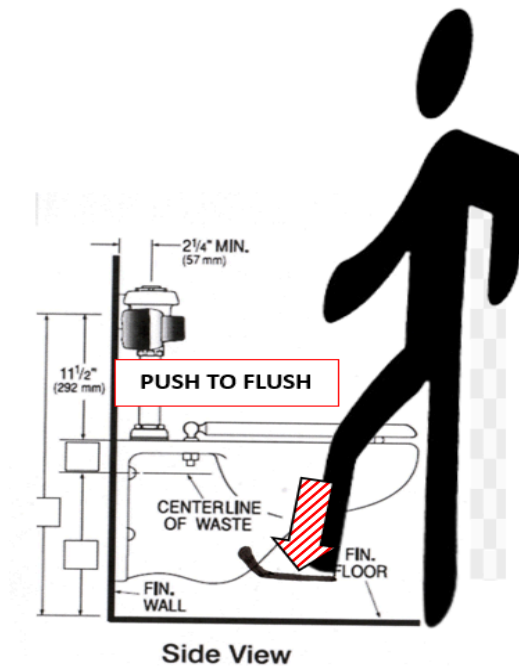


Figure 5—A usage diagram for the survey responders to evaluate

### 7.1.3 Inventory & requirements

The evaluation of this prototype will help determine if it adequately meets several of the needs identified in the data inventory. Survey participants are asked directly if they believe the design will provide a reliable safeguard against malfunctioning flushing devices in the toilet. They are also asked if they believe the design makes the touchless experience more hygienic.

### 7.2 Qualitative evaluation planning of the second prototype

The second prototype, which was introduced in *Prototyping 6.2: Integrated weight scale to trigger flushing*, will be qualitatively evaluated via a survey administered to a random pool of volunteers. The goal is to understand at an early stage of the prototyping process whether users find the design to be **useful**, **efficient**, and **optimal**. This step of evaluation is conducted with the intent of informing an iterative design process.

### 7.2.1 Procedural information

Survey questions will be created on the PeerSurvey platform and distributed to classmates from CS6750, family members of group members, friends, and encouraged them to spread the survey to more people. As most people would be considered users of self-flushing toilets, the goal is to have a larger, more diverse, and respondent pool.

### 7.2.2 Content

The survey will display the paper prototype in figure 11 along with the written description in *Prototyping 6.2: Integrated weight scale to trigger flushing* and ask the questions from *Appendix 11.4: The survey questions for evaluation 7.2*.

### 7.2.3 Inventory & requirements

The evaluation of this prototype will help determine if it adequately meets one of the needs identified in the data inventory. Survey participants are asked directly if they believe the design will reduce accidental flushes in the toilet system. This was one of the most commonly identified needs from users during the needfinding phase.

## 7.3 Predictive evaluation planning of both prototypes

### 7.3.1 Description

The predictive evaluation aims to uncover potential usability issues and ensure that users can intuitively interact with prototypes mentioned in both *Prototyping 6.1: Foot pedal for manual flushing* and *Prototyping 6.2: Integrated weight scale to trigger flushing*. While undergoing a cognitive walkthrough, we focus on assessing how easily users can accomplish each task associated with each prototype.

### 7.3.2 Thought processes, goals, and operators

For *Prototyping 6.1: Foot pedal for manual flushing*, the user's **goal** is to flush the toilet manually in case the automatic flushing function is not working. Available **operators** are a physical foot pedal that can be pressed with the foot to initiate

flushing and user's observation to check if the manual flush is successful such that:

1. User is aware of a malfunction in the automatic flushing function.
2. User identifies the foot pedal as the alternative flushing mechanism.
3. User presses the foot pedal and observes the toilet.
4. User confirms the flush is successful.

This predictive evaluation is planned to assess the user's ability to easily identify and use the foot pedal as an alternative to manual flushing or in case of automatic flushing malfunction.

For *Prototyping 6.2: Integrated weight scale to trigger flushing*, the user's **goal** is to ensure the automatic flushing function does not flush too early or too often. Available **operators** are an integrated scale to detect weight constantly and user's cognitive tasks to check if the flush is triggered appropriately such that:

1. User sits on the toilet, activating the built-in weight scale.
2. The weight scale constantly detects weights above 5 pounds.
3. The weight scale actively prevents automatic flushing during use.
4. User confirms that the toilet will not flush accidentally during use.
5. User leaves the toilet seat after use and starts observing.
6. The weight scale constantly detects 0 pounds for 10 seconds.
7. The weight scale executes a one-time flushing.
8. User confirms that the toilet flush after use.

This predictive evaluation is planned to assess the user's understanding of the built-in weight scale's functionality and its ability to control flushing.

#### **7.4 Preparing to execute**

We have elected to execute all evaluation strategies identified above. We believe that these 2 design alternatives are still in a concept phase, and will likely require an iterative development process to anchor optimal designs. The first step towards initiating this design iteration is to gather a wide range of user data to understand the initial thoughts and reactions to the ideas presented in the



prototypes. After this stage has been completed, it may be valuable to gather more evaluation data through empirical studies.

## 8 EVALUATION EXECUTION

### 8.1 Qualitative evaluation execution of the first prototype

This survey had 41 respondents. The survey remained the same for all participants. One thing that would be beneficial to do next time would be to combine the two surveys into one, to get the same participant pool and to save respondents' time.

#### 8.1.1 Raw results

Aggregate results can be found in *Appendix 11.4: Survey responses of the first prototype*.

#### 8.1.2 Analysis

The first, and most notable feedback about this interface is that there may be accessibility concerns with the design. Respondents noted that it may be difficult to use while sitting, or that users with accessibility issues may face difficulties operating the foot pedal.

Next, many users indicated that the design was intuitive, and even more indicated that the designed graphics for usage instructions were effective.

Lastly, nearly all survey respondents indicated that they believed the design prototype made the process of using the toilet more hygienic, and that it would provide an adequate alternate flushing method, which aligns with the targeted user needs of the design.

#### 8.1.3 Prototype changes

As a result of respondents' concerns about accessibility, the team has decided to leave **both** the traditional hand-operated lever and the new foot pedal. It is also important to note that this flushing mechanism is only to be used in cases of a malfunctioning automatic flushing mechanism, so it is expected that it will only

be used rarely. However, we decided to leave both options to ensure adequate accessibility for all users.

## **8.2 Qualitative evaluation execution of the second prototype**

This survey had 50 respondents. The survey remained the same for all participants. As noted in Section 8.1, one thing that would be beneficial to do next time would be to combine the two surveys into one, to get the same participant pool and to save respondents' time.

### **8.2.1 Raw results**

Aggregate results can be found in *Appendix 11.5: Survey responses of the second prototype*.

### **8.2.2 Analysis**

Over 70% of survey respondents indicated that they believed this design alternative would result in fewer accidental flushes, fulfilling our primary objective of the design. However, an alarming number of answers also indicated that they were either concerned or uncomfortable with the feature of the design that displayed a user's weight as they sat on the toilet seat. Many displayed discomfort, and some cited concerns of their privacy being breached, or simply felt the function was unnecessary.

Users also noted that the toilet relying on this detection method would not properly account for users that do not sit on the toilet while they use it (for example, standing while peeing into the toilet). They accurately asserted that this design would not detect their use, and as a result, would never flush.

Due to some of the aforementioned concerns, many of our respondents indicated that they felt less likely to want to use a toilet with this prototype put into action. Clearly, this design needs updating.

### **8.2.3 Prototype changes**

The first change to this prototype would be to remove the screen that shows users' weight while using the toilet, and replace it with an indicator light that

will illuminate while a user is detected sitting on the seat. After getting off the seat, the light will then turn off, indicating that the weight is no longer detected.

Next, the team will employ a combination of the current IR sensor with the new seat weight sensor, or will also add the design alternative from section 6.1 to give non-sitting users alternative flushing methods.

### **8.3 Predictive evaluation execution of both prototypes**

#### **8.3.1 *Cognitive walkthrough for the first prototype***

Regarding *Prototyping 6.1: Foot pedal for manual flushing*, the foot pedal is placed near the base of the toilet, within easy reach of the user's foot. It offers a hands-free alternative for flushing, enhancing the design principle of comfort. First, I approach the toilet and see the foot pedal, which is visibly different from the surroundings. The design principle of simplicity ensures that the foot pedal is the only noticeable interactive component, but a bright colored icon or light indicator near the foot pedal could be provided for additional visual cues. Next, when the automatic flushing is malfunctioning, I use the foot pedal. The placement of the foot pedal should allow my foot to rest and need to be reachable when I am done with using the toilet. The tactile feedback of the foot pedal, combined with the audible click, reinforces my action. This aligns with the design principle of ease of use. Then, the visual feedback of water movement in the bowl indicates a successful flush, aligning with the requirement of reliability.

#### **8.3.2 *Cognitive walkthrough for the second prototype***

Regarding *Prototyping 6.2: Integrated weight scale to trigger flushing*, the weight scale replaced the infrared sensor and took full control of the automatic flushing function, requiring no active user engagement. The weight scale is a passive feature, contributing to the design principle of simplicity. I can use the toilet without worrying about unintentional flushing, enhancing the design principle of comfort. First, my natural action of sitting in order to use the toilet initiates the weight scale, aligning with the design principle of ease of use. However, I am wondering how it works if I just need to pee as a male. Next, there is no action required from me during use, because the weight scale operates passively,

ensuring ease of use. I am wondering why the display screen is showing my weight in pounds, which is awkward. After use, the weight scale counts 10 seconds with a weight of zero. Then, a brief flash of the light indicator may signal me that a one-time flushing will be executed, aligning with the requirement of simplicity and reliability. Here, I'm also not sure if one flush is enough for special situations.

## **9 CONCLUSION**

### **9.1 Summary of findings**

We gained a comprehensive understanding of users and their needs regarding automatic flushing toilets throughout the first iteration of the design life cycle. The user demographic primarily consists of young adults, including those with varying technological expertise. Users seek a touchless, reliable, and comfortable restroom experience, with an emphasis on simplicity and ease of use.

#### ***9.1.1 User Understanding***

The design process evolved from initial needfinding through survey responses and participant observations. Takeaways of them highlighted concerns about the reliability of current automatic flushing toilets, emphasizing issues like untimely flushing, sensitivity problems, and privacy concerns. This information led to the formulation of the ultimate data inventory and requirements. By analyzing the data inventory and requirements, we found that the factors that mattered most to users were touchless interaction, reliability, simplicity, user comfort, and ease of use. This deeper understanding of the users allowed us to better meet their expectations and selected prototypes to address the identified issues from all design alternatives.

#### ***9.1.2 Model of the problem***

The initial problem modeling guided us to prototypes such as foot pedals and integrated weight scales. The first prototype introduced a foot pedal for manual flushing, offering an alternative in case of automatic flushing malfunctions. The second prototype replaced infrared sensors with an integrated weight scale to

prevent premature or excessive flushing. Throughout the execution of the survey and cognitive walkthrough, we obtained user perceptions of these designs. Similar to the cognitive walkthrough, user feedback from the survey revealed not only positive perceptions, but also some concerns such as accessibility issues with the foot pedal, privacy & public acceptance issues with the integrated scale. Finally, we considered some future adjustments for these two prototypes:

1. Incorporating a traditional lever alongside the foot pedal for accessibility in the first prototype.
2. Replacing the weight display with an indicator light for the second prototype.

## **9.2 Outline the next steps**

### ***9.2.1 Further research on user questions***

From user feedback we have learnt that there may be issues with the accessibility of the foot pedal. The question for further investigation is what specific groups of users may be experiencing difficulties in using it, and how these issues may be affecting their experience. Based on our insights into the accessibility issues, we need to redesign the foot pedal and may need to increase the fidelity of the prototype to more realistically simulate actual usage scenarios.

### ***9.2.2 Prototyping for increased fidelity and improvements***

The next steps in this project involve refining the prototypes. In response to the foot pedal accessibility issue, we plan to redesign the shape, position, and a traditional lever of the foot pedal. In addition, we will modify the design of the integrated scale to use an indicator light instead of a display, and we plan to use both infrared sensing and a new seat weight sensor to provide a reliable, clean design for triggered flushing. These modifications aim to enhance user comfort and privacy. The combination of sensors and alternative flushing methods further improves adaptability. Based on the new design adjustments, we will create higher fidelity prototypes, allowing for a more realistic representation of the proposed interfaces. Testing new improvements and changes would be vital

to gather more specific feedback on the usability and effectiveness of the prototypes.

### **9.2.3 Evaluate the combination of types**

In order to obtain more comprehensive data, we will expand the scale of our user surveys to ensure that each user group is represented. We will be ready to plan and execute empirical evaluation in order to measure the robustness and efficiency of designs. Ongoing user feedback and iterative testing would be crucial to refining the designs and ensuring the redesigned interfaces meet users' evolving needs. Therefore, new questions may arise when conducting larger user surveys, such as:

1. How does the user interact with these prototypes in various restroom environments?
2. Are there additional features or adjustments that could further enhance the user experience?

Taking into account the new user feedback and test results, we will conduct the next iteration of the design to ensure that accessibility issues and privacy concerns have been addressed. With new prototypes and design adjustments, prepare for more in-depth field testing and consider introducing the design into real-world use. Through these steps, we will be able to fully optimize the design, address the issues that have been identified, and ensure that the new design solution is accepted by a wider user base. Following the implementation of this series of steps, we may consider more extensive field testing to verify the feasibility and effectiveness of the design in actual use.

## **10 REFERENCES**

1. <https://learn.geberitnorthamerica.com/blog/hands-free-toilet-flush-all-you-need-to-know>
2. <https://science.howstuffworks.com/environmental/green-science/are-automatic-toilets-still-wasting-water.htm>

3. <https://www.tap-sensor.com/blog/what-is-automatic-toilet-flusher-and-how-does-it-work.html#:~:text=Automatic%20toilet%20flusher%20uses%20active,leave%2C%20it%20flushes%20water%20automatically>

## **11 APPENDICES**

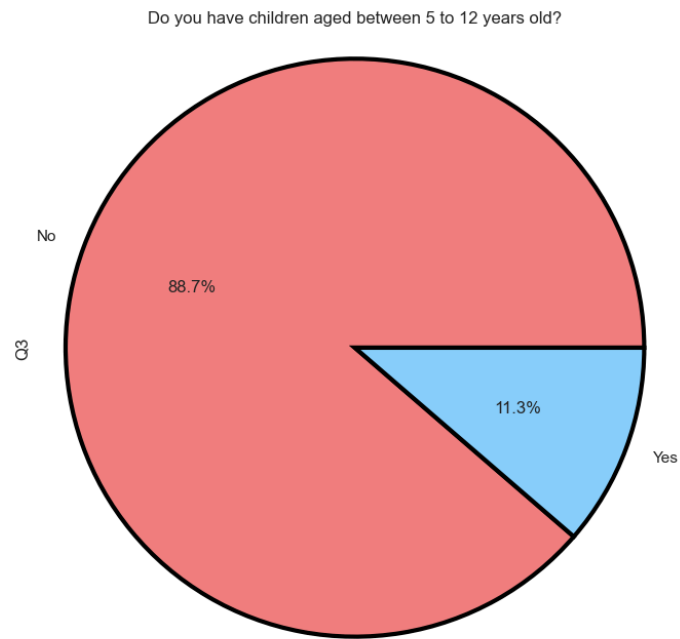
### **11.1 The survey questions for needfinding**

4. What is your age?
  - a. Under 18
  - b. 18 - 29
  - c. 30 - 39
  - d. 40 - 49
  - e. 50 - 64
  - f. 65+
5. What is your gender?
  - a. Female
  - b. Male
  - c. Prefer not to say
6. Do you have children aged between 5 to 12 years old?
  - a. Yes
  - b. No
7. What do you think about your technological expertise?
  - a. Novice
  - b. Moderate
  - c. Advanced
8. What is your frequency of using automatic flushing toilets?
  - a. Very Frequently
  - b. Frequently
  - c. Occasionally
  - d. Rarely
  - e. Never
9. Choose any following factors you believe are critical in improving the interface of automatic flushing toilets:

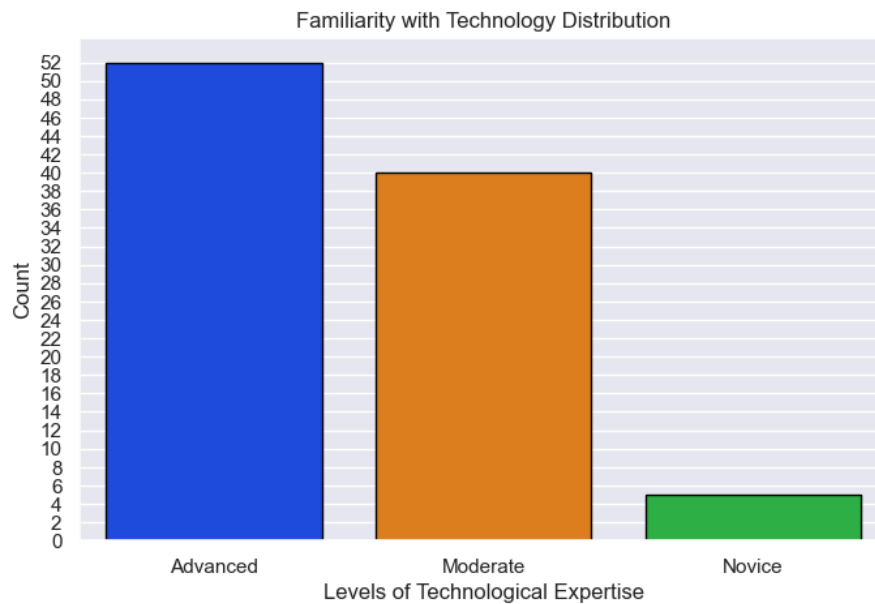
- a. Simplicity
  - b. Ease of use
  - c. Accessibility
  - d. Comfort
  - e. Supportiveness
  - f. Efficiency
  - g. Feedback
10. What are your locations for using automatic flushing toilets?
- a. Restaurants
  - b. Shopping malls
  - c. Offices
  - d. Homes
  - e. Hotels
  - f. Others
11. (Optional) If you choose "others", please specify below.
12. Could you briefly share some thoughts or concerns on your user experience of using automatic flushing toilets?
13. (Optional) If you have children, could you briefly share some thoughts, concerns, or suggestions of additional features for children using automatic flushing toilets?



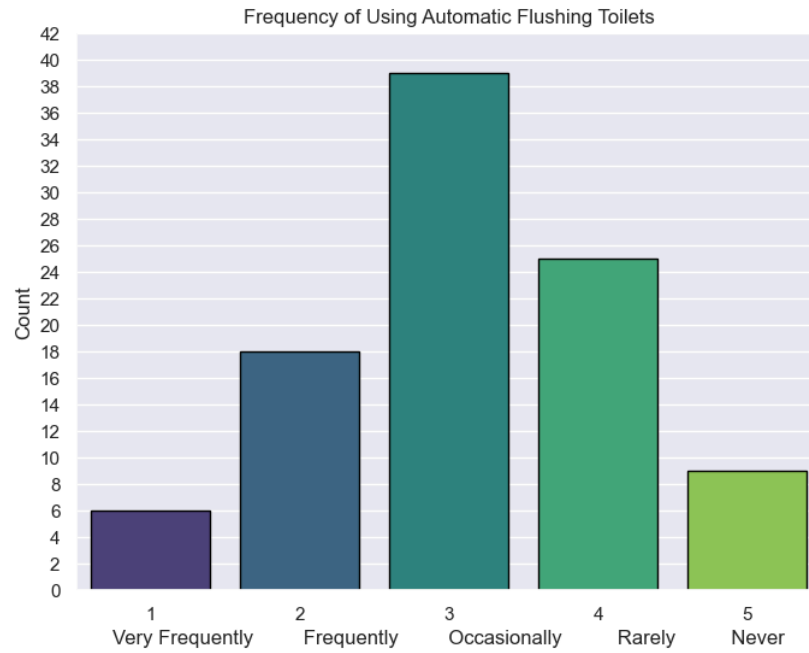
## 11.2 The preprocessed data and collected survey responses



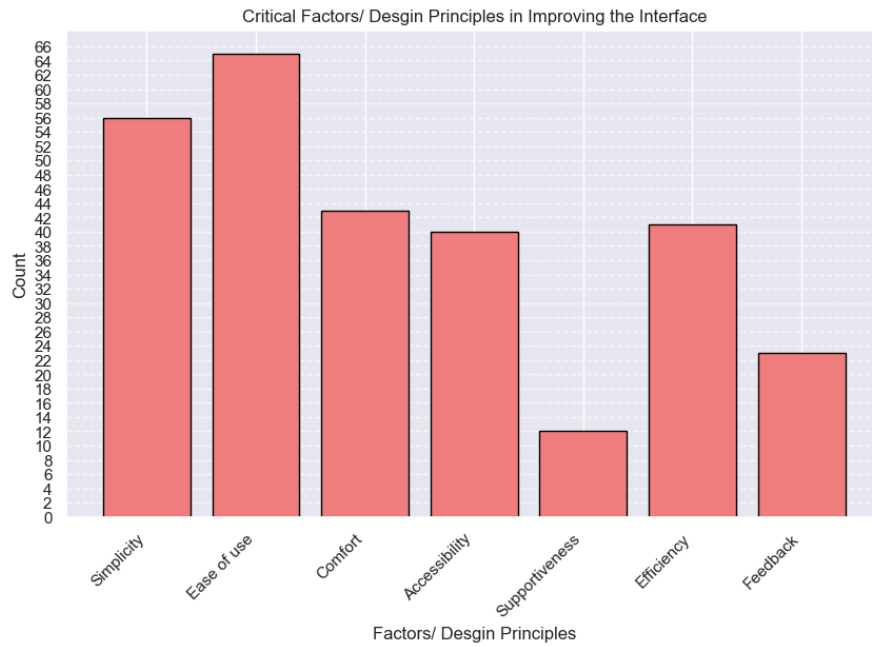
*Figure 6*—Children count. Majority of participants do **not** have children, but **11** participants who have children provided **valuable** additional feedback that represent the user type of **children**.



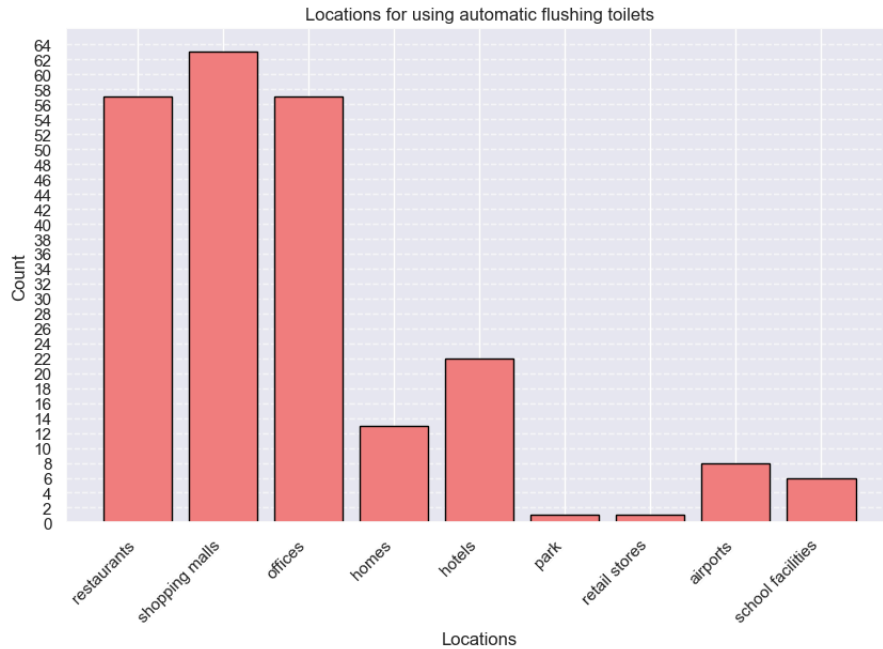
*Figure 7*—Technological expertise distribution. This could be correlated with the fact that the majority of participants fall in the 18-29 age group.



*Figure 8*—Automatic flushing toilets usage. Looks like a normal distribution.



**Figure 9**—Critical factor/ design principles in improving the interface. Higher importance placed on **ease of use, simplicity, comfort, and accessibility**.



**Figure 10**—Locations distribution. More common to use automatic flushing toilets in **restaurants, shopping malls, and offices**.



**Figure 11**—Generated WordCloud from **thoughts** or **concerns** on participants' experience of using automatic flushing toilets.



- a. Very Frequently ← **6 participants selected**
  - b. Frequently ← **18 participants selected**
  - c. Occasionally ← **39 participants selected**
  - d. Rarely ← **25 participants selected**
  - e. Never ← **9 participants selected**
19. Choose any following factors you believe are critical in improving the interface of automatic flushing toilets:
- a. Simplicity ← **56 participants selected**
  - b. Ease of use ← **65 participants selected**
  - c. Accessibility ← **40 participants selected**
  - d. Comfort ← **43 participants selected**
  - e. Supportiveness ← **12 participants selected**
  - f. Efficiency ← **41 participants selected**
  - g. Feedback ← **23 participants selected**
20. What are your locations for using automatic flushing toilets?
- a. Restaurants ← **57 participants selected**
  - b. Shopping malls ← **63 participants selected**
  - c. Offices ← **57 participants selected**
  - d. Homes ← **13 participants selected**
  - e. Hotels ← **22 participants selected**
  - f. Others ← **16 participants selected**
21. (Optional) If you choose "others", please specify below.
- a. park ← **1 participants selected**
  - b. retail stores ← **1 participants selected**
  - c. airports ← **8 participants selected**
  - d. school facilities ← **6 participants selected**
22. Could you briefly share some thoughts or concerns on your user experience of using automatic flushing toilets?
1. Most of them aren't automatic
  2. My experience using it is in Japan and the labels are in Japanese so I don't know what each button means. I have to guess based on the icons.

3. no toilet seat lids cause water to spray on you before you've been able to exit the stall
4. They flush too soon.
5. I don't know when they'll flush, poor feedback, it seems there is no identifiable pattern
6. Very convenient
7. Sometimes they won't flush and it's annoying trying to figure it out since it's supposed to do it on its own
8. they don't always work and you have to hit the button anyways. Or it will activate too early if you lean forward.
9. Overall, I think it's a good idea, but it needs to work properly - i.e. needs to flush at the correct time, not flush multiple times. The detection when it needs to flush has to be better.
10. It is not necessary in my mind..
11. A lot not responsive
12. Automatic flushing toilets are sometimes faulty and will flush when you go to sit down or won't flush when you stand back up.
13. I have been using them for pretty much my whole life and I don't even think about it anymore. They just work.
14. If you go to the toilet standing up, sometimes the sensor doesn't pick up and the toilet doesn't flush
15. I don't like that they regularly flush while they're still in use. I'd also like some sign that it's about to flush. Perhaps a way to delay the flush, like snoozing an alarm
16. They should be fast and reliable.
17. none

18. No concerns

19. NA

20. flush accuracy can be improved -- it sometimes doesn't flush when you want it to flush and sometimes flushes when you don't need it to flush. when it doesn't flush, sometimes it is hard to figure out where you are supposed to wave your hand or what button you need to press to manually trigger the flush

21. I was trying to get some tissue and the toilet started flushing. When I was trying to wipe my ass. The toilet when flushing out of nowhere

22. Seems like they waste water

23. usually they're pretty useful and they're in public places where you don't want to be touching an area where a bunch of other people are touching it

24. It's inconvenient when the sensor doesn't work and I have to press a button to flush. it defeats the purpose

25. My main issue with them is they tend to flush even if you just move your back a little. That's a little annoying.

26. Need for consistent flushing. Specifically determining how to optimize for false positives and true negatives better so your default interaction is more positive.

27. most of them work fine except for the one in the fine art building

28. They are too sensitive when it comes to moving around in the seat and flushing when you're just grabbing more toilet paper

29. Mainly the issues where the toilet flushes when not appropriate like while walking to the toilet or while using it

30. Too sensitive, too much water used

31. It's upsetting when they flush too early. It can also be annoying when they don't flush after use
32. Soso
33. Sometimes the sensor is inaccurate and flushes when I'm still on the toilet
34. it's horrible when they flush while you are still on the toilet
35. sensor
36. Sometimes the toilet flushes too early. Sometimes I am leaving and no flush happens.
37. The interfaces have lots of buttons and some with foreign language. It took me a while to figure out which button did what.
38. it flushes too quickly
39. Sometimes it's difficult to flush multiple times when needed or know how to flush when the sensor isn't working properly.
40. NA
41. sometimes they don't flush
42. How many time it flushes
43. I've felt they trigger falsely at times.
44. Need to increase more user control
45. I don't like when they flush when I don't want them to
46. water waste
47. They seem to flush kind of randomly (e.g. as you approach the toilet), not necessarily at the right time.
48. I hate how it starts flushing while you're still using it and haven't gotten up. Also hate how it's not sensitive enough and doesn't



automatically flush. In those instances sometimes it's hard to figure out which button needs to be pressed to manually flush.

49. I'm always scared of them flushing too early on me, and it occasionally happens :(((

50. sometimes I still have to reach for manually flushing

51. I am concerned that the sensor is too sensitive.

52. Flushing too soon or not flushing at all

53. I hate it when it automatically flushes when i don't need it to just yet

54. Sometimes they do not work and it's not always clear how to manually trigger

55. I find the current design to be effective when the motion sensor is functional and not too sensitive.

56. Potential waste for multiple flushes due to sensor issues

57. Accurate rate of flashing at the right time

58. simple is good

59. sometimes it doesn't detect when I'm done using the toilet

60. They can scare young kids

61. I am concerned about their hygiene in general

62. Splash back in urinals. For sit downs, high force that creates splashing... not good when I'm still sitting.

63. Great sensing technology can improve the automatic flushing toilet experience

64. being not sure when it will flash

65. Concern is of wastage of water, defected sensors

66. Automatic flushing toilets can be designed to use water more efficiently, helping to conserve water compared to traditional toilets. So water conservation in these toilets is a concern.

67. The toilet flushing while I'm still sitting on it.

68. sometimes they flush too early or not at all which can be a problem if you have to find the small button you need to press to flush it manually

69. bad flushing time

70. unreliable

71. Sometimes, the toilet doesn't immediately sense that the user has gotten up, so it doesn't flush right away; Other times, the sensor may get triggered when it shouldn't, wasting water

72. my main concern is that it flushes before I want it to sometimes

73. NA

74. Overly sensitive or hard to manually flush (e.g. tiny button to flush if toilet does not automatically flush)

75. Never used them, sounds super smart though

76. There's no way to increase or decrease the amount of water used for each flush.

77. Sensors sometimes trigger too quickly, an occasional inconvenience.

78. it's good

79. no reliable for when to flush

80. it wastes a lot of water with premature flushing

81. Sometimes it just doesn't work

82. None

83. It's frustrating when the sensor does not work. Many of the manual actuators are unable to be pressed hygienically (such as with my shoe)
84. I just want them to work consistently.
85. Flushing when laying the seat cover, not flushing when needed
86. sometime sensor doesn't detect and it takes a minute to identify the manual button
87. sometimes it's not reliable
88. na
89. It flushes too early and I will usually have to flush it again.
90. I would prefer a touchless option rather than automatic, or automatic after I have left the stall.
91. durability and cost of maintenance
92. Toilet flushing outside the bounds of when I expect it to flush
93. i fear there is hidden camera (safety i guess)
94. N/A
95. When I stand to reach out for something nearby, the sensor detects my move, and it flushes automatically. This is a bit annoying, not necessarily frustrating.
96. Take some time to understand the meaning of each button. Hard to read those tiny letters when I'm sitting on the toilet.
97. It flushes a few times.
23. (Optional) If you have children, could you briefly share some thoughts, concerns, or suggestions of additional features for children using automatic flushing toilets?

9. It's good for kids because they often forget to flush, or don't realize the 'need' to flush, so it's good for that, but on the other hand, if this system is widespread, they are never going to get into the habit of flushing. On the other hand, if this system is widespread, there is no need for anyone to learn how to flush :)

21. When my toddler falls into the toilet. The toilet will flush him away

24. They're very loud and usually scare little ones.

31. N/A - My children are not yet potty trained

41. kids often move around a lot, maybe making sure it doesn't flush until they actually leave the toilet

47. When my kids were small, they'd probably get a kick out of triggering the flush as many times as possible.

60. Kids would prefer quieter flushes

77. No children, but child-friendly designs could include adjustable sensor sensitivity and engaging visuals.

90. My kids were very scared of the anticipation of the toilet flushing when they weren't expecting it.

95. Child lock should be in place.

### **11.3 Survey questions for evaluation 7.1**

1. What is your age?
  - a. Under 18
  - b. 18 - 29
  - c. 30 - 39
  - d. 40 - 49
  - e. 50 - 64
  - f. 65+
2. What is your gender?

- a. Female
  - b. Male
  - c. Prefer not to say
3. Do you have children aged between 5 to 12 years old?
- a. Yes
  - b. No
4. What do you think about your technological expertise?
- a. Novice
  - b. Moderate
  - c. Advanced
5. What is your frequency of using automatic flushing toilets?
- a. Very Frequently
  - b. Frequently
  - c. Occasionally
  - d. Rarely
  - e. Never
6. Choose any following factors you believe are critical in improving the interface of automatic flushing toilets:
- a. Simplicity
  - b. Ease of use
  - c. Accessibility
  - d. Comfort
  - e. Supportiveness
  - f. Efficiency
  - g. Feedback
7. What are your locations for using automatic flushing toilets?
- a. Restaurants
  - b. Shopping malls
  - c. Offices
  - d. Homes
  - e. Hotels
  - f. Others

8. Based on the prototype shown, do you think you understand the purpose of the manual flushing foot pedal?:
  - a. Yes
  - b. No
9. Would you use the manual flush foot pedal?
  - a. Yes
  - b. No
  - c. Not sure
10. Based on the design as you see it, do you have any comments or suggestions for the design?
11. Now that you have been provided with instructions for use, do you think you understand the purpose of the manual flushing pedal?
12. Based on the instructions provided, do you have any comments or suggestions for the design?
13. How do you think the hygiene of this prototype compares to traditional, hand-operated flush levers or buttons?
  - a. More hygienic
  - b. The same
  - c. Less hygienic
14. Do you believe that this design would provide a reasonable method for you to flush a toilet manually in the case of a malfunction of the automatic flushing function?
  - a. Yes
  - b. No
15. Would you be more or less likely to own a self-flushing toilet if the prototype shown was implemented?
  - a. More likely
  - b. Less likely
  - c. The same

#### **11.4 Survey questions for evaluation 7.2**

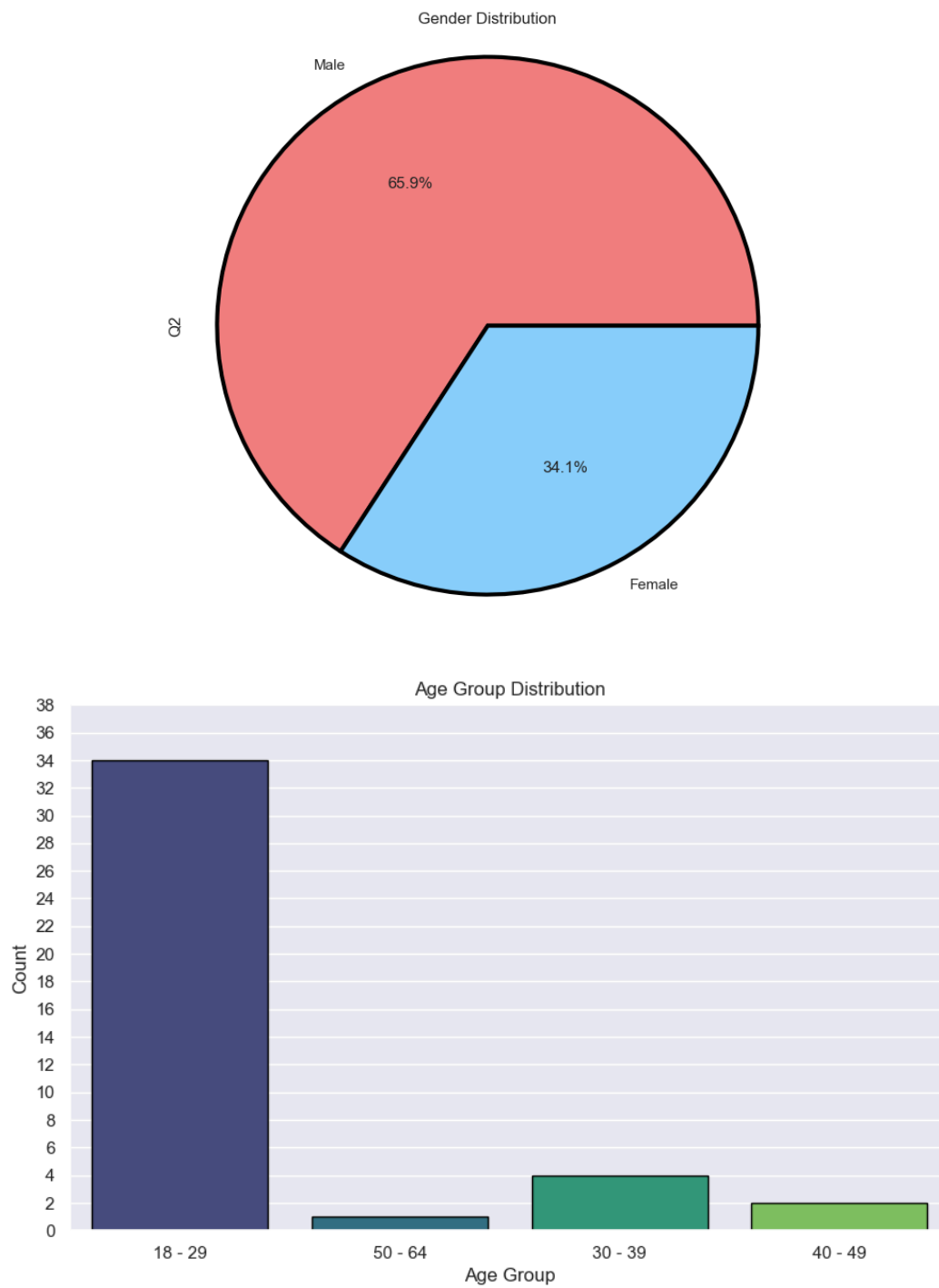
1. What is your age?
  - a. Under 18

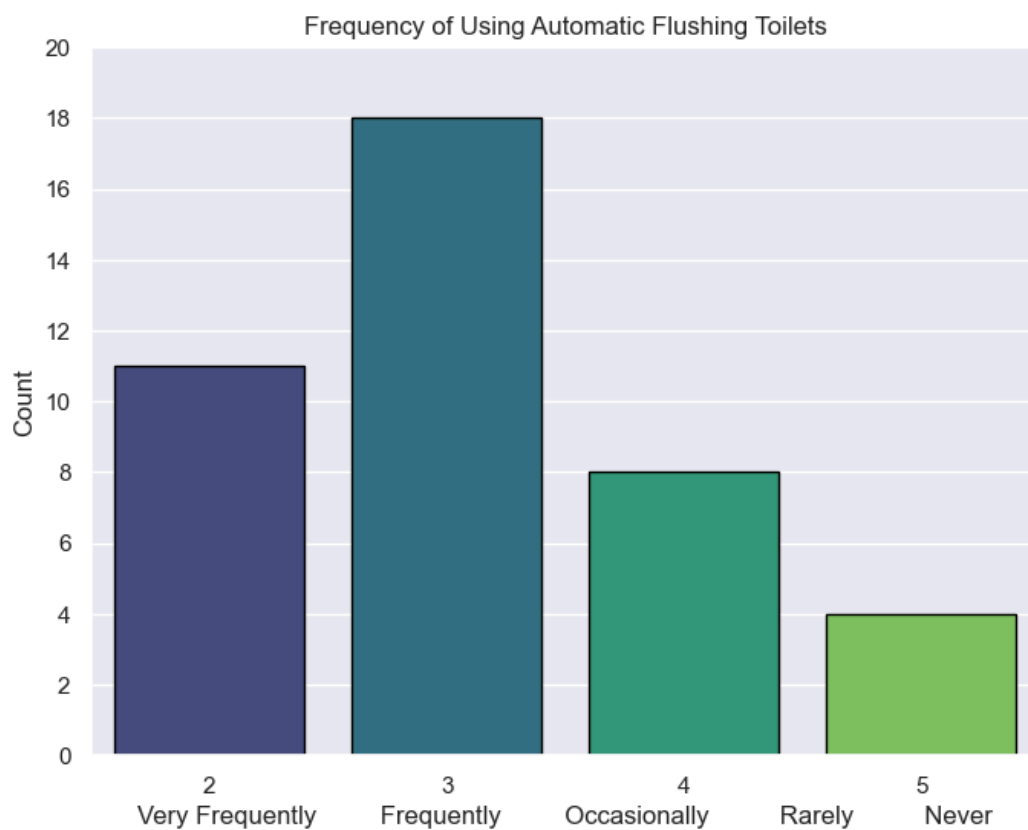
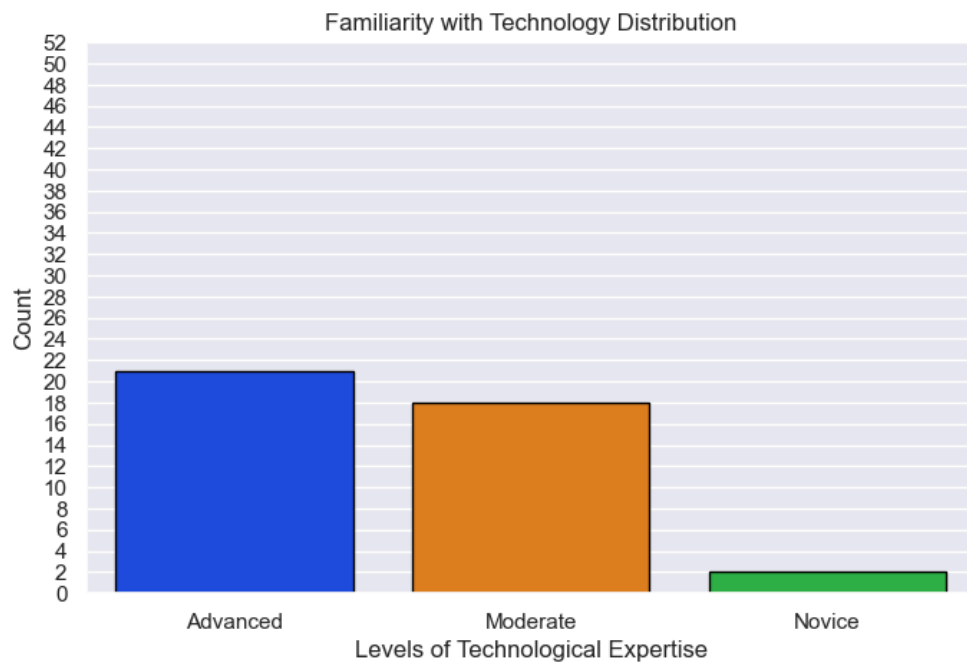
- b. 18 - 29
  - c. 30 - 39
  - d. 40 - 49
  - e. 50 - 64
  - f. 65+
2. What is your gender?
- a. Female
  - b. Male
  - c. Prefer not to say
3. Do you have children aged between 5 to 12 years old?
- a. Yes
  - b. No
4. What do you think about your technological expertise?
- a. Novice
  - b. Moderate
  - c. Advanced
5. What is your frequency of using automatic flushing toilets?
- a. Very Frequently
  - b. Frequently
  - c. Occasionally
  - d. Rarely
  - e. Never
6. Choose any following factors you believe are critical in improving the interface of automatic flushing toilets:
- a. Simplicity
  - b. Ease of use
  - c. Accessibility
  - d. Comfort
  - e. Supportiveness
  - f. Efficiency
  - g. Feedback
7. What are your locations for using automatic flushing toilets?

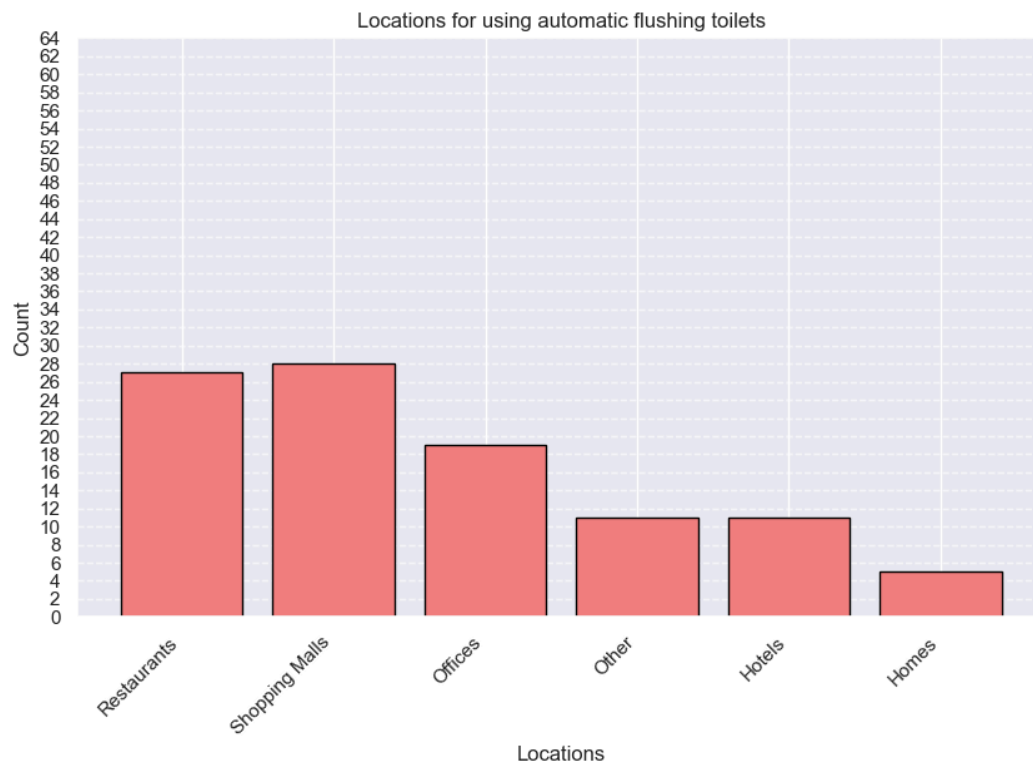
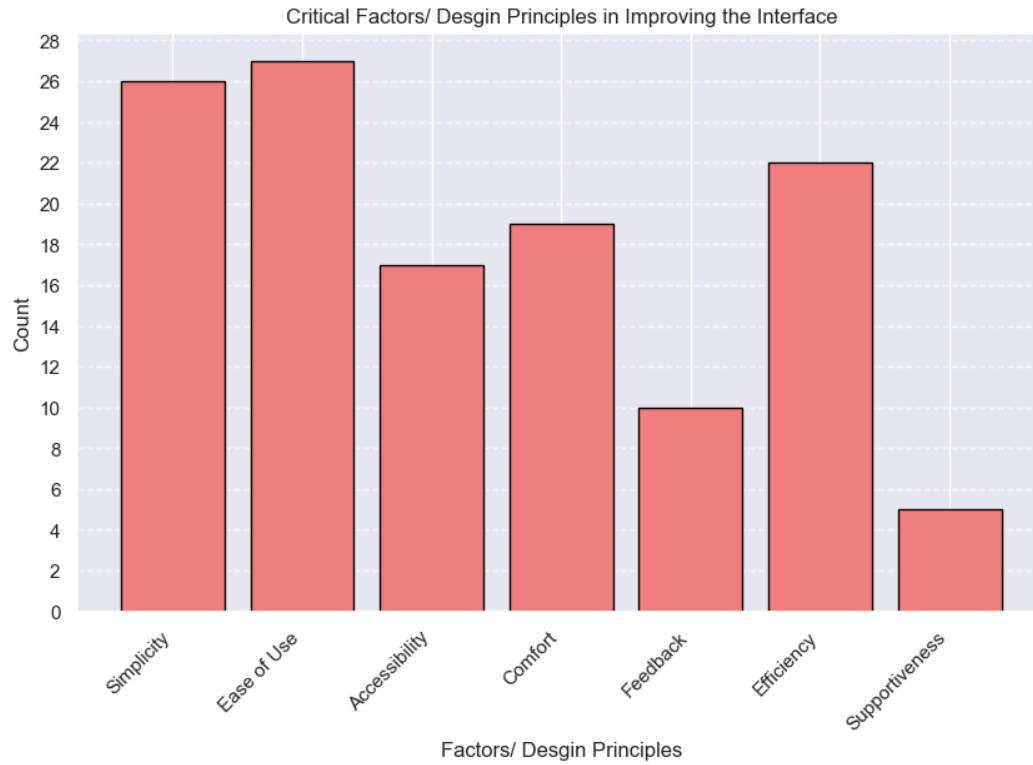
- a. Restaurants
  - b. Shopping malls
  - c. Offices
  - d. Homes
  - e. Hotels
  - f. Others
8. Based on the prototype shown, do you think you understand the purpose of the integrated scale?
- a. Yes
  - b. No
9. Do you think that the integrated scale is an effective means of reducing accidental or repetitive flushes?
- a. Yes
  - b. No
  - c. There are no such flushes to reduce.
10. Please share your thoughts regarding the proposed design:
11. Would you be more or less likely to own a self-flushing toilet if the prototype shown was implemented?
- a. More likely
  - b. Less likely
  - c. The same



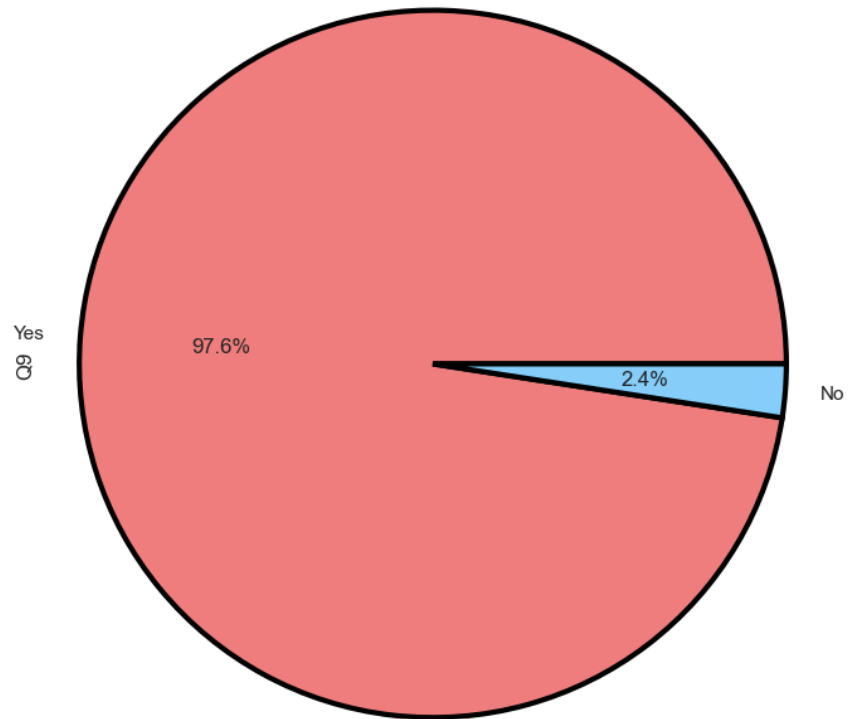
## 11.5 Survey responses of the first prototype



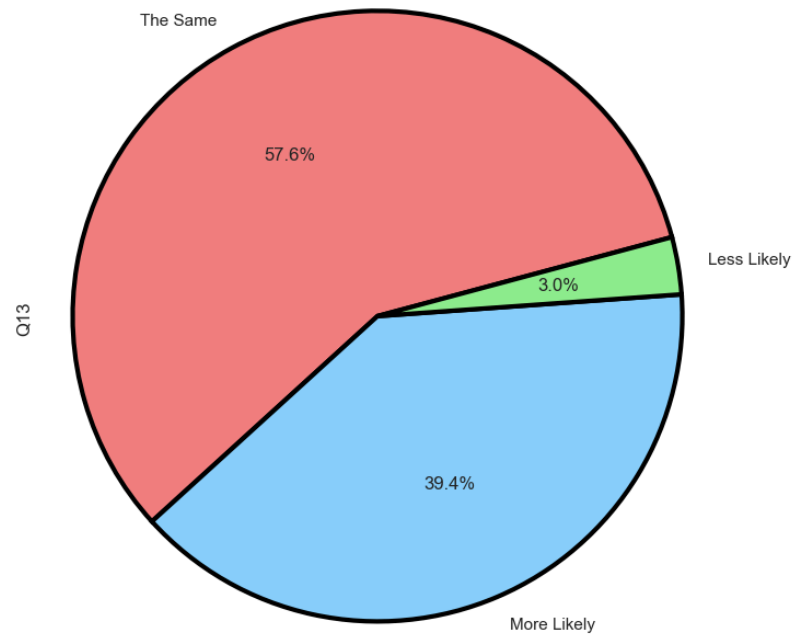




Would you use the manual flush foot pedal?



Would you be more or less likely to own a self-flushing toilet if the prototype shown was implemented?



**Please share your thoughts on the proposed design.**

- 1.
2. No
- 3.
- 4.
- 5.
6. Don't make the sensor too sensitive to the point where even movement on the seat can cause an accidental flush
- 7.
8. No, it looks good
9. Looks like there's an automatic detector, and if that doesn't work you can use the pedal
10. n/a
11. Good design.
12. I don't understand why the prototype shows an automatic flush control box, but also has a manual flush pedal.
13. It is convenient to avoid using your hands to flush.
14. Cleaner than using your hands
15. Can force break the pedal?
16. sounds good
17. nah
18. Great idea, however I don't think it'd be fully accessible for everyone.
19. Might be a little awkward to use manual flush pedal when sitting

20. No really
21. I think this is a good design as many prefer not to touch the handle in public settings.
22. The idea looks good - the logistics seems to state that the manual foot flush requires standing, but would be good to be able to press it while sitting. Also, would be curious how the flush works while sitting, since the detection is based on movement (I assume)
23. Seems to be more hygienic.
24. It's real nice looks easy to use and more sanitary
25. I'm not sure if the flush pedal is stepped on before or after using the toilet (if it flushes on press or release). Would likely assume press after using the toilet.
26. Good, better than touching dirty surfaces with hands
27. I like the physical intersection of pedal being used for flush
28. the automatic sensors are often inaccurate and flushes when I'm still using the toilet
29. You would be able to use the foot pedal that is more at the level of your foot instead of a flush lever higher on the toilet which would be beneficial and easier to push.
30. good ideas so you use your hands less. Less hands = less bacteria spreading.
31. I might not understand the purpose of the foot pedal right away, as it is not a design I have encountered. Otherwise, it seems very natural
32. I think it makes sense. Having a pedal significantly simplifies the process of flushing.
33. Yes
34. More hygiene

35. I like it overall. Hard to tell what the possibility of setting it off while using it is however.

36. Like that there is a pedal I can step on, rather than using my hand, to flush in case of the automatic flush not happening.

37. It looks like the pedal is used when the automatic flush does not trigger, and is a way to flush hygienically

38. why is there a pedal

39. N/A

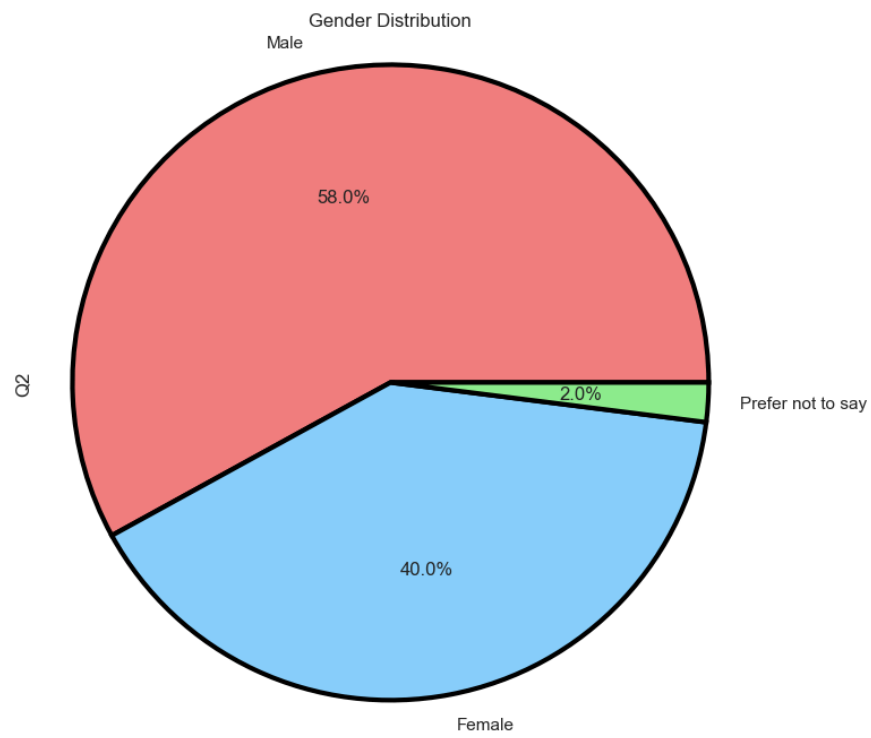
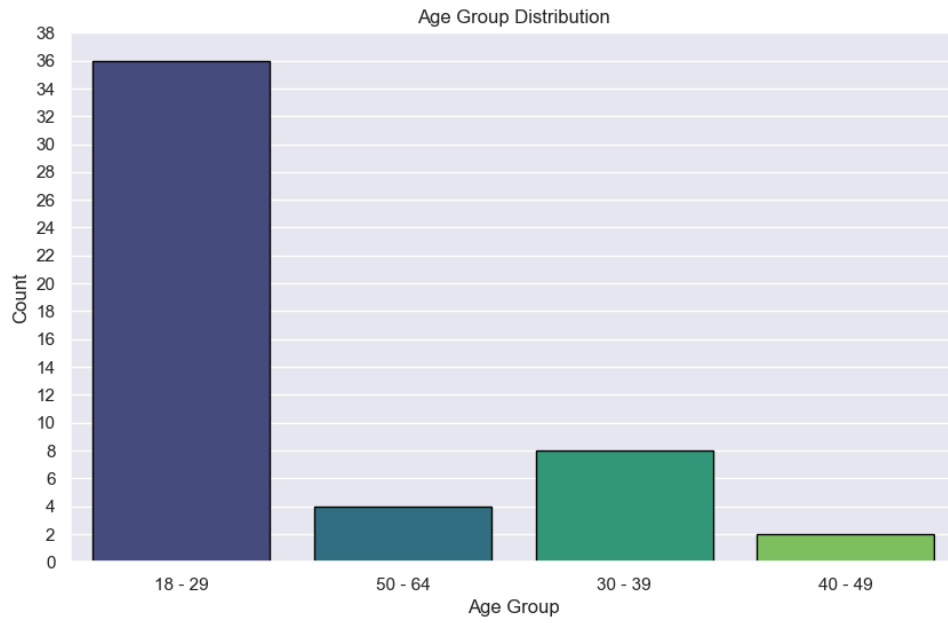
40. How do I flush it while I'm sitting down?? With my heel?

41. looks good

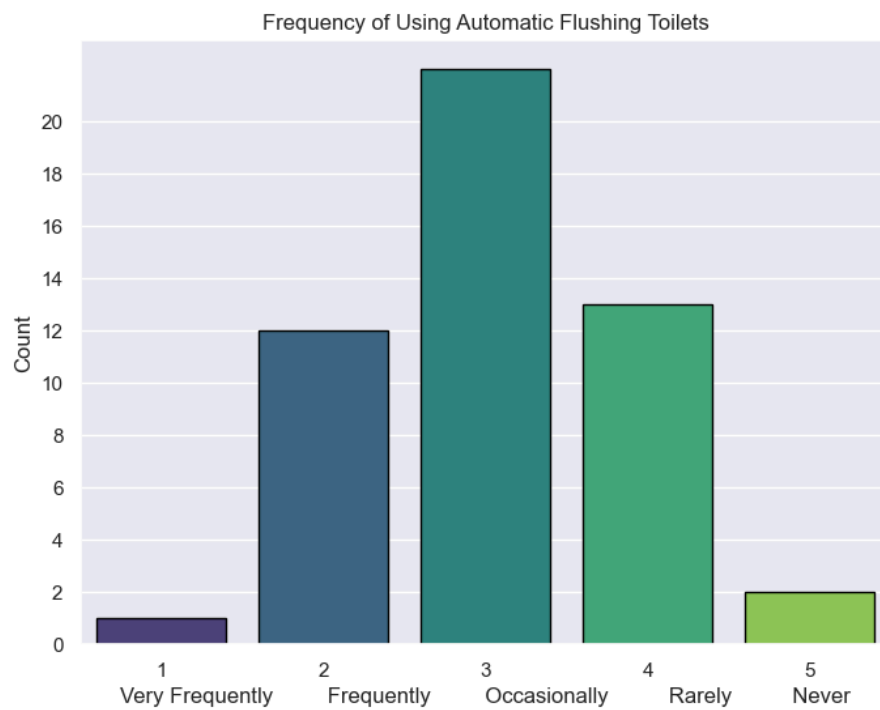
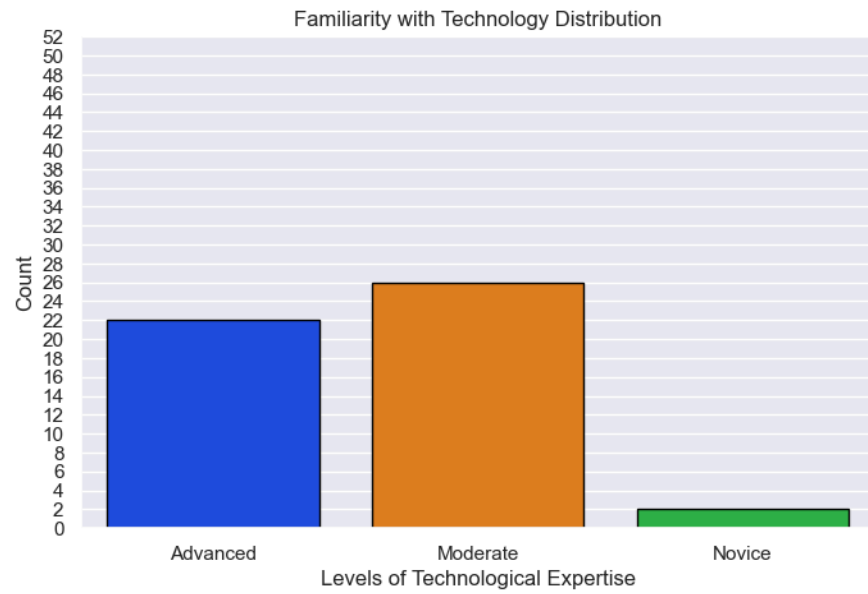
42. Slight concern of accidental trigger.

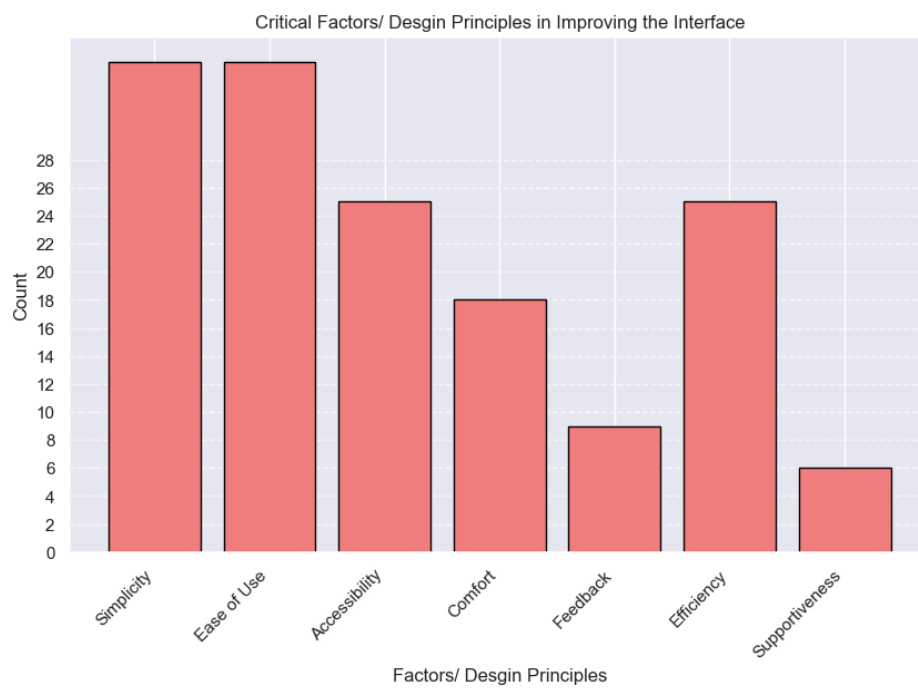
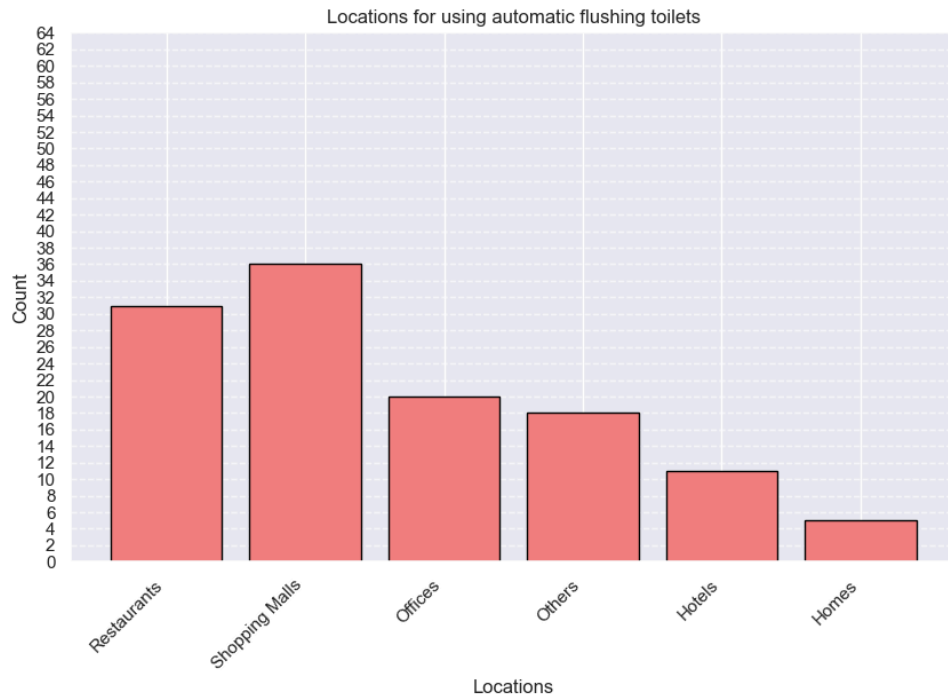
43. A little cluttered and a little difficult to understand

#### **11.6 Survey responses of the second prototype**

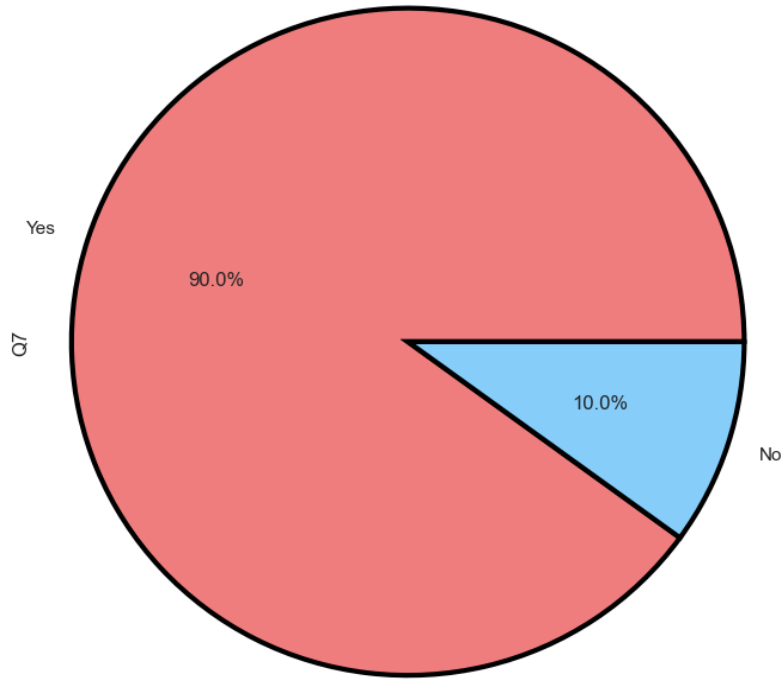




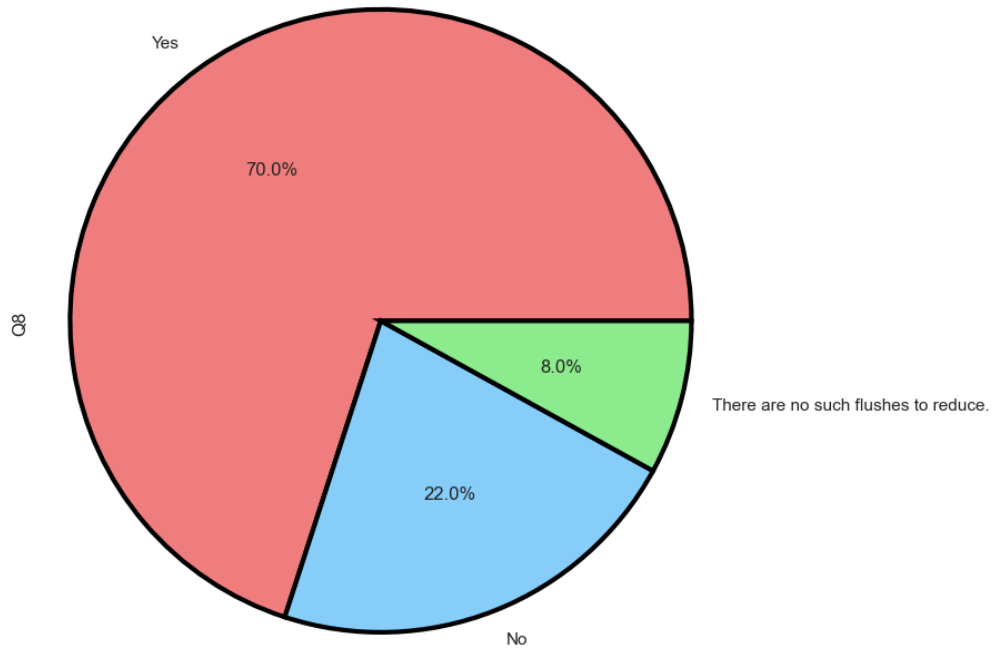




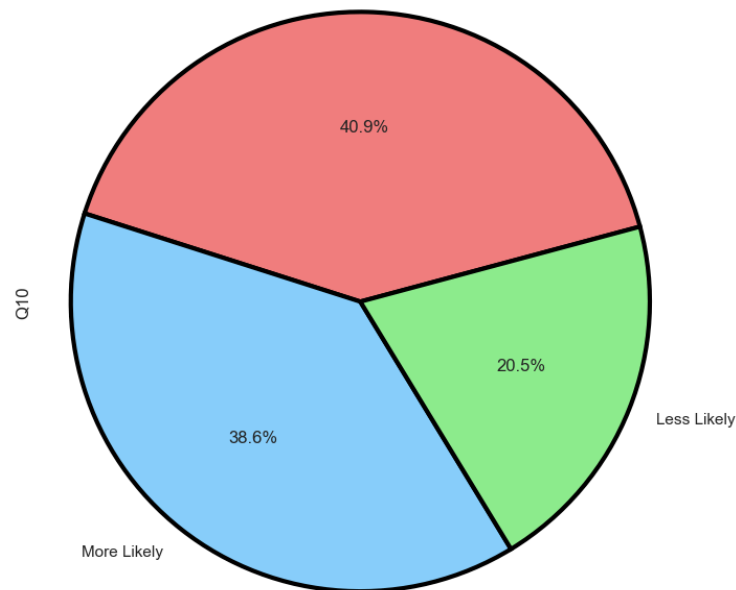
Do you think you understand the purpose of the integrated scale?



Do you think that the integrated scale is an effective means of reducing accidental or repetitive flushes?



Would you be more or less likely to own a self-flushing toilet if the prototype shown was implemented?  
The Same



Share your thoughts regarding the proposed design.

1. No
2. Way too complicated, no need for a screen to show users their weight. Just a simple mechanism to detect when the weight is gone.
3. I do think the integrated scale would be the best for understanding the body mass I've lost during the session.... also what if multiple flushes are needed ?

4. Toilet will flush prematurely at ten seconds of zero weight when the user may not be finished wiping.
5. Toilet will flush prematurely at ten seconds of zero weight when the user may not be finished wiping.
6. I believe that this type of fixture would only really be appreciated in private restrooms. Most people would not sit on a public toilet even if there were hygienic paper covers available.
7. Displaying a weight may seem problematic to some users. Maybe a message saying "weight detected" would be ok.
8. I think it is a very cool and efficient feature to integrate in an automatic/self-flushing toilet which can prove to be very useful
9. If it can actually detect the constant weight that would be great. My only complaint for self flushing toilets is that they flush when you're still sitting
10. n/a
11. simplicity
12. n/a
13. I like it. I would buy it.
14. I'm not sure why the design shows the weight from the scale--it is actually very odd to me. Registering someone's weight is enough to reduce accidental or repetitive flushing, please further explain why you would also include a screen.
15. Good design I hope it doesn't display the weight. Also is there a spring mechanism to the part where people will sit?
16. It's nice.
- 17.
18. While I understand the purpose of displaying the current weight, some people may not feel comfortable with that constantly presented to them while

using the toilet. Also, this seems limited: how would this work for someone just peeing?

19. I believe this will improve the efficiency of the automatically flushing toilets.

20. I like the design

21. Same as the manual flush - would like to know how to trigger the flush while sitting.

22. I think the functionality is cool. I think the actual design should look more like a toilet though.

23. I think it looks ok it's just why display the weight on the screen that seems a bit weird

24. I like the 10 second addition.

25. 10 seconds seems unnecessarily long. 2-3 seconds seems more reasonable.

26. Interesting and worth a try. Maybe be careful with displaying the \*full\* weight as some people are weight conscious.

27. Very sleek, but I'm not sure about actually seeing my own weight displayed to me. That might be upsetting to some people who have issues with weight, even though I understand the function of it.

28. IR sensor design works fine, manual pedal much more effective as backup

29. I like the 10 second addition.

30. feels like the budget and extra electric used would be more than the water bill.

31. I really like the idea of detecting if someone's weight is on the throne, but I don't know if it needs to display their weight. Only concern would be to ensure the weight does not remain on the display for long so the next person can see.

32. Interesting prototype, I like the interaction of human and technology in your prototype

33. I don't think you need to show the weight in pounds, maybe an indication that it's in use.
34. nothing
35. I think this would help with accidental flashes as long as the scale is accurate and not too sensitive
36. NA
37. This would help the issue of toilets flushing too early.
38. my two cats may trigger it quite often
39. some people would not want to be weighed, or at the very least would not want to see the weight. Potential privacy issues if it was hacked. Also it looks more like a composting toilet than a flushable one.
40. I think this is a very good idea and would be more reliable than current sensors. One change I would make is for the display screen only to say whether the toilet is in use, as many people would not want to see their weight
41. I don't see the benefit of having a scale.
42. Useful
43. Lid feels more hygienic than no lid
44. I'm not sure anyone really wants to be weighed while using the toilet
45. I think intuitively it makes sense, however I personally would not like to see my weight when sitting on the toilet
46. I like the 10 second wait limit before the flush is initiated. Although idk if its necessary to display the actual weight. Instead there could be a light or some other indication showing that the toilet is being used.
47. Good idea!
48. what if the person does not want to see their weight

49. N/A

50. Why display the weight?

## 12 INDIVIDUAL REFLECTIONS

### 12.1 Xiangsheng Gu

I initialized the sharable textual skeleton on Google docs for our team's collaborative working environment after reviewing assignments from M1 to M5 and connecting individual structure with the team project contents and criteria. I proofread the introduction and defined the problem space and user types. I completed the entire needfinding planning section. For participant observation, I reported survey results, summarized my interpretations, and discussed how I handled or acknowledged biases. For my second needfinding plan, I collected all the survey responses in the form of a CSV file and processed raw data into histograms, pie charts, and WordCloud using Python via JupyterLab. I reported its result with graphs, summarizing my interpretations, and discussing how I handled biases. I wrote the *Appendix 11.2: The preprocessed data and collected survey responses* and I wrote the abstract (week 13, **22** hours). In order to complete the whole section 4: *Data inventory and requirement definitions*, I compared data inventory from *Needfinding planning 2.1.1: Data inventory* and *Needfinding planning 2.2.1: Data inventory* with takeaways from executions. I finished the data inventory and requirements that align with design principles and I made evaluation metrics for measuring success of redesign interface. I modified my previous brainstorming plan from assignment M3 and used it to revise the general planning of individual brainstorming. I set up the meeting for the group brainstorming session. In the role of host and recorder, I gathered a voice chat for the group session via Discord and recorded the entire process by writing down all ideas during the session. I contributed 5 design alternatives from my individual brainstorming to the list of ideas and expanded them during group brainstorming. I rewrote *Design alternatives 5.2: Selection criteria* in order to specifically discuss heuristics for selecting ideas and connections of section 4: *Data inventory and requirement definitions*. I designed the paper prototype for the second idea, provided its explanation, and its evaluation. (week 14, **13** hours). I



proofread and revised some parts of *Evaluation planning 7.1* and *Evaluation planning 7.2*. I developed the plan of cognitive walkthrough for *Evaluation planning 7.3 Predictive evaluation planning of both prototypes*. I executed my predictive evaluation and wrote *Evaluation execution 8.3 Predictive evaluation execution of both prototypes* (week 15, 8 hours). I added more details in the conclusion section regarding my perspective throughout this project and completed my individual reflection. (week 16, 4 hours).

**Spencer Browne** conducted research related to automatic flushing toilets and wrote the introduction of the project. To facilitate an effective brainstorming, he developed and refined procedures and rules for both brainstorming plans. He actively participated in the group brainstorming session and contributed 9 good ideas. He designed the first prototype and formulated two qualitative evaluation plans for each design alternative. He made two surveys for each design alternative, analyzed the collected responses in the executions of qualitative evaluations, and proposed changes for these prototypes. **Cuicheng Zheng** actively participated in the group brainstorming session, summarized the impact of time span on user experience participant observation, contributed some good ideas, and wrote the draft of the conclusion section. **Qisheng Zhang** outlined brainstorming plans and selection criteria, actively participated in the group brainstorming session, contributed some good ideas, wrote the draft of the conclusion section, and made some refinements on sections 7 & 8.

I gained a deeper understanding of the iterative user-centered design process, and I shaped my skills throughout the intensive engagement of the past 4 weeks of project development. All efforts contributed to the overall success, but the lack of accessibility in prototypes became evident during the evaluation phase. This problem may be due to lack of considerations in selection criteria. Additionally, more group involvements in early stages of the project may balance individual workload, and more group engagements in developing prototypes may achieve better fidelity.

## 12.2 Spencer Browne

*What you individually contributed to the project:*

1. I researched the history of automatic flushing toilets for the background of the project. Using this information, I prepared the project introduction for section 1 of the report.
2. I developed and revised the individual brainstorming session procedures and rules and prepared section 5.1 and 5.1.1 of the report
3. I developed and prepared the group brainstorming session procedures and rules and prepared sections 5.2, 5.2.2, and 5.2.3 of the report.
4. I conducted 2 individual brainstorming sessions in which I generated over 40 ideas for design alternatives.
5. I participated in the group brainstorming session and contributed 9 design alternative ideas to the group's list.
6. I designed the initial prototype for the manual flush foot pedal design alternative and prepared section 6.1 of the report.
7. I designed the evaluation plans for each of our design alternatives and prepared section 7 of the report.
8. I analyzed the evaluation for the design alternatives and came up with prototype changes and prepared sections 8.1 & 8.2 of the report.

*What each of your teammates contributed to the project:*

**Xiangsheng Gu** was a force to be reckoned with on this project. He got the process jumpstarted and did the majority of the legwork for the project up to through the needfinding phase. He contributed more than any of the other team members, myself included. **Cuicheng Zheng** and **Qisheng Zhang** were on Chinese time and we had a hard time coordinating with them, but they were both active and helpful in the team brainstorming session, as well as doing valuable work towards polishing the report up and putting finishing touches on our work. **Qisheng Zhang** wrote the conclusion of the report.

*Your overall reflections on how the project progressed: what worked well, what could have worked better, and what you wish you had known prior to the start of the project:*

I think the early stages of the project were a bit difficult, mostly due to difficulties surrounding communication. Some of our team members were in a significantly different time zone than others, so it was difficult to have productive

conversations. Thankfully, **Xiangsheng Gu** took it upon himself to start the ball rolling and make progress on the early phases, whereupon I was able to do meaningful work in the brainstorming, prototyping, and evaluation phases. One thing I think would make the process go more smoothly in the future is having a better-defined team plan for the timeline of the project. Some members of our group were motivated to complete the project before it was due, and I am not sure that we reached a concrete agreement on this, which left it difficult for other members to contribute as significantly as they might have otherwise, because the project was nearly finished at that point.

### **12.3 Cuicheng Zheng**

In week 13 I reviewed the M1-M5 assignments, combining the M assignments with the TEAM PROJECT, reviewing and familiarizing myself with the overall framework of the project, as well as reviewing the information to understand the background of the project, the history and current status of the auto-flush toilet. In the 14th week, through familiarizing myself with the content of the first four chapters, I personally conducted a human brainstorming session and completed writing section 5.2; participated in a group brainstorming session, in which I contributed five individual ideas for design solutions, and revised and improved the content of section 5.2 after the group brainstorming session technique. In week 15, I optimized the first seven chapters of the report by proofreading the content for spelling errors and correcting them, as well as revising some of the content to make it more concise and coherent. In week 16, I reviewed and familiarized myself with all the content of the report, carried out personal brainstorming, completed 9.1 section in conclusion of the report, added content to chapters 2 and 3 of the project, added a temporal dimension to the observations and comparisons, and wrote a section on personal contributions and reflections.

**Xiangsheng Gu** initialized a shared text skeleton for our team's collaborative working environment on Google docs, which played a key role in writing and organizing the project in the early stages. He defined the problem space, user types and needs, planned the overall investigation idea, and completed the

overall framework of the project. Actively involved in all aspects of the project, reviewing and optimizing content.

**Spencer Browne** developed and refined the procedures and rules for the two brainstorming sessions. He actively participated in the group brainstorming sessions and contributed many good ideas. He designed the first prototypes in the project and developed two qualitative evaluation plans and two questionnaires, analyzed the responses collected during the qualitative evaluation implementation and proposed changes to these prototypes.

**Qisheng Zhang** outlined the brainstorming plan and selection criteria, actively participated in the group brainstorming sessions and came up with some good ideas. He also wrote and optimized the summary section of the project, as well as chapter 7 of the project to include his own views on the project, making it more detailed.

In the early stages of the project, we spent a lot of time getting to know our users better and gaining comprehensive user insights through requirements analyses and surveys. This laid a solid foundation for subsequent design choices. Multiple design options were successfully generated through individual brainstorming and group brainstorming. I feel that my contribution to the project at the beginning of the project was not high due to the different regions we were in and due to other things I was doing, I feel that I could have carried out meetings at the beginning of the project to divide up the project, and that it may be more efficient to start the project together with clear goals and tasks. At the same time, mid-project prototype adjustments are positive, but may require more frequent iterations, especially in terms of user feedback. Timely adjustments and improvements to the prototype can help to better meet user needs. Before starting the project I would like to be able to understand the project's considerations in terms of practical applications, and to consider the feasibility and challenges of practical applications during the design phase. This helps the project to better transition to the next steps, such as more extensive user testing and actual deployment.

## 12.4 Qisheng Zhang

1. I drafted the initial brainstorm plan and rule 5.11
2. For the individual brainstorm, I generate 5 ideas and alternative designs, I participated the group brainstorm and contribute 2 ideas in the list
3. I completed the initial draft of the outline the next step in part 9.2
4. I make some revision to section 7.4 where we might have some challenges.
5. I add a change to our second prototype which suppose to improve the accuracy

**Xiangsheng Gu** did most of the initial work in week 2 check-in, he organized the brainstorm meeting, and gathered all the ideas for the paperwork including the revision part. He gave out the surveys of this report, and did all the analysis of the survey results, and turned them into virtualized graphs. He also designed the second prototype and gave out the evaluation plan for both prototypes. Thanks for the huge contribution of Xiangsheng Gu to this project.

**Spencer Browne** added a lot of his ideas to the brainstorming part, he designed our first prototype and designed the evaluation plans for each of our design alternatives and prepared section 7 of the report. He also analyzed the evaluation for the design alternatives and came up with prototype changes and prepared sections 8.1 & 8.2 of the report. Thanks for the huge contribution of Spencer Browne to this project.

**Cuicheng Zheng** actively participated in the brainstorm, and contributed some good ideas, he also did the revisions to the final edition. Thanks for his contributions to this project.

At the beginning of this project, we started a little bit behind. Especially thanks to **Xiangsheng Gu**, he contributed to the most of the check-in 2, and let this project go through the most hard time. The brainstorming session was great, all the teammates gave out good ideas, and we were able to get our prototypes out of them. The design and evaluation parts are greatly done by my teammates, and during my revisions I can see how solid the work my teammates have done. On

the other hand, I should start work on the project earlier, because when I start to work on the project, a lot of work has been done by my teammates, and that I can contribute more.