Self-Sanitizing Toilet Lid

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Executive Summary

Over time, the evolution of healthcare has increased rapidly, and in the age of technology, we have never seen such leaps in the medical field as we have in the past few years. As a global pandemic affected us all, we were reminded that there is no such thing as taking too many precautions when it comes to our health, and most importantly, the evolution of a healthier environment never ceases to be a necessity. This is what inspired the creation of the Self-Sanitizing Toilet Lid. An evolution in sanitization specifically designed to target one of the dirtiest places we encounter daily, and create a safer, healthier environment for all.

The Self-Sanitizing Toilet Lid is designed to kill microorganisms by use of a specific wavelength of light called UV-C lighting. UV-C lighting uses a higher frequency of UV light (ultraviolet light) that can kill up to 99.9% of bacteria and microorganisms. The Self-Sanitizing Toilet Lid utilizes this UV-C lighting and is sold in a lid and seat combo, which will ensure optimum light projection angles, and as a result, maximum sanitization. The Self-Sanitizing Toilet Lid also enhances users' needs providing the highest quality experience and satisfaction from users and investors in all areas of the globe by improving the health and quality of life for all who use it.

The Self-Sanitizing Toilet Lid is attached to the seat by a hinge system, which also allows for easy installation of the combo onto any toilet. The only thing required to operate the system is a wall outlet to plug the lid into. Once power has been supplied to the lid, the user can choose when to penetrate the lid. By simply shutting the lid and pressing the button on the top, the user can activate the UV-C lighting which will run for a time span of 5 minutes, allowing for an optimum time to kill 99.9% of microorganisms residing on the toilet seat. A safety switch is also located in the seat which will prevent any light from being displayed on a user if the lid were to be lifted for use during its running time. Lastly, the lid features a watertight build that will allow for easy cleanup if necessary and prevent any damage to the lighting and workings inside. The use of the UV-C toilet lid will not only increase health and safety but will also reduce the amount of cleaning by use of chemicals required to maintain a sanitized environment.

Overall, the prototype that was created was not what was originally desired, but it met almost all the goals that were set out for it, and it properly shows what the actual product will be intended to be. A self-sanitizing toilet lid is something that can world in the real world that would help create a cleaner and healthier bathroom environment for all users. It will not only save money but will decrease the amount of work needed to clean off toilet seats significantly. Although the prototype that this team was able to make does satisfy the basic idea and concept of the actual toilet lid, there are still several improvements that can be made to create an even better prototype and a better finished product.

R1 - Problem Definition Review

Introduction and Value Proposition

Trends today show the growing need and concern for a healthier environment. Innovation in sanitization has never been more necessary to combat the bacteria and viruses that threaten lives today. COVID-19 not only changed the way we live but changed the way we view health in society today, turning everyone's attention to the battle against enemies we can't see. This leaves the market wide open for innovation in any area of sanitization and health. Research has come to show that public restrooms are a breeding ground for pathogens and fecal bacteria. These pathogens such as Legionella pneumophila, Hepatitis A virus, Salmonella, and Shigella are just a few of the deadly diseases found on toilet seats in public restrooms [9]. This makes those who reside in congregate settings the most susceptible to the catching and spread of these unseen enemies. This leaves public universities and companies with public restrooms in need of innovation to help keep people safe and healthy. Through extensive research, it has been concluded that the use of UV-C lighting in the form of a toilet seat would not only meet stakeholders needs, but provide the reliability, usability, and the effectiveness that the user needs.

In the current state of the world, the need for a sanitary environment is more important than ever. This is the most important for those individuals who reside in a congregate setting as well as individuals who are in constant use of public restrooms and toilets. The one place that multiple people contact while using public toilets is the toilet seat. To combat the spread of germs and diseases from the use of public restrooms, our team plans to create a product that can rid toilet seats of harmful germs and bacteria after each use without the need for a person constantly sanitizing the seat. This toilet seat, lined with UV-C lighting, will turn on when the lid is closed, making this product simple, safe, and effective. Its custom-made design is specially made to fit the specific toilet in which its use is required, resulting in better efficiency. This not only stops the growth of bacteria but prevents any bacteria from being spread onto or by the user, making our public restrooms cleaner, and further making our society a cleaner and healthier place to live.

Problem Definition

As anyone could guess, cleaning out bathrooms, specifically toilets, is most certainly not a fun task. It is gross and often involves discomfort and sometimes back pain. Disinfecting toilets is not a simple and quick task either and there are a lot of places that need to be cleaned off. Not to mention that the cleaning products needed are not necessarily the cheapest, and a new solution could help save money in the long run. A new solution to this also creates cleaner and healthier bathrooms that involves the spread of fewer germs and a constant cleaning of toilets rather than once a day. Below is a list of the pains associated with cleaning bathrooms.

Pains**:**

- Disinfecting and cleaning toilets are not a quick task, and it can often be time consuming, especially if there is more than one toilet
- It is a gross job having to clean a toilet/bathroom
- Cleaning materials are not cheap to obtain

Gains**:**

- Having a clean environment that eliminates germs improves overall health
- Having a comfortable environment that you know is free from bacteria and viruses
- Stop the spread of germs and bacteria creating a healthier environment overall

Task: People who regularly clean and disinfect their own bathrooms or public bathrooms

Table 1: User Experience Chart: Chart ranking the user experiences based around the task of cleaning bathrooms. (++) for super positive experience level, (+) for positive, (0) for neutral, (-) for negative, (--) for super negative.

	Using Public Restrooms	Germ free environments	Uncleanliness	Well-kept and cleaned public facilities	Making efforts to live a healthy lifestyle	Cleaning toilets
++		X		X		
+					X	
0	X					
-						X
--			X			

As anyone could guess, cleaning out bathrooms, specifically toilets, is most certainly not a fun task. It is gross and often involves discomfort and sometimes back pain. Disinfecting toilets is not a simple and quick task either and there are a lot of places that need to be cleaned off. Not to mention that the cleaning products needed are not necessarily the cheapest, and a new solution could help save money in the long run. A new solution to this also creates cleaner and healthier bathrooms that involves the spread of fewer germs and a constant cleaning of toilets rather than once a day.

Research Plan

Cleaning bathrooms has been a task done for thousands of years. Bathrooms have always been dirty environments full of germs and bacteria no matter where you go. Conducted surveys and articles have been published which include lots of data and knowledge on the cleanliness of bathrooms particularly toilets, and we plan to use those resources to research how to help aid in this task of cleaning bathrooms making a cleaner environment for everyone. The research collected from these published journals and surveys on bathroom cleanliness will be used to find solutions and help aid in common problems that seem to recur in collected journals and surveys. We expect there to be lots of data and info on the harmful bacteria that remain on toilet seats and on toilets in general, as well as how often bathrooms are cleaned, why people tend to crouch over toilets and place paper instead of just sitting straight down, and how newer technology affects the bacteria in these bathrooms. In our research, it is very important to us to make sure that in all our research and public surveys gathered, private information stays private and all interviewees who request to be anonymous remain anonymous. Below is a table representing different ways to gather research for our specific task.

Table 2. Research Plan: An organized table with ways to gather research for the task.

Research Question:	Qualitative Data Collection:	Quantitative Data Collection:
(**RQ1**) How often are public/private bathrooms cleaned?	Find a survey or interview about how often the average household or business cleans the bathrooms	
(**RQ2**) How many bacteria do toilet seats contain?		Find an article about toilets/bathrooms that contains statistics about the number of bacteria located within
(**RQ3**) What groups of people use the restroom less?	Find a survey or interview about people who tend not to use public restrooms due to the risk of bacteria	
(**RQ4**) What are UV-C lights effective on high touch surfaces?	Look for research on the effectiveness of UV-C on high-touch surfaces	Find an article that has statistics about the effectiveness of UV-C lights and how successful it is at killing bacteria

(**RQ5**) Determination of the percentage of people who squat/place paper on toilet seats vs sitting on the seat.	Find a survey of people who put paper over toilet seats/squat over them.	Find an article or journal containing statistics about the number of people who won't touch public restroom toilet seats
(**RQ6**) Does newer technology stop the spread of bacteria in restrooms?		Find a journal or article that contains data about how newer technology has fared against bacteria.
(**RQ7**) What bacteria to look out for from toilet seats	Look for research of the types of bacteria on toilet seats	Find data on the number of bacteria and how much bacteria there is for each type.

Research Results

a. End Users.

Our user persona is Spencer Martin, a 32-year-old male who is an exercise specialist at Blue Cable. Spencer Martin's hobbies are typical such as working out at the gym and going to work, he also has some typical frustrations such as being cautious of germs and bacteria. Spencer Martin makes a perfect candidate for our user persona because of his acceptance to newer technology and the fact that he fits such a typical person to show that innovating technology to stop the spread of germs and bacteria is good for everyone, and not an unusual topic; research over the implementations of newer technology in bathrooms has been gathered which shows "...a reduction in bacterial CFU/ml for participants using newer technology public restrooms...", and "...bacterial CFU/ml increased for participants using older technology public restrooms [12]."

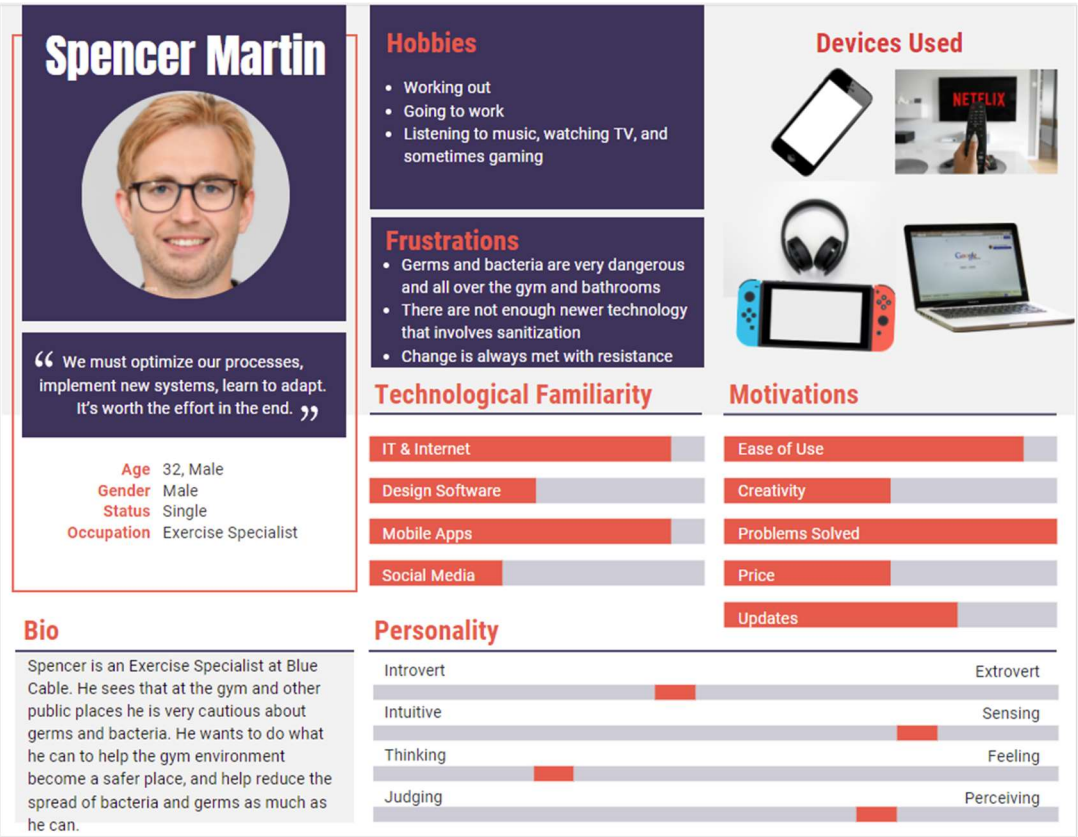

Figure 1: User Persona. Fictional persona who represents the average user being targeted and their traits.

Our user needs chart ranks the user's expectations and needs of our product where each need is ranked on a 1-5 scale. Next, we ranked usability and efficiency as the next most important consumer needs because a product must be very usable to all as well as efficient for it to be the most versatile and satisfying. After that, we had longevity and reliability in the second highest ranking spot because it is important to us that our product is good for the long run and companies, or any consumers will not be wasting their money on something that will go to waste. Our middle rankings consisted of simple factors, such as affordability, durability, and of course simplicity. We decided that those would be ranked in the middle because although they are not the number one priority, it is still a priority for us to have and assume a product is simple. Finally, our user needs that we concluded would rank towards the bottom were miscellaneous needs like customizability which we believe are important in developing a superior quality product, but not the number one priority when it comes to all our other needs. Although we do believe that customizability and aesthetic options allow for lots of versatility in our product as well as having an eye-catching product that stands out, again when developing something for the safety and greater good of humanity there are other priorities that come first.

Table 3: User Needs Table. A ranking system based on the user needs for a toilet / toilet seat.

User Needs Chart	Ranking (1-5)
Intigrated	2
Affordable	3
Customizable	1
Reliability	4
Longevity	4
Usability	5
Simplicity	3
Efficency	5
Durability	3
Aesthetic	1

When analyzed in the pairwise comparison chart, our users' needs came out not far from what we had predicted in the user needs chart. The results from the pairwise comparison chart revealed the users' number one need being reliability, which was ranked as the second most important need in the user needs chart. The next most important need shown to be longevity, as it was also ranked the second most important need in the user needs chart. Usability and simplicity are tied for the next most important needs, falling into the same place of importance as they had in the users' need chart. Affordable, customizable, efficiency and durability all tied for the fourth most necessary user need. In the user need chart, affordability and durability were tied for the third most important need while efficiency was ranked as one of the most important, and affordability was ranked as one of the lowest. Integration was ranked as the second to last need with aesthetics ranked as last. In the user needs chart, integration was ranked also as second to last, and aesthetics was similarly ranked in last place.

Table 4. A pairwise comparison chart representing the user needs in a nominated ranking system.

	Intigrated	Affordable	Customizable	Reliability	Longevity	Usability	Simplicity	Efficency	Durability	Aesthetic	Total	Normalized	Original
Intigrated		0	1	0	0	0	0	0	0	1	2	1.0	2
Affordable	0		1	0	0	0	1	0	0	1	3	1.8	3
Customizable	0	0		0	0	1	0	1	0	1	3	1.8	1
Reliability	0	1	0		1	1	1	1	1	1	7	5.0	4
Longevity	1	0	1	0		0	1	0	1	1	5	3.4	4
Usability	0	0	0	0	0		1	1	1	1	4	2.6	5
Simplicity	1	0	1	0	0	0		0	1	1	4	2.6	3
Efficency	0	0	0	0	1	0	0		1	1	3	1.8	5
Durability	0	1	1	0	0	0	0	0		1	3	1.8	3
Aesthetic	0	0	0	0	0	0	0	0	0		0	0.0	1

After looking into our user needs and accurately rating each of these user needs using the pairwise comparison chart, there are quite a few differences to what we originally thought users would want. The closest rating that we had was the reliability rating. Reliability was originally ranked as a 4 but was deemed to be a 5 according to the pairwise comparison chart. We found that reliability is one of the most important factors when it comes to people's decision making with bathroom cleaning products. “Initial cost, environmental impact, energy efficiency, hygiene and reliability are identified as five factors that have most impacts on people’s decision when furnishing or using public bathroom [2].”

We also we very close on simplicity as we know people value it, but it isn’t extremely important, and we were also close on aesthetics as bathroom products normally aren’t very aesthetically pleasing and consumers won’t care for it if it works fine. We had usability rated as 5, but it seemed to be lower on the pairwise comparison chart but was still rated as the third most important item. Affordability, integration, longevity, efficiency, and durability were all rated higher on our original user needs chart than what stated in the pairwise comparison chart. Ratings such as efficiency were updated higher than we initially thought were due to several pieces of data that we have found. One of which involves women’s use of public restrooms: “Of 528 consecutive women who attended a general gynecological clinic and completed an anonymous questionnaire, 85% usually crouched over the toilet when using a public convenience, 12% applied paper to the seat and 2% sat directly on public toilet seats [6].”

With the highest ranked categories in the pairwise comparison chart being longevity and reliability, we believe that something that can be used to meet these needs could potentially be UVC cleaning lights. When used in “... negative air-pressure isolation units (patient room, anteroom, and bathroom) ... UVC disinfection significantly reduced the number of bacteria on surfaces directly or indirectly exposed to UVC to a very low number, as did 5% chloramine

disinfection alone (P<.001 for both). Completely shadowed areas in the isolation unit (e.g., the bed rail, lockers, and mattresses) still required disinfection by chemicals [4].” To keep toilet seats cleaner, UVC lights could possibly be used rather than other products and ‘elbow grease.’

b. Market Character.

There are various stakeholders involved with the task of cleaning bathrooms. Here are lists to get a better understanding of the stakeholders of this task and how a solution of this task could affect the stakeholders listed.

- Janitors / Anybody who is cleaning any restroom
    - Make their work easier by providing more efficient / automated ways of cleaning toilets
- People who use restrooms
    - Provide a cleaner restroom with less germs and bacteria, providing a cleaner safer environment.
    - May have to learn to adapt to a new technology to retain a cleaner environment.
- Cleaning supply businesses
    - May hurt cleaning supply businesses where a product would replace older ways of cleaning bathrooms.
    - May involve cleaning supply businesses by using their cleaning products in an automated technology developed
- Companies and families who have restrooms (public or private)
    - Create a safer environment for people using their restrooms which would in the end lead to bringing more attraction.
    - For families it would help reduce the spread of germs, creating a safer environment for the whole family.
- Manufacturers and companies in the restroom / public restroom field
    - May hurt companies that develop toilets by reducing business.
    - May provide more work and more money for companies who develop toilets by involving them.

In the current state of the world, the need for a sanitary environment is more important than ever. In the past two years, lives have changed dramatically as an unseen enemy has swept through people’s homes, threatening their lives. COVID-19 not only changed the way we live but changed the way we view health in society today, turning everyone’s attention to the battle against enemies we can’t see. With this common enemy, society has been able to turn its focus, and find unity in the fight for a healthier and safer way to live. This fight leaves the market wide open for any type of new private or public sanitization techniques, equipment, and products. Restrooms are a great target for this innovation, as this is most likely one of the dirtiest places, we visit every day with 70 samples collected from toilet seats and 27 agar plates on which bacteria were tested with 38% positivity rate of samples there was a maximum of 15 number of coliforms detected on a single plate [5]. Universities, hospitals, and large corporations all around

the world are responsible for providing restrooms for all faculty, staff, and students day to day. This makes these one of the primary users of sanitization innovation.

Table 5. Current Alternatives. User needs listed, for current alternatives to cleaning a bathroom.

User Need (Toilet Seat Cleaner)	Bleach w/ wipe	Home Remedies	Clorox Toilet Wand	Disenfecting Wipes	Cleaning Spray w/ Sponge
Simple (easy to use)	Yes	Yes	Yes	Yes	Yes
Cheap	Yes	Yes	Yes	Yes	Yes
Comprehensive (covers all situations)	Yes	Yes	Yes	Yes	Yes
Integrated (connects to other solutions)	No	No	Yes	No	No
Long-Term	No	No	No	No	No
Reliable (does not break)	Yes	Yes	Yes	Yes	Yes
Smart (makes cleaning easier)	No	No	Yes	No	No
Efficent	No	No	No	No	No
Durable	No	No	Yes	No	No

There are many stakeholders that could use a better solution to the task of cleaning toilet seats which is a long task undesirable task, and it seems like there could be a better, more efficient solution for the task which creates a market size for the task of cleaning toilet seats that must follow the current alternatives in optimizing the most efficient and desirable technology to develop what's best for society.

Trends today show the growing need and concern for a healthier environment. Innovation in the realm of sanitization has never been more necessary to combat the bacteria and viruses that threaten lives today. As COVID-19 has taught us, there is no such thing as being too prepared, or too clean for that matter. This leaves the market wide open for innovation in any area of sanitization and health. These trends have come to show that the need for improvement in sanitization will never cease to exist, and always be necessary to make the world a safer place to live. Research has come to show that public restrooms are a breeding ground for pathogens and fecal bacteria. These pathogens such as Legionella pneumophila, Hepatitis A virus, Salmonella, and Shigella are just a few of the deadly diseases found on toilet seats in public restrooms in concentrations of 100000 – 1 x 10^11 g^-1 ml^-1 [9]. This only further proves the trends and market size of sanitization in public restrooms and the need for innovation in the realm of cleaning products.

Restroom cleanliness in particular toilet cleanliness has a huge effect on a variety of groups so to narrow down who's being affected by toilet cleanliness a list of stakeholders must be introduced, starting off with janitors and anyone who cleans any toilet. A study was conducted to determine the spread of bacteria in university dormitories, which affects large amounts of students world-wide. "This study on the bacteriological assessment of toilet seats in the student hostels has shown the bacterial profile of shared toilets in a university setting. The study shows that bacterial contamination was higher in the male hostel toilets compared to the female hotel toilet seats. The bacterial species isolated in this study are known to be associated with various forms of infection in humans and is therefore of public health concern as students may get infected using shared toilets in the university. Therefore, proper sanitary measures should be taken to prevent the outbreak and spread of infection among students dwelling in the dormitories [11]." Bacteria

through toilet seats, as stated, can cause huge health concerns among groups of people, and a proper, more efficient solution can be found.

People who clean toilets and restrooms may be affected by a product that deals with the task of cleaning restrooms mainly by making their job easier with an implemented technology of cleaning restrooms. Another stakeholder that must be introduced is the people who use restrooms and will benefit from technology in having a safer and cleaner environment where the possibility of being exposed to bacteria is greatly reduced. In addition to that cleaning supply business may be greatly affected by this in two different ways, if the technology is independent that technology may become a competitor to those businesses although on the other hand if the technology relies on the cleaning supply business, they may work hand in hand in creating more business. Companies and families who have restrooms will have a safer place for the people in the company or family where they won't be exposed to as many harmful bacteria reducing sicknesses and other health issues. On the other hand, there are going to be toilet manufacturers and other companies that specialize in restroom cleanliness that will be hurt or will benefit from the technology like the cleaning supply businesses where the technology may work with these businesses or take away from the businesses by becoming a competitor to them.

Through research into possible competing companies for our potential product, we investigated several other "solutions" to the problem of cleaning toilet seats that people use today. One solution that we have researched was a self-cleaning toilet. "The self-cleaning toilets are gender-neutral single-stall permanent stand-alone public toilets that operate all year from 6 am - 12 am. The toilets go through a 90-second cleaning cycle every time someone finishes using them (Scott, 2018). The toilet is free of charge to users, but officials have considered charging a small fee to reduce the number of people who open the doors to view the toilet since it must go through a cleaning cycle every time (Scott, 2018). After 15 minutes of use, the toilet doors open, and there is a 660-pound weight limit; both features Page | 9 exist to prevent illegal activities (Jagger Haines, 2018). There are needle disposal boxes inside the toilets so people can dispose of needles safely (Deschamps, 2018) [7]." The problem with this solution is that it seemingly would be too expensive for businesses and households to adequately and commonly use.

The most used items were bleach, several home remedies (baker soda paste for example), toilet wands such as the one from Clorox, disinfecting wipes, and cleaning sprays. Each of the competitor's items was deemed simple, cheap, comprehensive, and reliable. We say this because each of these products are hands on and must be used by a person to be able to clean off the toilet seats that are not very expensive (the wand is only 9 dollars) and each of these cleaning products can clean all exterior facets of a toilet. The toilet wand was deemed to be integrated, smart, and durable as the wand could be used by attaching a wipe to the end to clean off toilet seats so the user won't have to bend down to clean the seat. The other products are not as they involve the user getting into uncomfortable positions, they can only be used one way, and they are each only one-time uses. According to our research, we believe that the stakeholders and potential market would prefer an efficient, and long-term solution to the task of cleaning toilet seats as none of

our competitors have found ways to combat the problem of a cleaner toilet seat.

Design Focus

Our design of the self-sanitizing toilet lid is a product of our group's extensive research about bacterial growth rates and types in public restrooms, use and effectiveness of UV-C lighting, and general restroom habits of the average individual. Our research in these fields shaped our product into the safe, easy to use, efficient, integrated, efficient, and durable product that it is. Research proves that “Pulsed-UV technology was effective at reducing overall bacterial counts and significantly more successful than manual disinfection alone [3]”, showing us that the main component of our design is effective. We also can tell from our research that this design is necessary, as can be seen: “The following bacteria genera and species were isolated from the students’ toilets; Staphylococcus aureus (25.0%), Escherichia coli (36.7%), Pseudomonas aeruginosa (13.3%), Streptococcus pyogenes (6.7%), Proteus mirabilis (6.7%) and Klebsiella pneumonia (11.6%) [1].” This research phase has shown our group how to effectively meet our users' needs, while meeting our stakeholders' considerations, and helped us design a product unlike anything created before, leaving little room for competitive alternatives like the self-cleaning toilet, due to cost effectiveness, versatility, and usability. This brought our thinking to the next level, considering more than just the result, and considering more on the journey to get there. This allowed us to look at important user needs, like effectiveness and usability, competitive alternatives like manual chemical cleaning, and stakeholder considerations like durability and reliability, and create the one and only self-sanitizing toilet seat.

R2 - Conceptual Design Review

Concept Brainstorming & Ideation

Process Description/Brainstorming Results - Landon Muhlenkamp

To produce this concept sketch, I tried to think a lot about the competition, as in, companies that specialize in the production of toilets and their parts. I also kept in mind the end user, and what this design would require meeting their needs sufficiently. That is how I produce this design, integrated with both usability and efficiency. The four UV-C lights line the sides to sanitize the seat of the toilet, and the UV-C light running through the middle ensures that the inside of the toilet stays sanitized as well. Its hefty design ensures that it will be both durable and able to contain all the components necessary to make the functionality of this product at its highest peak. This design maximizes users' needs, as well as efficiency and durability that companies rely on.

Process Description/Brainstorming Results – Andrew Neate:

This group's task is oriented towards trying to perfect a design towards a better way to sanitize toilet seats as those are one of the main parts of the toilet that gets touched, but it does not have a solution towards getting immediately cleaned/disinfected. The solutions that have already been created seem to be lacking 2 components that users are looking for according to research: longevity and efficiency (See table 3). Going forward with my planning, an efficient and long-term solution, that also satisfies all the other user needs, should be developed. For my brainstorming method, my main way of producing ideas was to use a concept map (See Appendix A, figure 2). I only continued down paths that would lead to long-term and efficient solutions. Users would not be interested in aesthetics, so that would be ignored during the brainstorming process. At any point where the map led to a solution that has already been created, the path would stop, and I would continue down a different path.

I thought of a few ideas that could be more efficient and long-term than the ideas in place today. My first idea was to have a cover that the users can put onto the seats, but that would not be efficient as the cover would have to be replaced after each use. My second idea was a self-cleaning cover that would clean itself off after each use where the user would press a button after they were finished. The idea I ended up believing would be the best would be to create a toilet seat with UV-C disinfecting lights on the toilet lid placed. The UV-C lights could then be implemented with a system that would make sure that they turn on when the toilet lid is down and turned off when the lid is lifted upwards off the seat. This way, users could simply close the lid after each use and the seat would then disinfect itself for the next user.

Process Description/Brainstorming Results - Nick Webber

Based on this user needs chart. I started searching for various toilet seats and seeing what was already highly common and practical. I then started thinking about how to implement the UV-C lighting system and what kind of toilet seat design would be most practical as well as fitting the user needs chart.

I was sketching out various kinds of modern toilet lids and I produced a thicker toilet lid with more of a boxier shape to hold the UV-C lighting. The lid had little shells that were intended to later have wiring connected to the UV-C lighting rays to eliminate bacteria affectively while covering most of if not all the surface area of the toilet seat. I then finally started deciding on a shape and sticking with that shape, and I tested out a few distinctive designs with different heights and thought that it was optimal to have a 1.5:2 ratio for the UV-C lighting so 1.5 inches of height for UV-C lighting and 2 inches of height for the toilet seat so that there could be wiring fit into it and a cover without it looking too funky. Later, I can create these shells and lights to continue to cover more of the toilet seat surface area once I have light projection angles and more.

Concept Brainstorming & Ideation.

a. Process description:

One process used to further develop the design solution was the process of elimination. We had to produce a toilet seat that would best fit potential end user needs; we tried thinking of a universal type of toilet seat and could not really produce any, then tried finding what the most common toilet seat size was and started basing the design off that. According to the data that is collected from potential users, it is believed that users want a more efficient, long-term solution to the problem of cleaning toilet seats. The idea produced was to base the model on the most used toilet seat sizes. Another process used was mind mapping. A mind map was created that helped us come up more with some specific features of the design and help organize thoughts in general more (Appendix A, figure 11). The mind map stemmed into four dissimilar categories, UV-C placement, usability, versatility, and functionality and from there producing different ideas which helped is aim more towards the best product.

b. Brainstorming results:

To produce the first sketch (Appendix A, Figure 12.1), consideration was given to the competition. This design maximizes users' needs, as well as the efficiency and durability that companies rely on. That makes this design integrated with both usability and efficiency. The four UV-C lights line the sides to sanitize the seat of the toilet, and the UV-C light running through the middle ensures that the inside of the toilet stays sanitized as well. Its hefty design ensures that it will be both durable and able to contain all the components necessary to make the functionality of this product at its highest peak.

In sketching out various kinds of “modernized” toilet lids, it was decided that a thicker toilet lid with more of a boxier shape (Appendix A, Figure 12.2) would be sufficient to hold the UV-C lighting. The lid had little shells that were intended to later have wiring connected to the UV-C lighting rays to eliminate bacteria effectively while covering most of if not all the surface area of

the toilet seat. It was then concluded that the optimal ratio for the UV-C lighting was 1.5:2, leaving 1.5 units of height for UV-C lighting and 2 units of height for the toilet seat so that wiring could fit into and cover without it looking unappealing. In addition, these shells and lights would continue to cover more of the toilet seat surface area once the light projection angles have been calculated.

Ideas were brought in from each of the three originally brainstormed designs and aspects of each design are to be included in a 'perfect' toilet seat design. It was determined that rather than one larger UV-C light that would go around the seat, several lights would be placed about the seat to make a more flexible area of coverage (Appendix A, Figure 12.3) as well as a long, thin light down the middle of the seat to help with disinfecting within the toilet itself (Appendix A, Figure 12.1). The idea is that an automatic switch or sensor will then turn the UV-C lighting on when the toilet lid is placed down on the seat.

Concept Selection

a. Down Selection to Two Concepts:

UV-C Design 1 (Appendix A, Figure 12.1) and UV-C Design 2 (Appendix A, Figure 12.2) were the most viable designs for potential users based off the needs of the end users. In an interview with two staff members at The Ohio State University, who are both in charge of the cleaning of restrooms in the Universities congregate settings (dormitories), they revealed their thoughts on the use of the Self Sanitizing toilet lid. Both individuals said that they think not only is it a great and effective idea for killing and stopping the spread of bacteria, but also a versatile product that could be both used in large settings such as college dormitories, or in small settings, such as individual homeowners. They also mentioned that the simplicity of just closing the lid to activate the light would be extremely useful. This interview, along with the users' needs chart led to the discarding of figure 12.3 due to worry that the usability and the reliability would not be sufficient. The two designs remaining (Appendix A, Figures 12.1 and 12.2) utilized the versatility, reliability, and usability needed by the end users to create a positive user experience with the product. This was confirmed in an interview in which those being interviewed stated that versatility along with usability and reliability would be a nice addition to the product.

b. Pugh Scoring Matrix:

Need	Weight (1-5)	O'Hare Airport Seat		UV-C Seat Design 1		UV-C Seat Design 2	
		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Simplicity	3	3	9	5	15	5	15
Affordability	3	3	9	3	9	3	9
Usability	5	3	15	4	20	3	15
Integrated (connects to other solutions)	2	1	2	4	8	2	4
Longevity	4	2	8	5	20	4	16
Reliability (does not break)	4	2	8	3	12	4	16
Customizable	1	1	1	4	4	3	3
Smart (makes cleaning easier)	4	4	16	4	16	4	16
Efficent	5	4	20	4	20	4	20
Durability	3	2	6	3	9	2	6
TOTAL			94		133		120

Figure 2. A Pugh Matrix is used to determine the best concept weighted by user needs.

Using information that we have obtained from users, we listed 10 needs for users when it came to cleaning toilet seats. We weighed each need on a scale of 1-5 determining those potential users cared mostly for an efficient and usable solution to cleaning of the seats. We determined that the users care the least about something customizable as they would mostly care about whether it would work properly. We compared the final two designs to the O'Hare airport toilet seat that revolved and sanitized a plastic covering over the toilet seat with the click of a button after each user. We determined that the two designs would be better overall due to user needs, but design 1 ended up with a higher score than design 2.

c. Final Concept Selection:

According to the Pugh scoring matrix, the UV-C Seat Design 1(Appendix A, Figure 12.1) will be the final concept design selection since most of the user needs are best met with Design 1 accumulating the greatest score of 133. According to user feedback obtained from not only the interview with the Ohio State faculty members, but through multiple online sources and surveys as well, we properly ranked each of the designs after properly weighing them in the Pugh Scoring Matrix. We believe that the toilet cleaning enterprise needs an easier and more efficient way to clean their toilet seats, as the average household and business clean their toilet seats manually with a cleaning product such as bleach and a sponge/rag. The self-sanitizing toilet seat using UV-C lighting would be a reliable, efficient, and simple solution that would clean off the seat after each use rather than once a day, decreasing the spread of bacteria and diseases. The risks of this design are that companies may hesitate to try the toilet lid at first as it will be a bit pricey compared to a simple bottle of cleaning product, but we can assure that the toilet lid will save businesses/homeowners much more money overall. UV-C Seat Design 1 consists of a modernized universal toilet seat, designed with common measurements of 16 and a half inches in length and 13 inches wide. The lid will be a little bit thicker to contain wiring and lining for UV-C lights. All the other components of the toilet seat including concave will consist of the most common measurements to fit end user needs. As shown in Figure 12.1. After doing some

research on common toilet seat measurements it was clear that using measurements of a common toilet seat, the design would be a lot easier to implement in more toilets.

Grand Concept Design

For the grand concept design the UV-C Seat Design 1 has been further developed and added on, to best fit the end user needs. UV-C is a type of ultraviolet light that releases radiation due to a specific frequency of light emitted from the lighting source. This form of radiation can cause irritation to skin if exposed for periods of time, but safety measures have been implemented so that the light cannot be activated when any person is around or in use of the product. An inverted button on the back of the toilet lid has been added with a LED ring light around the button to display whether the UV-C cleaning is in process or not with a five-minute timer. The reason for the button being inverted is to add more of a clean design but more importantly avoid the button being pressed when someone leans against the back of the toilet lid. In addition to adding the cleaning button for end users to use properly, a switch was also added that will monitor if the seat is raised during the UV-C cleaning process or if it is closed. If the seat is raised the switch will flick and then open the circuit of the UV-C light shutting off the cleaning process, as well as the ring light LED around the button. In addition to some new functioning features based off end user feedback, the design has been edited to best fit end user needs by changing the bottom half of the top cover that covers the entirety of the toilet seat to be a partially translucent material with UV-C lights spread out evenly inside the translucent material to cover as much surface as possible. A challenge that might come into play could be with the five-minute timer and whether the switch will shut both the lighting and reset the timer, or if the timer will stop at whatever time, it is on, or even add more time. This design must prove that it is able to sanitize the toilet seat efficiently and effectively and must be especially easy to use and understand to confirm its feasibility to gain traction in today's market.

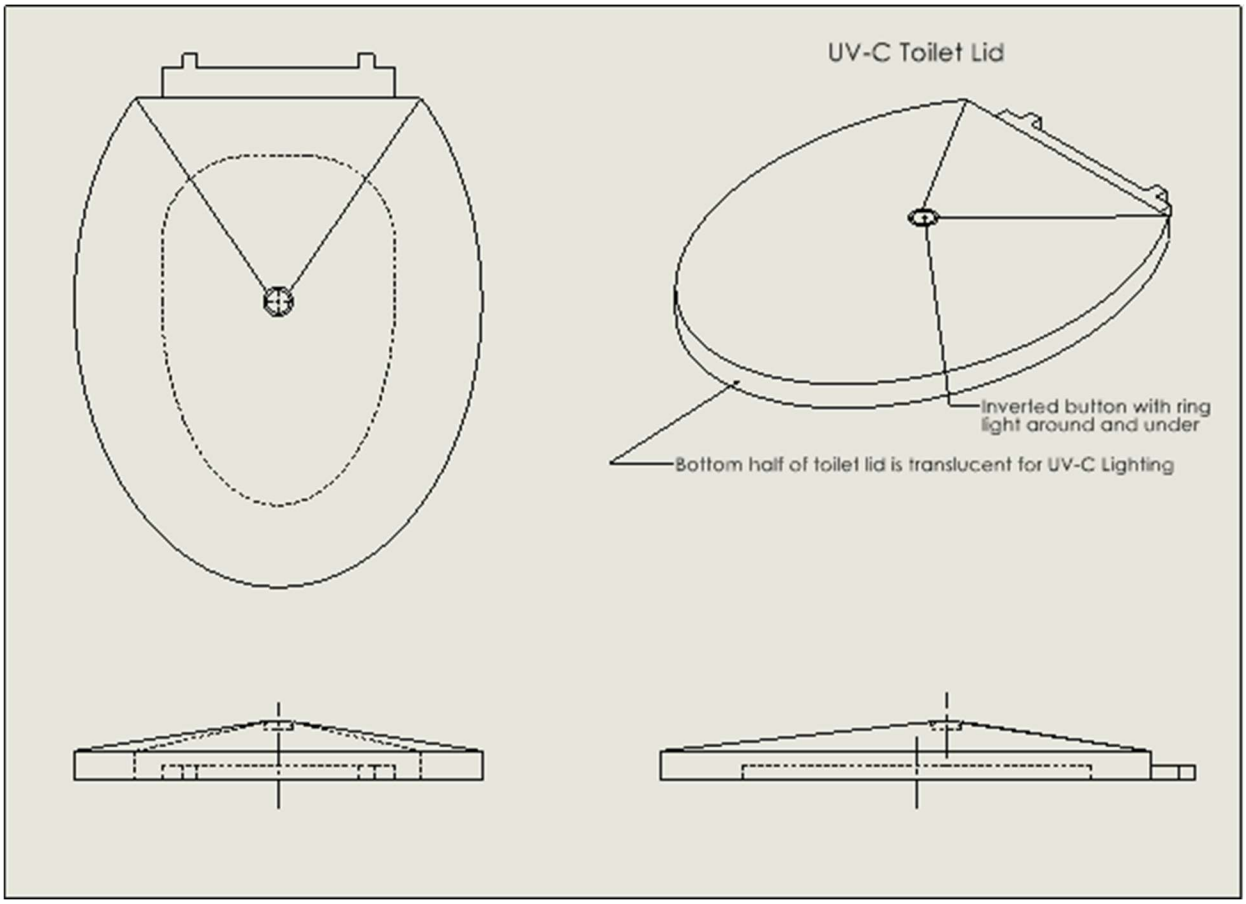

Figure 3.1. Grand Concept UV-C Lid Design. The toilet lid with added button with ring light, and UV-C lights added.

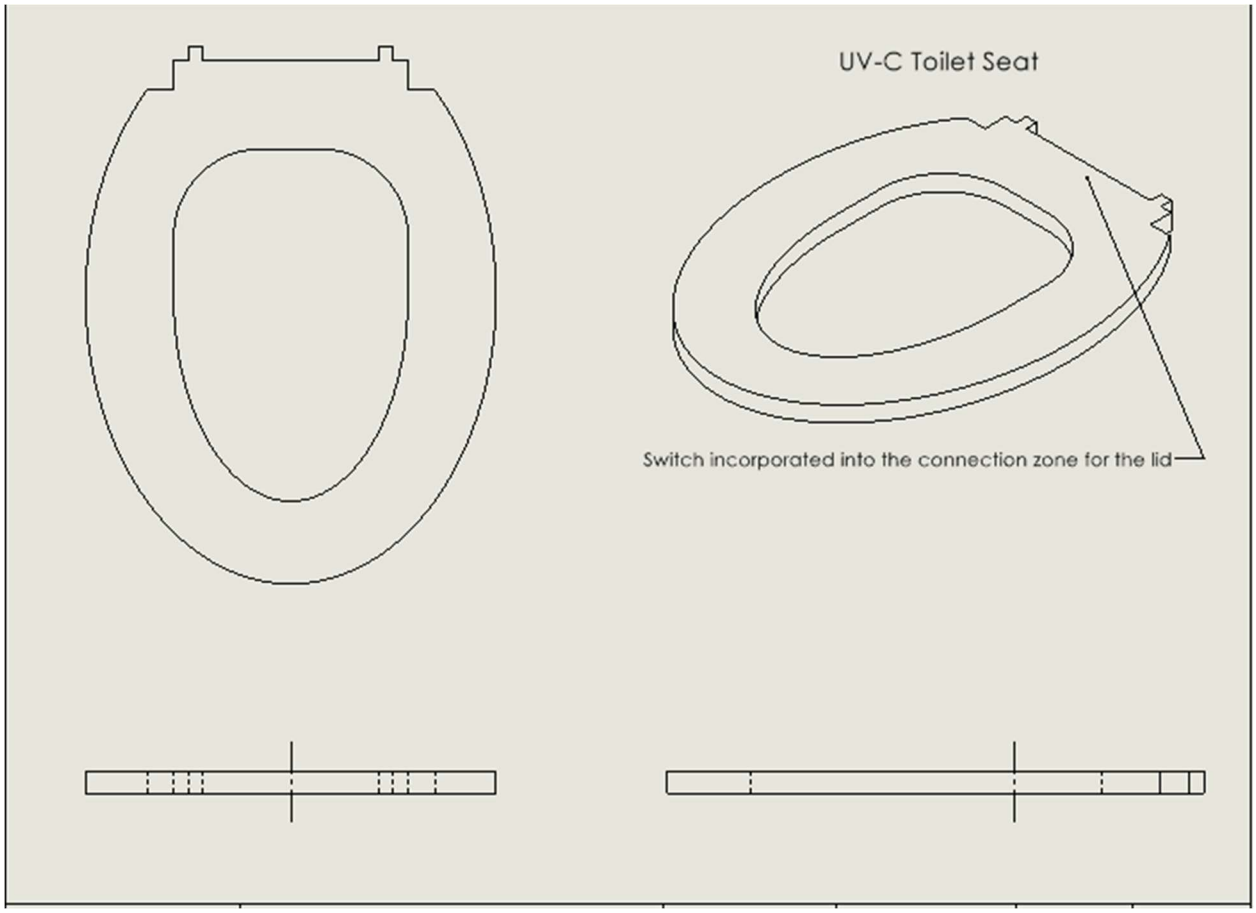

Figure 3.2. Grand Concept UV-C Seat Design. The toilet seat with switch incorporated into back connection piece.

Prototype Design

a. Description of Prototype:

The general idea of this prototype was to originally have it so that there would be a switch that it turned on whenever the lid is placed down, the UV-C light is activated. It was deemed a problem that the users could accidentally hit the switch when using the toilet, so a button was instead placed on the top of the toilet lid. The button is also inverted so that it won't be clicked on when pressure is applied to the lid on the back of the toilet. When the button is pressed, a timer is then started for several minutes for optimal bacterial disinfection while not being on for possibly hours at a time. If the lid is opened before the timer is up, then the circuit for the UV-C lights is switched off. When the lid is closed, the user must press the button for the circuit to start. The top of the lid is thicker than a normal toilet lid to not only include the UV-C lights, but also to protect the lights and circuit so they are not damaged if the lid is sat on or slammed down. The interior of the toilet lid will have a sturdy yet translucent cover (most likely a type of clear plastic material) to allow for the UV-C light to show through without it being subject to the outside and

possibly breaking. The lid itself will be made of a plastic material. Most lids are made of polypropylene, so the lid will most likely be made of a high-quality polypropylene.

b. Prototype Design Requirements:

REQUIREMENT	RANGE
Electricity/Energy Usage	< 12 kWh used in a month
UV-C light covers seat for proper time	Exactly 5 minutes of coverage time after press or until lid lifted
Coverage of Seat By light	< 1 square inch of seat not covered by light
Water Resistant	< 0.1 mL of water entering transloucent material over 24 hours
Cleans Seat Efficently	>99.9% of bacteria eradicated after each use

Goal	Score
less than 12 kWh used in a month	5
Light is on for 30 seconds; Light turns off when pressure is removed	5
All of the surface area of the seat is covered	5
No water enters the lid	3
99.9% of bacteria killed	7

Figure 4. A table that lists five requirements for the toilet lid with a measurable range for each requirement

c. Testing Methodology/Verification Plan:

The five requirements that were determined to be the most important for the functionality of the toilet lid according to our end users are the amount of electricity/energy used by the toilet lid should not be overbearing, the UV-C light from the toilet lid needs to turn on after the button is pressed, the toilet seat needs to be as covered up by the UV-C light as possible for proper disinfection, the see-through material covering the lights needs to be water resistant, and the light needs to be able to properly disinfect the toilet seat from bacteria and germs. A proper measurement for electricity and energy usage for the toilet seat is less than 12 kWh a month. Of course, the seat needs to use power, but it should not be used too much. The number comes from being compared to the usage of a 100-Watt light bulb in a month. The UV-C light not only needs to turn on after each button press, but it needs to be on for its 5-minute timer after the button is pressed. If the seat is lifted, the lights need to turn off. As much surface area of the seat needs to be covered as possible by the UV-C light to reach proper disinfection, anything more than one square inch of area left uncovered is unacceptable. Absolutely no water should enter the area that the UV-C light is in, so anything more than 0.1 mL of water entering the area would also be unacceptable. Finally, UV-C light kills more than 99.9% of all bacteria, so if there are significant bacteria on the seat after a cleaning by testing the surface after a 5-minute cleaning cycle, changes will need to be made. Overall, we want the electricity usage for this product to be under

12 kWh a month. 10 kWh would be a good starting point to aim for. For the light, we want the timer for this prototype to have 30 seconds on it so that it isn't on all day. We also want the light to turn off when the pressure of the seat is removed. We want the entire surface area of the seat to be covered with the UV-C light, we want absolutely no water to enter the area for the lights, and we want the UV-C light to be able to kill 99.9% of all of the bacteria on the toilet seat to ensure proper eradication of harmful germs and disease.

d. Correlation Matrix & Verification Scorecard

	Electricity / Energy Usage	UV-C Light covers seat for proper tim	Coverage of Seat by Light	Water Resistant	Rids seat of Bacteria	User Need Weight
Intigrated		3	9		3	2
Affordable			3			2
Customizable			3	3	3	2
Reliability	1	9		3	3	5
Longevity	3			3		4
Usability	3		9		9	4
Simplicity		3				3
Efficiency	9	3	1		9	5
Durability				3		3
Aesthetic						1
Importance ->	74	75	71	42	108	

Figure 5.1 Correlation Matrix is used to determine which design requirements are most important for our user needs.

Verification Scorecard Points Distribution*

	Raw Percentage	Score Card Points (25 total)
Electricity/Energy Usage	20.0%	5
UV-C light covers seat for proper time	20.3%	5
Coverage of Seat by Light	19.2%	5
Water Resistant	11.4%	3
Rids Seat of Bacteria	29.2%	7
		25

Table 5.2. Scorecard determines which design requirements are most important from the correlation matrix.

From the verification scorecard, the most important design requirement is that the UV-C light properly rids the seat from bacteria. The least important design requirement is whether the area covering the lights is perfectly water resistant or not. It is still an important requirement, but if it gets in the way of a more important requirement, then sacrifices may have to be made to create a product more suited for our users. Electricity usage, proper coverage, and proper running time for the UV-C light are all on similar grounds for importance.

e. Prototype Preliminary Design & Mock-Up:

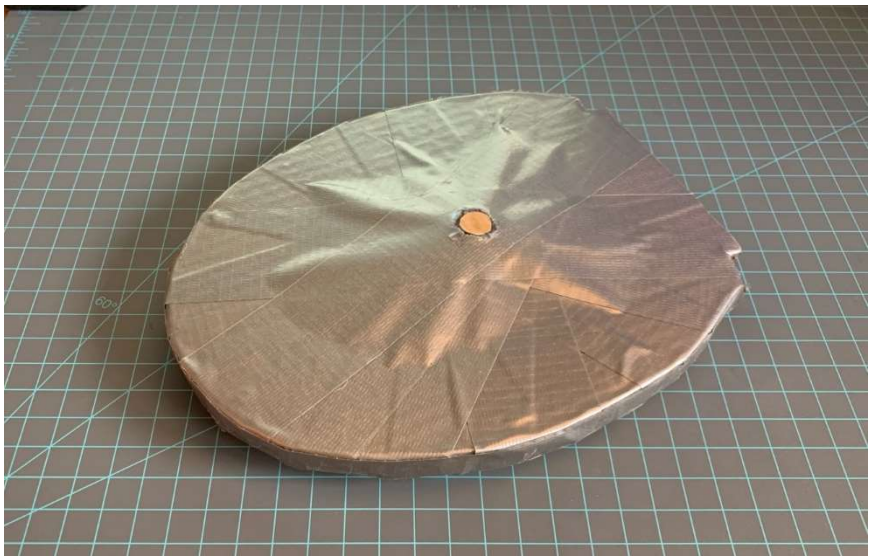

Figure 6.1. Prototype Preliminary Design Closed. A rough model made of cardboard, duct tape, and other household materials to model the UV-C Toilet seat design when it is closed.

Figure 6.2. Prototype Preliminary Design Open. A rough model made of cardboard, duct tape, and other household materials to model the UV-C Toilet seat design when it is completely opened.

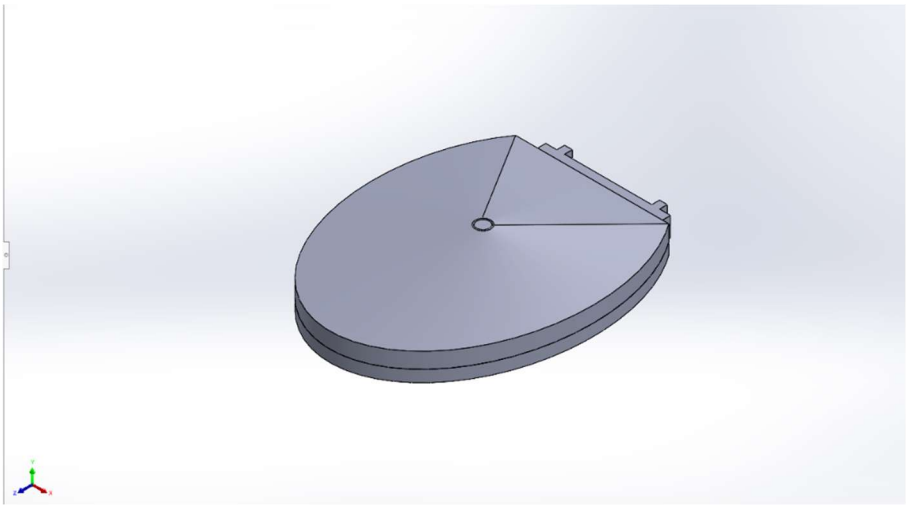

Figure 7.1. Prototype Preliminary 3D Model Design Closed. A 3D model made using a 3D modeling software, SolidWorks, to model the UV-C Toilet seat design when it is completely closed.

Figure 7.2. Prototype Preliminary 3D Model Design Open. A 3D model made using a 3D modeling software, SolidWorks, to model the UV-C Toilet seat design when open

As seen in both solid works designs and in the cardboard prototype, the self-sanitizing toilet lid is featured in a combination of both a lid and a seat, which differs from the original concept of just a lid. This limits the customization needed to fit a toilet lid onto a seat, considering that there are many different sized seats in the world. This also means that there would be optimal coverage on the seat, increasing the number of bacteria killed by the UV-C lights. The prototypes also feature a rounded top for storing cords and electronics of the lid, and a plexiglass bottom allowing the UV-C light to pass through with ease, while also providing the durability and water resistance needed to function properly. A button to activate the lid was added on the top of the

lid instead of the original motion sensors to save electricity and to make the seat safer. The use of the button would not allow the light to turn on when in use, while light sensors might.

R3 – Detailed Design Review

Prototype Fabrication & Evolution.

The very first prototype of the Self-Sanitizing toilet Lid was a six-inch-long cardboard replica of what the final product would look like. Based off this model, it was decided that a bigger model would be necessary to be able to fit the required elements of the Self-Sanitizing Toilet Lid into the prototype. Not only would the final prototype need to be bigger, but after research, it was decided that it would be better for the end user if the lid was sold in a lid and seat combo. This would limit the need for customized options and ensure that light projection angles would be optimized, resulting in more efficient cleaning and better fit. Further into the research and development phase the decision was made that a 3D printed model would be the most accurate representation of the real-world model to attempt to replicate the plastic exterior most toilet lids and seats have. Though, due to complications with the 3D printing, and lack of resources, it was unsure if any of the orders would be completed before the deadline. Because of this incident, the main design was laid to the side, and a model was created utilizing fiber board and a bulkier design that would allow the walls to be cut and hollowed, allowing space for the lighting necessary to test light projection angles. Due to lack of a power supply, the operation system (FE Controller) was moved outside of the prototype and simply used to demonstrate what the real-world model would be capable of doing, such as timed lighting to save energy and the life of the UV-C, as well as a pressure plate to ensure that light does not project on any users when the lid is opened. The hinges and button of the solid works prototype also had to be sacrificed due to time and materials, and in place a door hinge was used to connect the lid to the seat and a hole was cut into the top of the lid allowing access to the on off switch for the lighting. The type of lighting was also changed from UV-C lighting to LED lighting due to the price of UV-C lighting and the hazards of working with it. The use of LED lighting, although it would not allow the testing of bacterial load on a toilet seat, will still allow for the testing of light projection angles. Since previous research show the effectiveness of UV-C lighting in public restrooms, it is not a concern of whether the light will kill the bacteria, it is more a concern of whether the light will reach all the seat and is able to kill the bacteria present.

Detailed Design.

a. Final Prototype Design.

The final design of the Self-Sanitizing Toilet Seat prototype isn't what the typical toilet lid and seat combo would be made of but is still effective at demonstrating the highest ranked user needs being optimized in the final product. The final prototype shell as well as top of the lid and the entire seat is made from hand-cut fiber board. Since fiberboard was utilized in the creating of this prototype, the walls of the shell had to be made thicker for the pieces to be able to be cut to sizes. The prototype also utilizes 4 meters of LED lighting in replacement of the UV-C lighting, which will allow for the demonstration of light projection angles. Plexiglass covers the lights and protects them from any water damage. The lid and seat are held together with a door hinge that allows the lid to be opened and closed whenever a user desires for the seat to be sanitized. The

top of the lid has a hole drilled allowing access to a push button operation switch letting the lights to turn on and off when desired. Due to lack of power, the FE controller responsible for the operation and timing of the lights is a separate entity of the final prototype but does still display the necessary function to meet the highest ranked user needs. According to user needs, the final prototype displays all the most necessary and highest ranked user needs for the greatest user satisfaction. In comparison to the prototype, the real-world model will be made of higher tensile plastic instead of wood, and will be equipped with UV-C lights, a built-in button on the lid, and have a smart system installed in the lid that will control all aspects of the lighting, including safety switches to keep from the light being shined on users. The entire drawing packet for the prototype is in the Appendix.

b. Revised Grand Concept:

The original Grand Concept Design for this product was to have a slimmer, sleeker model. The lid was to have a button at the top that when pressed, would turn the lights on within it. The entire bottom of the lid was to be made of see-through material and the seat would look mountain-like with the bottom being the peak (See Figure 3.1). A motion sensor and actual timer was originally sought after, but neither were attainable. An attempt with the Arduino was used to create such a lighting system, but proper lighting strips were not compatible with it. Through limitations and an attempt to make things easier, the lid's new prototype looks bulkier with the edges of the seat not being curved at the top, but the lid is still in an ellipse shape like normal lids. The original hinge was to be one piece that would attach to the seat, but for the newer prototype, it was replaced with two door hinges (See Appendix A, Figure 13.2). The button that turns on the created prototype is now located inside the lid and is directly attached to the light source (See Appendix A, Figure 13.1). The lights do not turn off when the seat is lifted or after a certain time, but by using the Arduino, it can be shown that this is possible. Overall, while the created prototype is missing some of the ideas of the original concept design, it still is something that was imagined for the product. The lid still turns on lights that will cover the seat. These lights in an actual product would then be able to disinfect the seat. The created prototype may not have been what was perfectly hoped for, but it is still an accurate prototype of the desired product.

Final Prototype Verification.

To accurately represent and acquire all the details of the self-sanitizing toilet lid as described in the planning stages of the product, the team plans to prototype a coherent toilet lid and seat that can be connected to the brackets previously installed on a toilet. The use of the lid and seat combo would ensure that optimum light angles would be projected onto the seat, increasing the efficiency of the product. The lid and seat combination would also eliminate the uncertainties of proper fit and function due to various sizes and shapes of toilet seats in various settings. The toilet lid will require power to activate the UV-C light installed in it that will be responsible for the elimination of bacteria on the included toilet seat after each use. The toilet seat will receive its power through an attached power cord that can be plugged into a nearby outlet on the wall. Unlike the final product, the prototype will be equipped with LED lighting instead of UV-C lighting due to the lack of availability of UV-C lighting. The LED lights used will still accurately

represent the angles of the light projections onto the toilet seat if the UV-C lighting were to be used. Also, unlike the final product, the prototype will be significantly smaller due to limitations of funding that would be necessary to build a prototype to full scale. Consequently, the prototype will have to be on a much smaller scale to be able to create a fully functional prototype with all components necessary for full functionality. Most of the prototypes will be built in a 3D printer and later assembled using epoxy and other methods of installation. The team will also need to utilize laser cutting to acquire clear plastic that will cover and protect the UV-C lighting from damage. Other parts such as the lighting, working button, plug in cords, timers, and motion sensors will have to be installed a programmed by hand, before the finalization of the prototype. The final prototype should be an accurate representation of the final product and will be created using a high standard of prototyping.

Major Project Deliverables.

The goal for this project is to create a well-made, hopefully foolproof prototype of a toilet seat cleaning lid. The goal is for this lid to use UV-C light (a disinfecting light that kills 99.9% of germs when properly applied onto a surface) that turns on when the seat is placed down, and a button is pressed activating the lights. The deliverables for this prototype involve a toilet seat with several installed lights within it. For the actual product it would be real UV-C lighting, but for the prototype regular lights would be a good starting point. These lights must activate when the button at the top of the seat is pressed to activate it. Another goal will be to have a timer for the lights and that the lights would turn off when the seat is open. These goals may not be plausible with what is being worked with, but if it can be reasonably achieved, it will be. The goal for the lighting is to cover the entire area of the seat, to be waterproof so that water cannot reach the lights, and for the lights to not use an extreme amount of power. The goal for this prototype is to create a prototype that properly meets the user needs. This prototype needs to be usable/workable with the lights and the switch being able to work. This prototype also needs to be reliable and efficient. The prototype needs to prove that the actual concept of a UV-C toilet lid would be effective in the real world and not something that would flail out and never gain traction in the toilet disinfecting market.

User Validation Plan

Top 3 User Needs:

Reliability, longevity, and usability are the three highest ranked user needs according to the pairwise comparison chart (Table 8). Usability and simplicity were tied in the table, but we believe that usability just barely edges out simplicity for the user needs as the users would rather have a product that is usable than a product that is simple, when tough the product will be usable and simple. Reliability is so important because the users want something that will not only reliably work, but they will want something that will reliably disinfect their toilet seat to stop the spread of germs in bathrooms. Longevity is important to the users because they want a product

that will work more than once. When users purchase this product, they want it to last several years and not just a month. If the lid could only last for a month at a time, there would be no point in buying it. Lastly, usability is so important to the users because this product needs to be usable. They want it to be able to work on their toilet, and to work at the press of a button.

Table 7: **Pairwise Comparison Chart.** A chart representing the user needs in a nominated ranking system.

	Intigrated	Affordable	Customizable	Reliability	Longevity	Usability	Simplicity	Efficency	Durability	Aesthetic	Total	Normalized	Original
Intigrated		0	1	0	0	0	0	0	0	1	2	1.0	2
Affordable	0		1	0	0	0	1	0	0	1	3	1.8	3
Customizable	0	0		0	0	1	0	1	0	1	3	1.8	1
Reliability	0	1	0		1	1	1	1	1	1	7	5.0	4
Longevity	1	0	1	0		0	1	0	1	1	5	3.4	4
Usability	0	0	0	0	0		1	1	1	1	4	2.6	5
Simplicity	1	0	1	0	0	0		0	1	1	4	2.6	3
Efficency	0	0	0	0	1	0	0		1	1	3	1.8	5
Durability	0	1	1	0	0	0	0	0		1	3	1.8	3
Aesthetic	0	0	0	0	0	0	0	0	0		0	0.0	1

Goals:

User validation will be acquired through systematically performed user validation tests. The primary goals of these tests are to acquire the opinions and perceptions of potential end users based on usability, longevity, and reliability of our product. Interviews will be the primary method of collecting consumer data, while surveys will be given to individuals to test their understanding of the product after their first encounter. Surveys will ask questions based on one's understanding and ability to use the product while interviews will be solely based on conversation and individuals' opinions on the design and concept of the product. It is from these interviews and surveys that it may be determined if the product meets the requirements set by the top three user needs. Users feedback will provide the data necessary to better the product and determine the next course of action required to optimize the reliability, longevity, and usability of the product.

Methodology:

The first top user need is reliability. To test this with our prototype, since obtaining actual UV-C light will not be plausible for our prototype, the working of the lighting will be what is tested. Through interviews with potential users, we will ask if the light is being turned on with the press of a button whilst having a proper timer would be reliable enough. Another question to be asked would be about their thoughts on the reliability of a small pressure pad that would turn the light off if the seat is lifted. For longevity, the question to be asked would be how long they would want a proper UV-C lid to last. UV-C lights normally last up to 10,000 hours which is the

equivalent to about 416 days, so the product should last at least 2 years since it would not be running for 416 days straight. For usability, the question for the users would be if they would properly use the product and how often they would use it. Would they use it maybe once a day, or after every use. Would they be willing to replace their normal toilet seat with this UV-C seat, or would they rather take their chances with the normal way of grabbing a rag and some bleach?

Ethics:

In performing these tests, an ethical standpoint must be taken to keep users' information and opinion undisclosed to the public and to ensure their privacy is respected. It is of utmost importance that permission and consent is present before any personal information is collected or even asked for. All collected data will be anonymous to protect the identities of the individuals who choose to participate in us interviews and/or surveys. Information will only be collected from individuals who give us permission to collect data from them. If the individual being interviewed feels uncomfortable at any point during the interview, they may leave or stop answering any or all questions at their convenience. Nothing will be forced onto any individual at any point in the interaction. A form stating consent and our values can be provided upon request.

Table 8: Value Matrix. A visual representation of the difference between economic and social value that different stakeholders gain.

	Value Categories		
Stakeholders	**economic**	**social**	**environmental**
End users (janitors / cleaners who clean bathrooms)	Could save time cleaning toilets and get their job done faster.	Would make their work easier and more satisfying with more efficient ways of cleaning.	Eliminate the use of cleaning supplies in plastic bottles, wipes, and other non reusable supplies.
People who use restrooms	Preventing the spread of germs leads to less sick days taken.	Feel more comfortable and cleaner in the restroom.	Not waste wipes or disinfectent wiping down toilet seats.
Cleaning supply businesses	Could lose some business due by being replaced.	Competitive atitude by introducing new techniques	Produce less plastic, non environmentally friendly materials
Bigger companies with higher traffic restrooms.	Less workers taking sick days and less people getting sick leading to more business flow.	More people coming in and more happy customers / workers that are healthy.	Massive waste of cleaning materials would be replaced and a cleaner environment.
Manufacturers / companies in the restroom / public restroom field	Either a loss or gain of business from trying out a new technique or fighting against this new successful technique.	Another competitive target to either work with or compete against.	Reduce the massive import by by trucks shipping supplies, with one final import of a UV-C toilet seat.

Value & Impact.

Economical:

For each of the possible stakeholders, there will be an economic impact and value that will affect them due to the product. For the end users, janitors could get the work done quicker by making more time to do other parts of their jobs that could increase wages. Saving time also gives at home users more time for working and less time for cleaning their toilet. For people who use public restrooms, the economic impact on them would be that they would be at less risk of

getting sick from germs on the seat. With less of a chance of being sick, that means they would have a significantly less chance of missing work and income. The cleaning supply business would certainly lose a good amount of income due to our product. Our product would be self-sustaining and long-lasting compared to their products where the user would have to manually clean the seat themselves. Users would know that they can save money overall with our product compared to constantly spending money on cleaning products leading to a loss of profit for those businesses. For larger companies that buy the UV-C toilet lids, they would also save money overall as they would not have to spend as much on cleaning products. It would also lead to less disease being spread between workers and staff, meaning more productive days and business flow. For manufacturers/companies in the public restroom industries, this could be big for them economically if they can embrace the idea of the UV-C lid and it catches on. For the companies that oppose this change, it could lead to a large loss of profit for them. Compared to other alternatives and competitors being classic cleaning supplies such as bleach, this product would be more expensive at first, but this product would be a one-time buy. A large purchase that will last well over two years compared to the constant buying of a cleaning product and wasting of time. The revenue for this product would be much greater than the costs as the most expensive part would be the circuitry and sensor for the UV-C light as well as the UV-C lights themselves, which would be in the $15-30 range for getting the lighting to be the correct shape.

Social:

As for the social impact and value, for our end users, the positives would be that this would make their jobs/work easier. It would have them spend less time cleaning the seats and more time cleaning other important areas. This product would save time and money. The only negative for the users would be that this toilet lid would take energy to run for the circuits and the lighting while the older solutions did not involve electricity to run. For the users that use the restrooms, it would give them more comfortable experiences in public restrooms and the lid would keep things much more sanitary. This lid would decrease the spread of disease and illness keeping people who use these public restrooms healthier overall. The negative would be that the UV-C light must be turned on manually with the press of a button, and many users may forget to activate it after use. For the cleaning supply businesses, this newfound competition would hopefully inspire the competitors to create more advanced cleaning products of their own creating an even healthier atmosphere around public restrooms. For the larger companies, this would create a healthier bathroom environment for them as well. It would also make things much easier for their workers. The only populations that would have special needs with the product would be those with disabilities that would restrict their use of the lid. The lid for these users may be modified to have a motion sensor to start the activation of the UV-C lighting for specific models.

Project Recommendations:

For this product, several recommendations can be made for the possible design and production of it if it makes it past the prototyping phase. For a more improved prototype design, actual UV-C lighting should be used rather than a strand of LEDs. The prototype created has several strands, while a more improved prototype would have one large UV-C light that goes around the interior of the lid and is placed directly above the seat. For the actual creation of this product, it should

have a timer of 5 minutes, with more research being including to determine the most efficient time for killing of the bacteria. A motion sensor or pressure plate should be used to turn the UV-C light off when the seat is lifted so that a user doesn't accidentally stare into the light or have it on their skin for too long. A more improved design would have the seat made from polypropylene or some type of durable plastic. This should be done for easier mass production of the product as casting and molding could be used for the lid. A more improved design would also allow for a sleeker exterior for the lid as toilet seats today are curvy on the top and very smooth with no rough corners. More output from users would also be helpful as knowing that potential users would use our product with no doubts in their mind that this product would work would be very beneficial in the long run. The user's needs are what is most important.

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Appendix A: Evidence of Brainstorming

Figure 8. Narrowing down process for user task

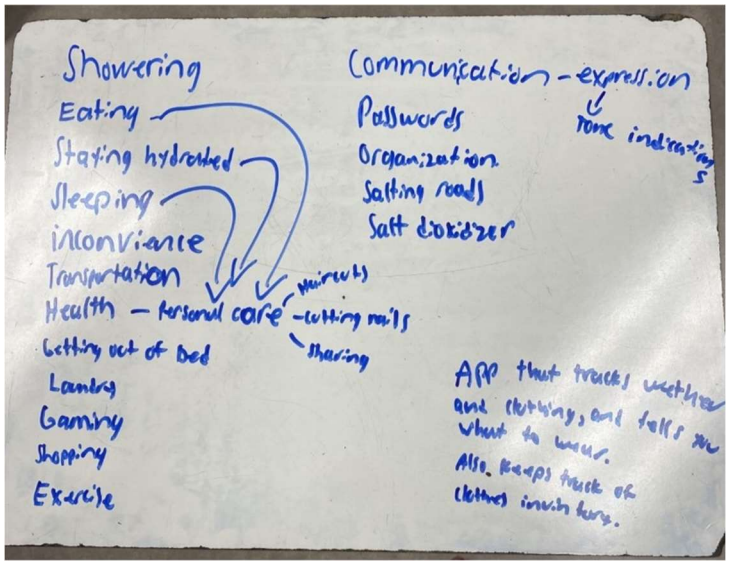


Figure 9. Further narrowing down process for user task

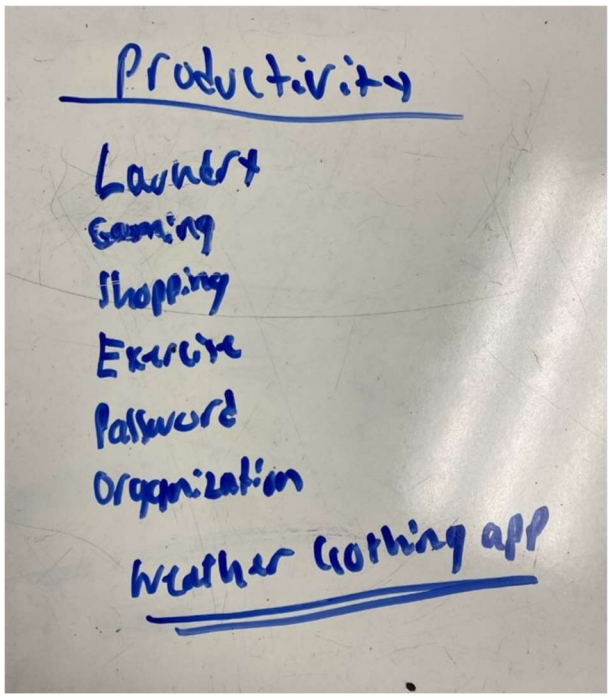
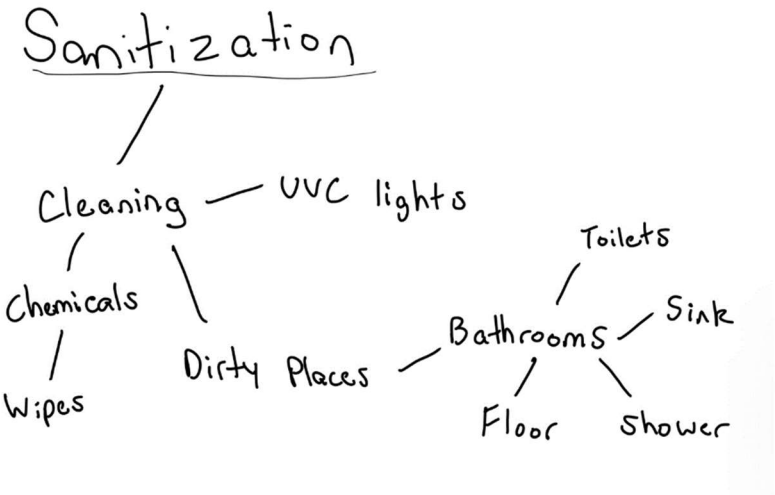


Figure 10. Concept Map for determining the focused upon user task.



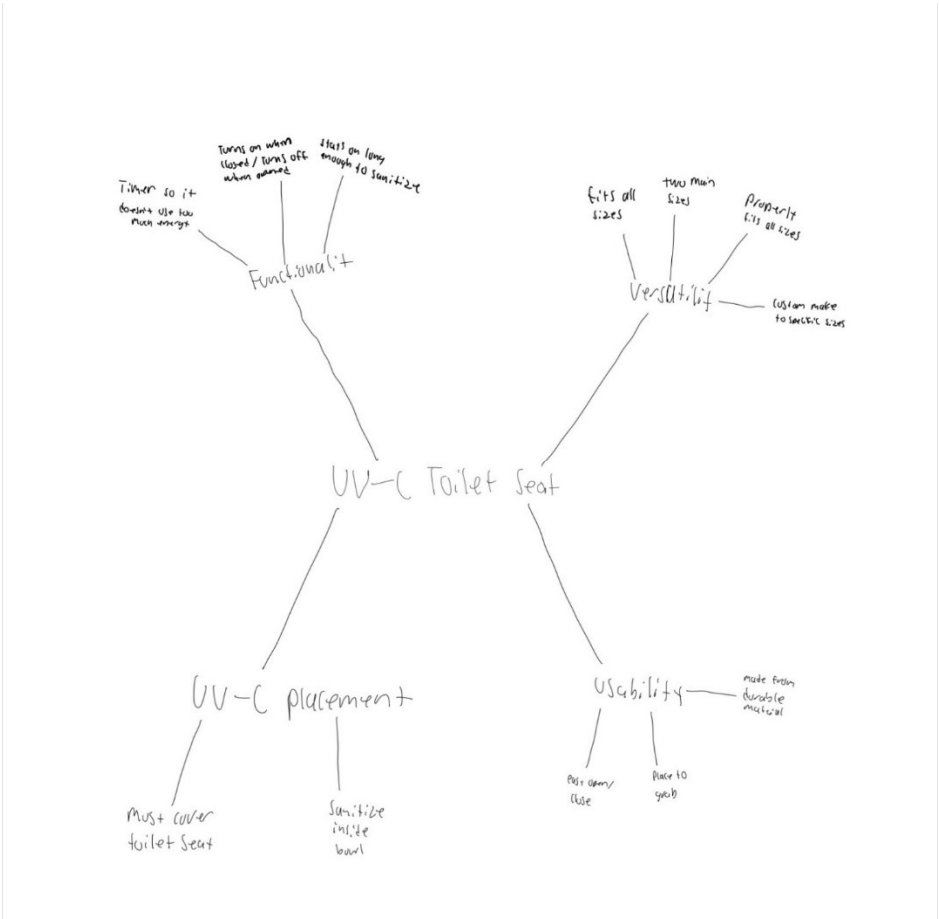


Figure 11: Brainstorming Process showing the thought process to help determine and narrow down our main idea.

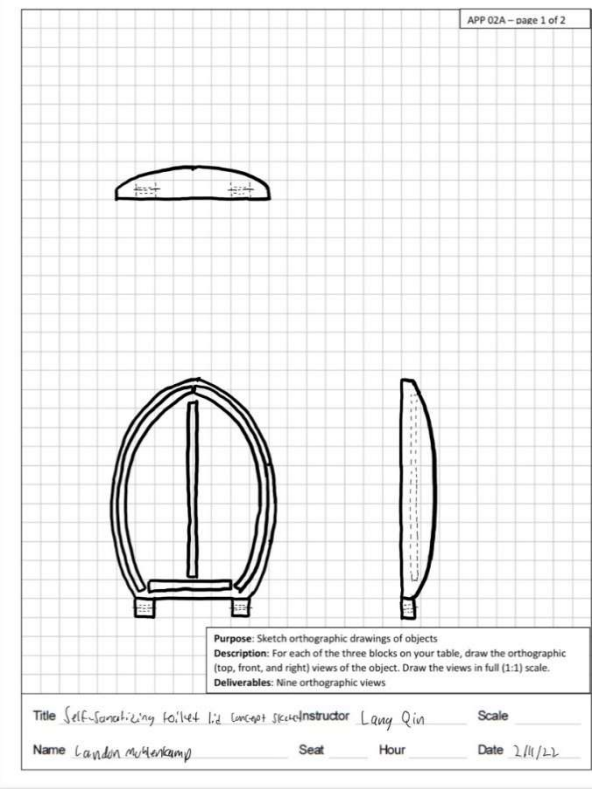


Figure 12.1. Concept Design 1 designed by Landon Muhlenkamp using 3 orthographic views to show what a possible design could be for the toilet seat.

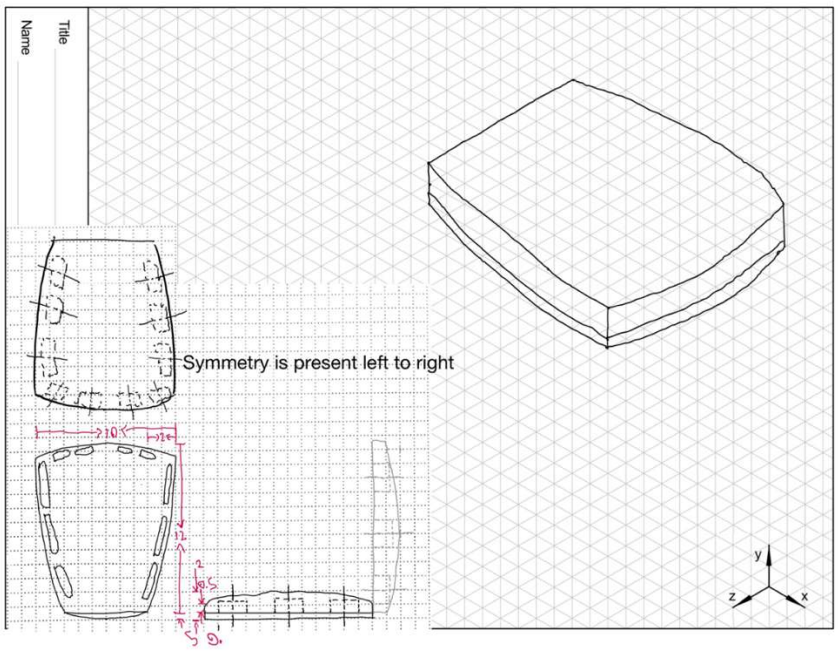


Figure 12.2. Concept Design 2 drawn by Nick Webber showing a thicker build for the lid to be able to incorporate more

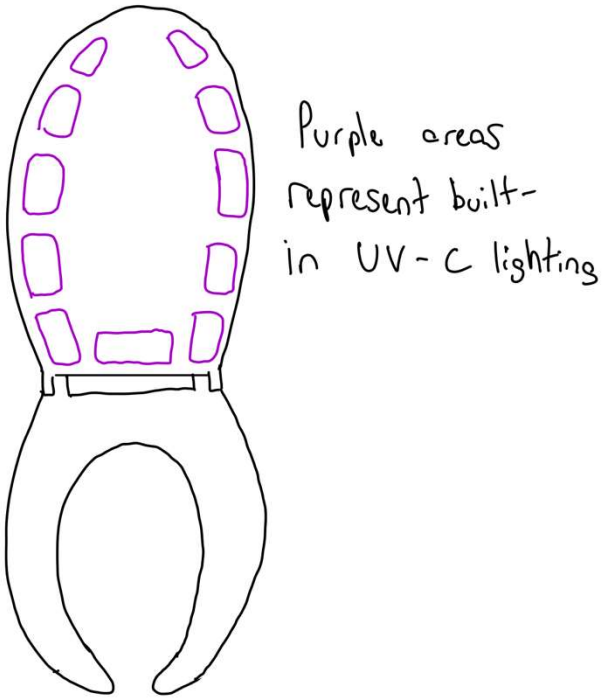


Figure 12.3. Concept Design 3

Appendix B: Prototype Working Drawings Packet

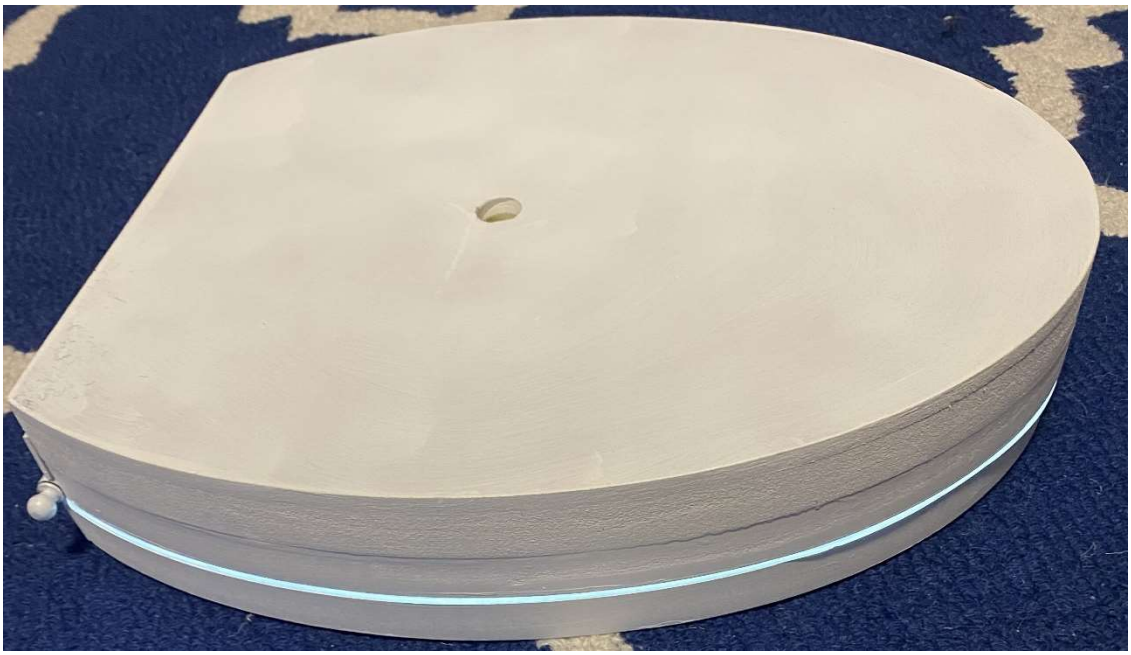


Figure 13.1. The finished prototype. The outer material made of fiberboard is shown with the hole on the top being the spot for the button.

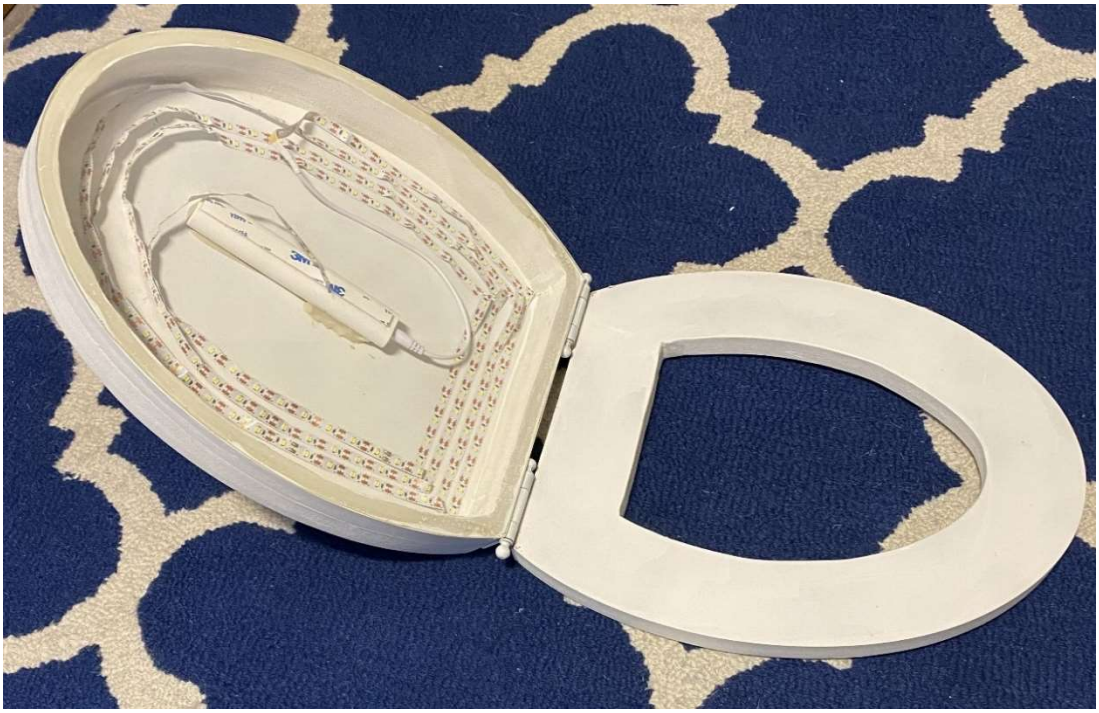


Figure 13.2. The finished prototype. The inside shown covered by plexiglass with the light strand inside.

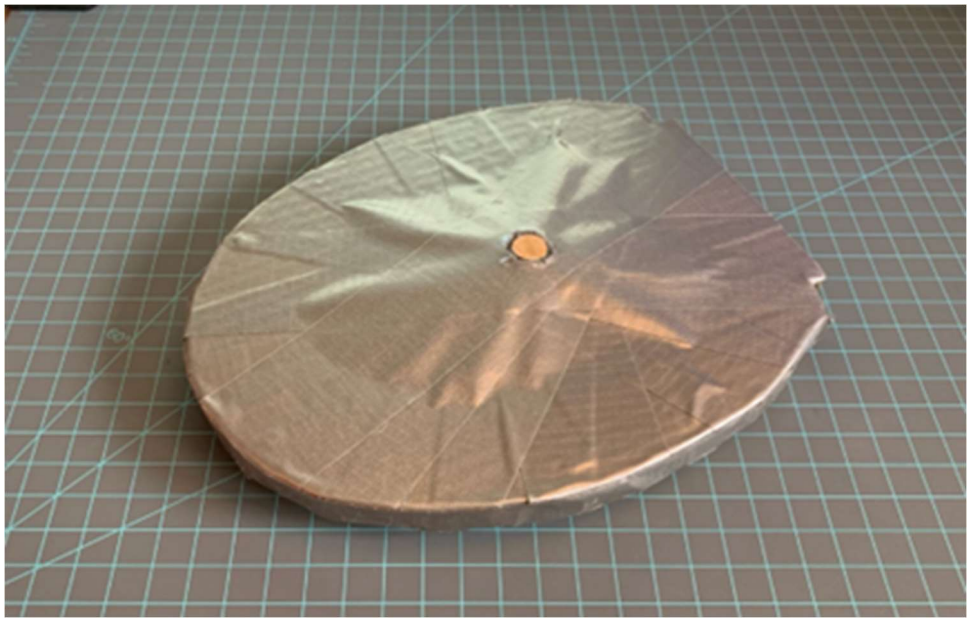


Figure 14. Prototype Preliminary Design Closed. A rough model made of cardboard, duct tape, and other household materials to model the UV-C Toilet seat design when it is closed.

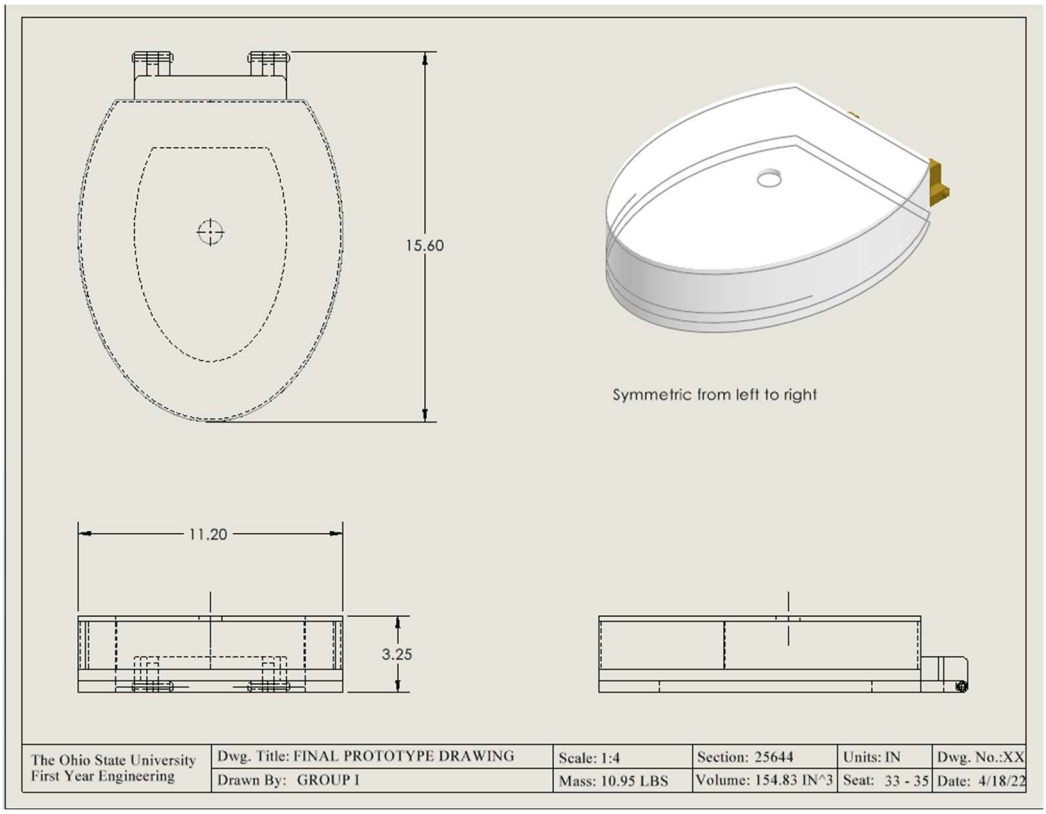
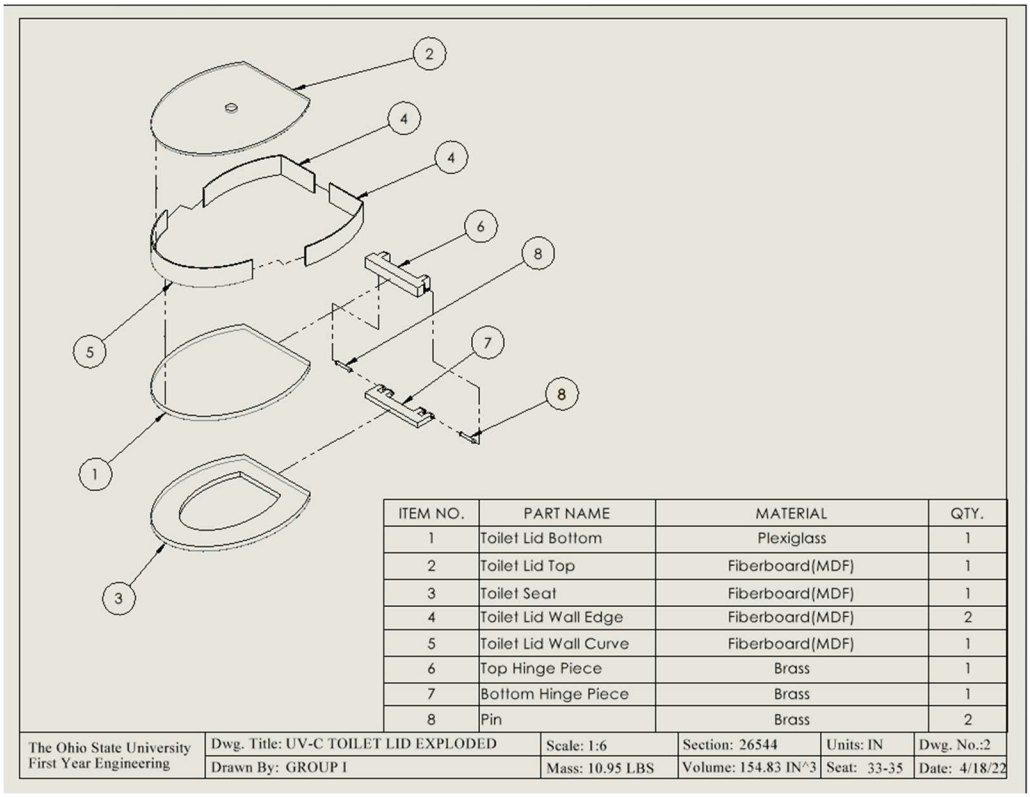


Figure 15.1. Page one of Final Prototype Drawing Packet. It has three orthographic views of the full design and one isometric.



ITEM NO.	PART NAME	MATERIAL	QTY.
1	Toilet Lid Bottom	Plexiglass	1
2	Toilet Lid Top	Fiberboard(MDF)	1
3	Toilet Seat	Fiberboard(MDF)	1
4	Toilet Lid Wall Edge	Fiberboard(MDF)	2
5	Toilet Lid Wall Curve	Fiberboard(MDF)	1
6	Top Hinge Piece	Brass	1
7	Bottom Hinge Piece	Brass	1
8	Pin	Brass	2

The Ohio State University First Year Engineering	Dwg. Title: UV-C TOILET LID EXPLODED	Scale: 1:6	Section: 26544	Units: IN	Dwg. No.:2
	Drawn By: GROUP I	Mass: 10.95 LBS	Volume: 154.83 IN^3	Seat: 33-35	Date: 4/18/22

Figure 15.2. Drawing #2 that contains the exploded view of all the parts used within the entire prototype.

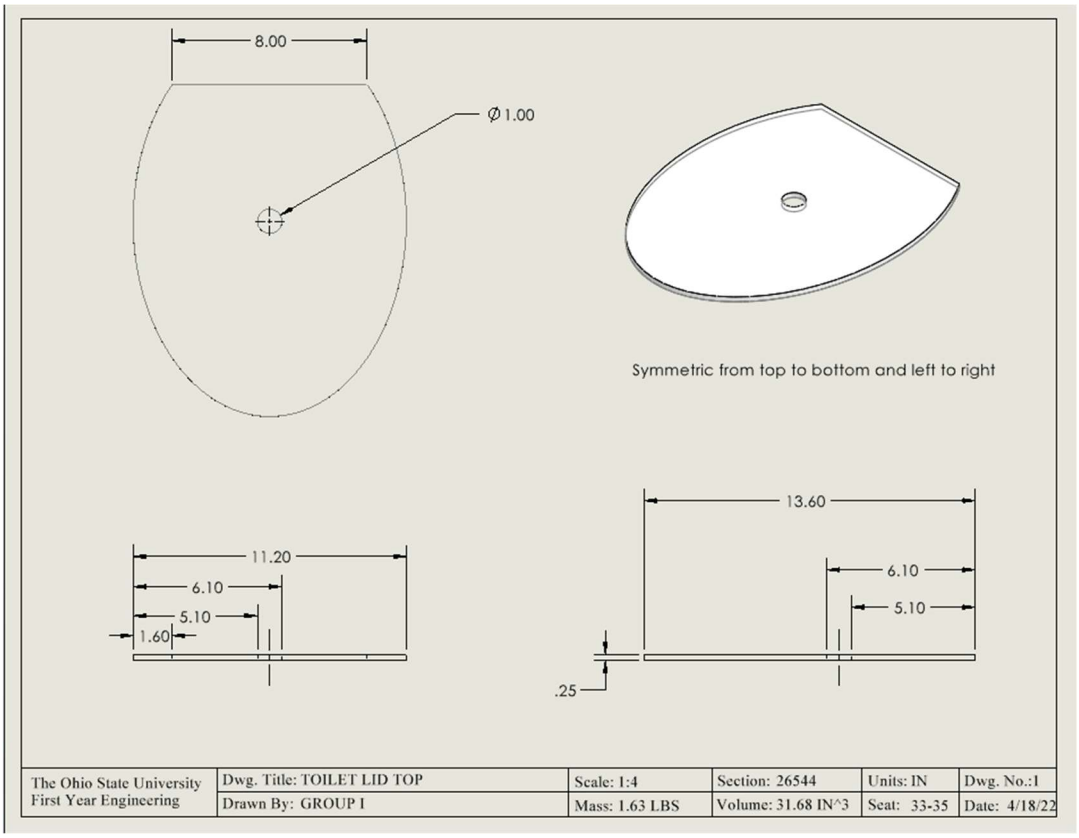


Figure 15.3. Detailed drawing of the lid for the prototype. It has a hole for the button used to turn the LED lights on.

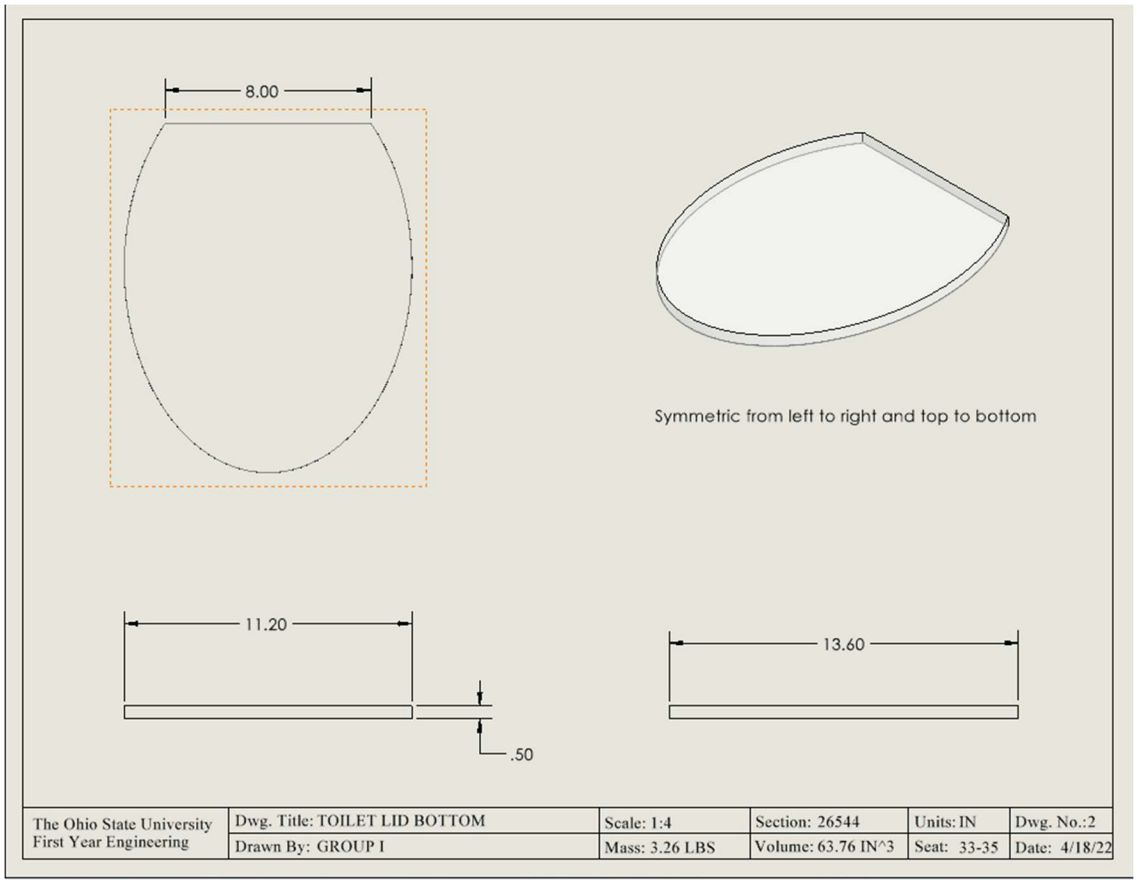


Figure 15.4. This Drawing is of the plexiglass bottom of the lid that's allows for the lights to be displayed onto the seat.

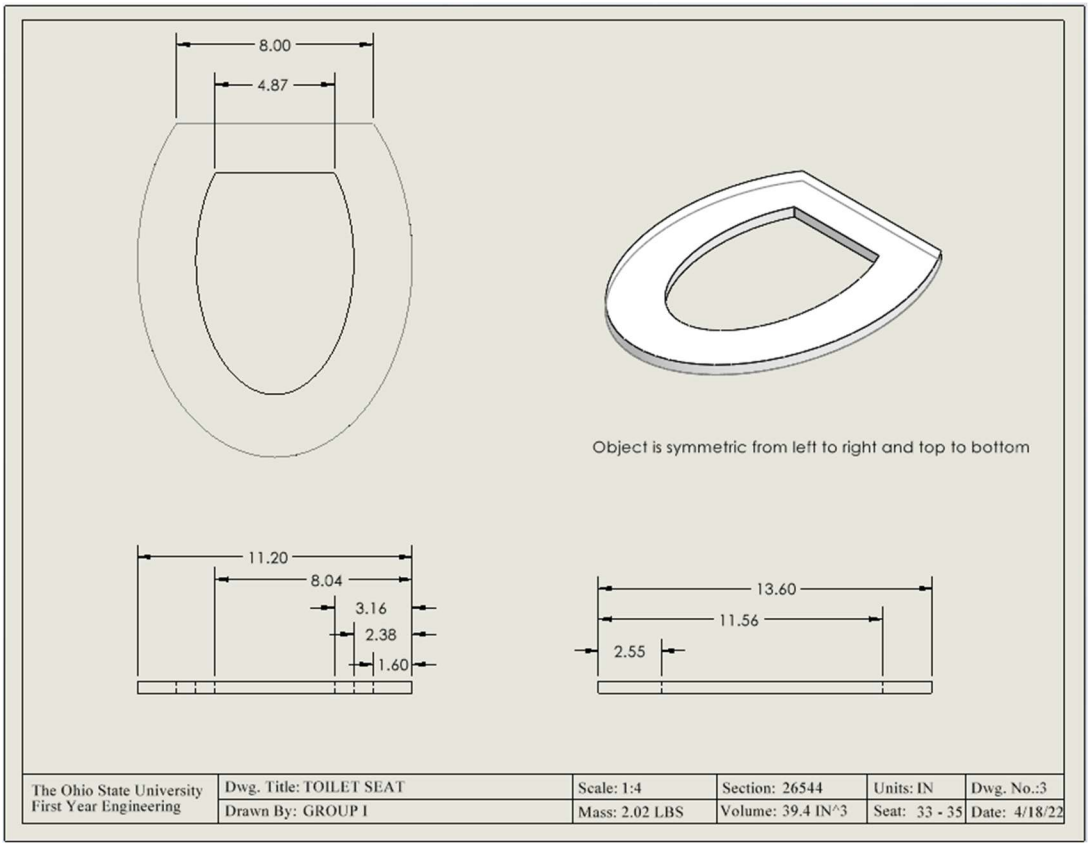


Figure 15.5. This is the drawing of the toilet seat that will be used to test if the light properly covers it.

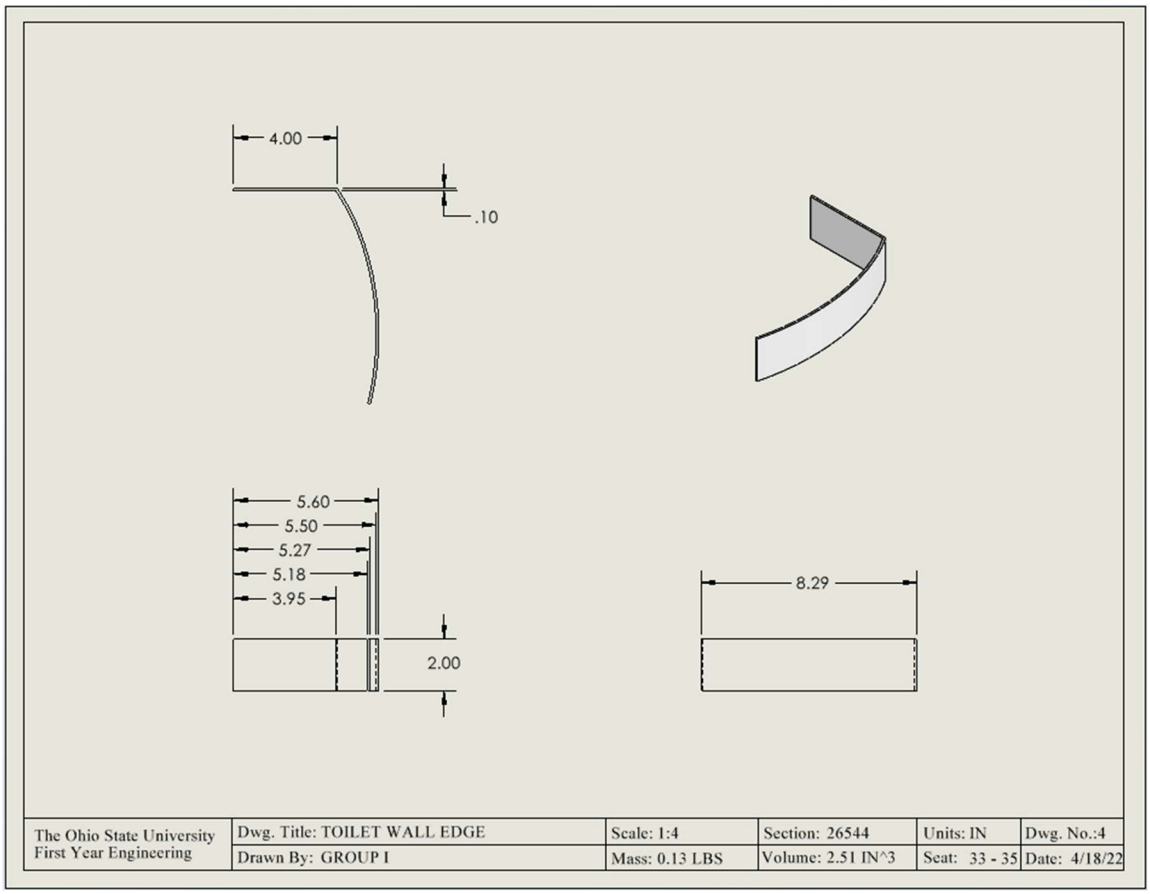


Figure 15.6. This contains one of the edges of the lid's walls. It isn't very thick and is simply used to protect the lights and hold the top up.

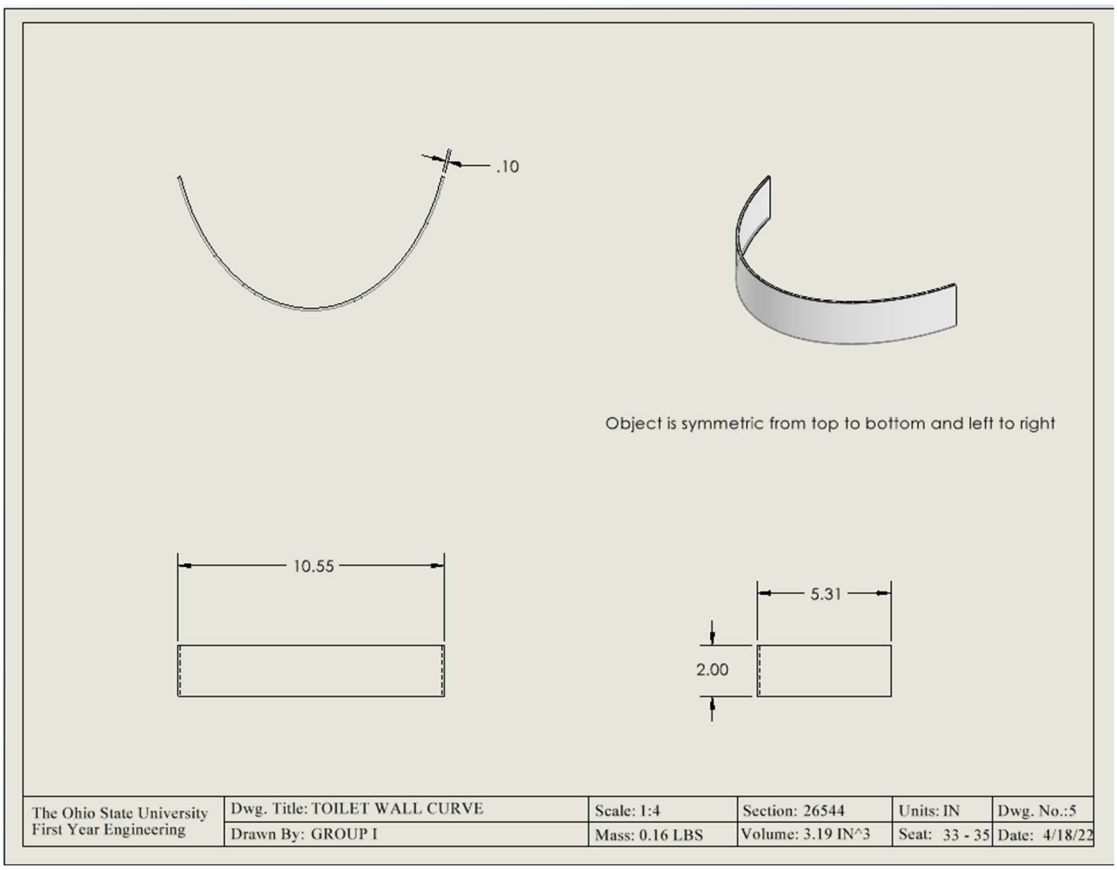


Figure 15.7. This is the other piece of the outer wall of the lid. It is made of fiberwood

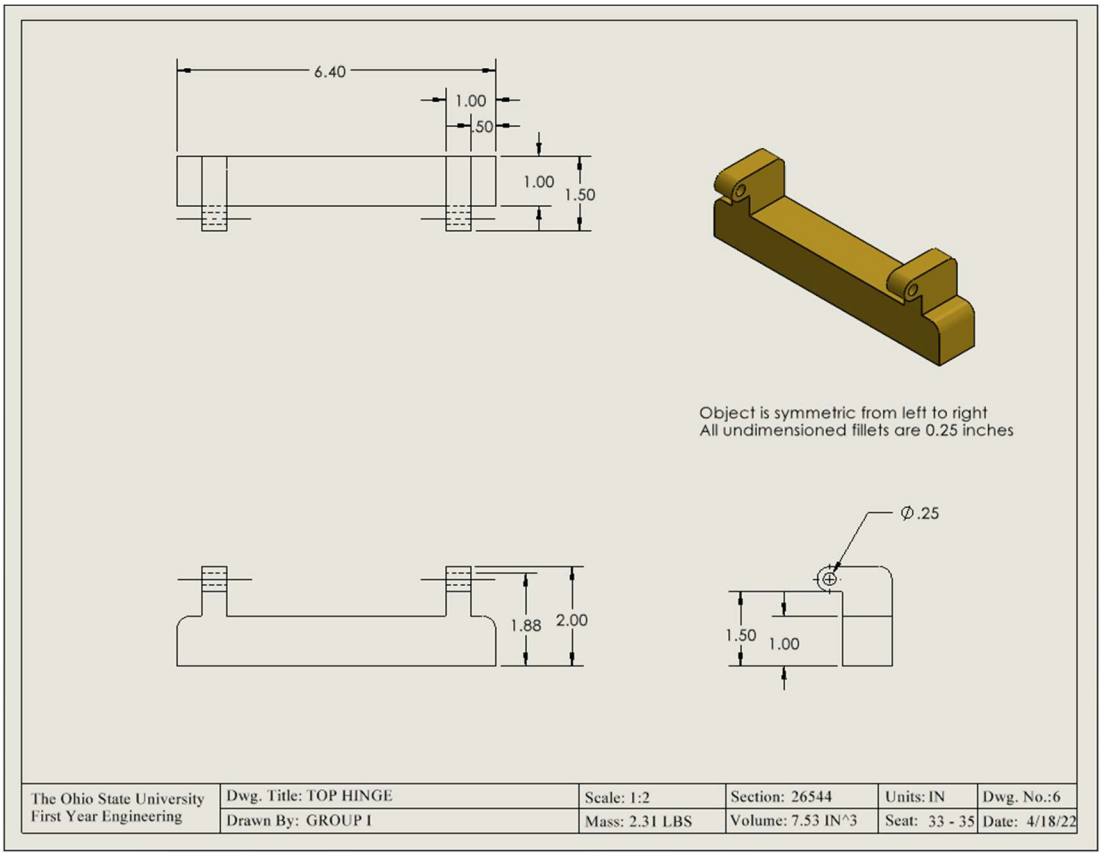


Figure 15.8. This is the top part of the hinge that attaches the lid to the seat. It allows for the proper rotation.

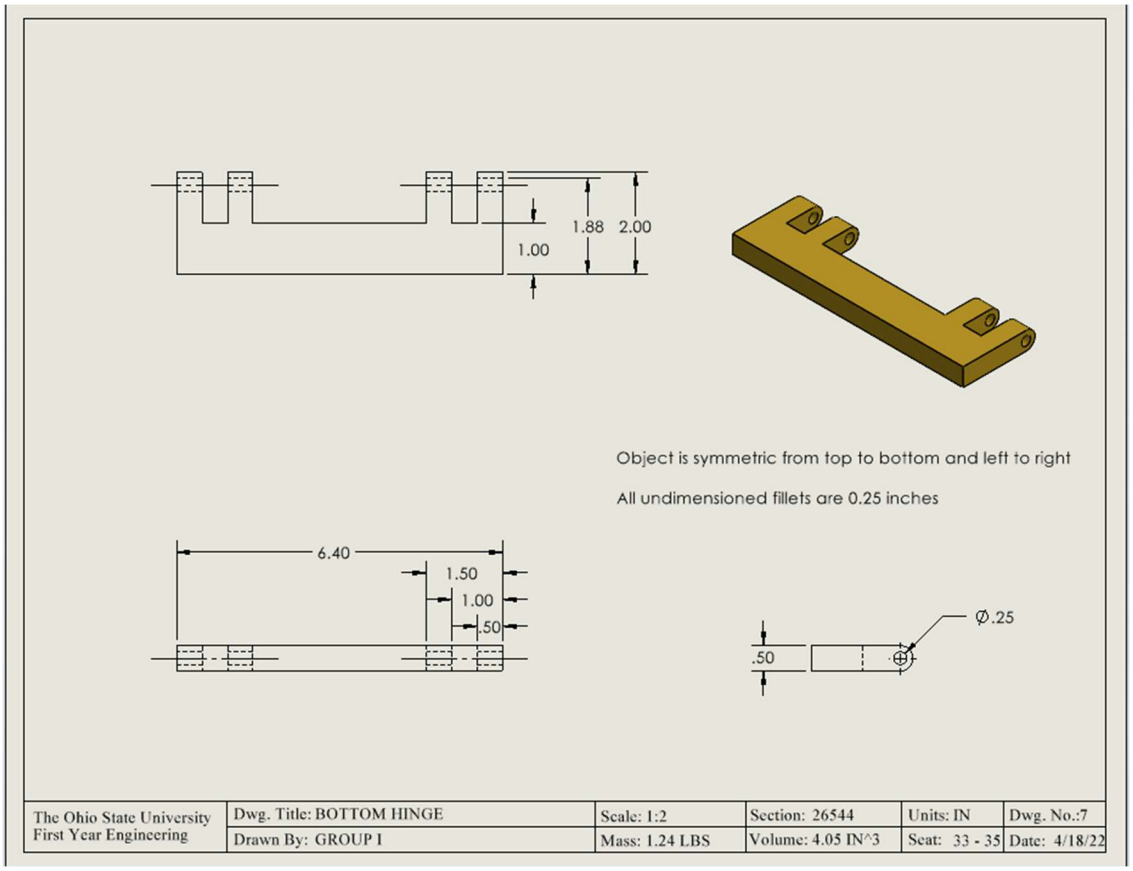


Figure 15.9. This is the bottom part of the hinge. It is attached to the seat.

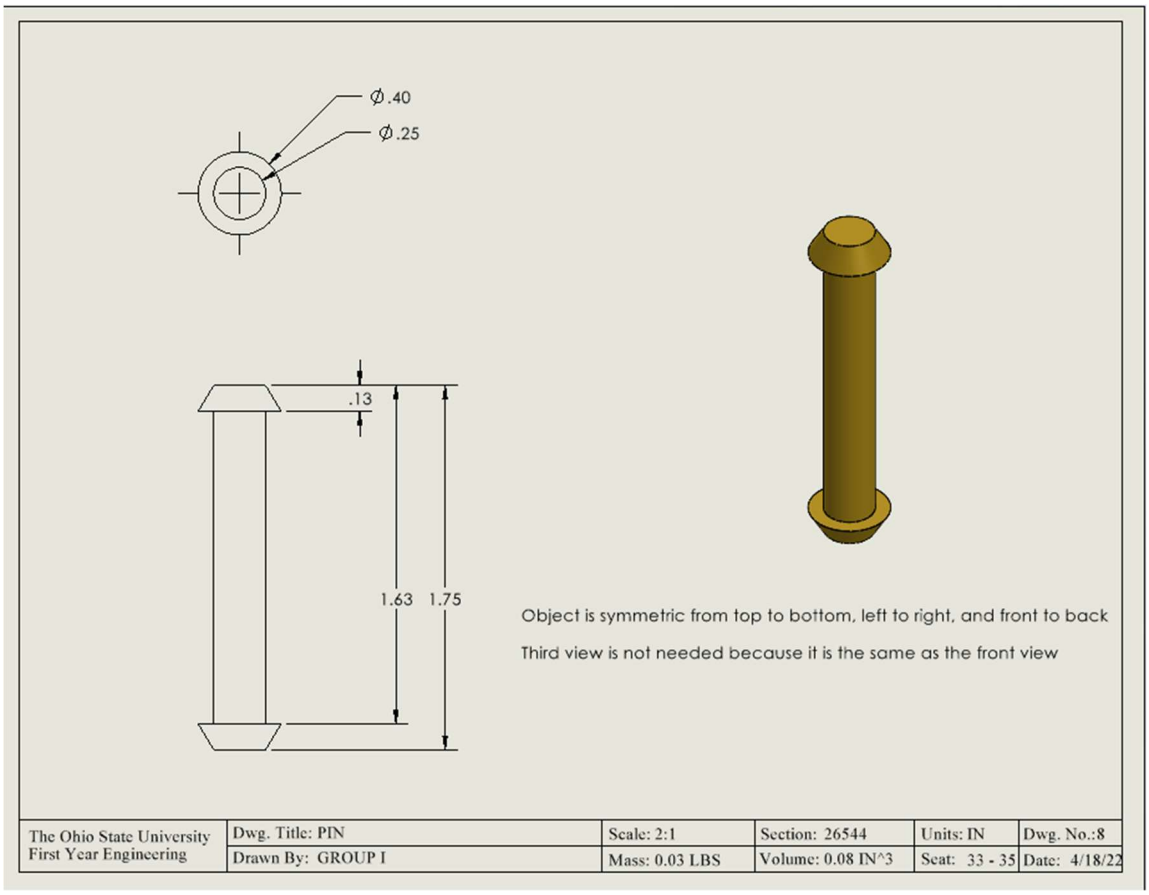


Figure 15.10. This is the pin piece. It attaches the top hinge to the bottom hinge, so the seat and the lid do not fall apart.

Appendix C: Software Code

```
void myCode()
{
  //-------------------------------------------------------------------------------------
  // This is the tab where student programming is done.
  // A list of available function calls are listed in detail under tab "Student_Functions"
  //
  // NOTE: Always comment your code. Debugging will be quicker and easier to do and will
  //       especially aid the instructional team in helping you.
  //
  // IF YOU ARE RECORDING DATA TO EEPROM:
  // (2) DO NOT turn the controller off, connect/disconnect the controller to a computer, or
  //     push the reset button on the Arduino until your program has run to completion and
  //     the indicator LED has stopped flashing. There is a 13 second processing period when
  //     data is stored and battery recuperation takes place.
  // (2) Data will be recorded approximately every 100 milliseconds. This may vary depending
  //     on code complexity & operational tasks of your prototype.
  //-------------------------------------------------------------------------------------

  // Program between here-----------------------------------------------------------------

  // use pinMode() function to set IO_PORT3 as an output, and IO_PORT1 as input
  pinMode(IO_PORT1, INPUT);
  pinMode(IO_PORT3, OUTPUT);
  /*
   * turn led on
   */
    digitalWrite(IO_PORT3,HIGH);
    /*
    * keep led on for 30 seconds unless motion sensor is sensed
    */
    int i = 0;
    // initialize pressureRead to something other than zero to enter loop
    int pressureRead = 10;
    while ((i <= 30) && (pressureRead != 0)){
      pauseFor(1);
      i++;
      pressureRead = analogRead(IO_PORT1);
    }
    digitalWrite(IO_PORT3,LOW);

  // And here-----------------------------------------------------------------------------
EndMyCode(); //Comment out this function to loop myCode
} // DO NOT REMOVE. end of void myCode()
```

Appendix D: Additional Raw Data

Table 9. Table that shows the detection of naturally occurring coliforms on bathroom surfaces [5]

Surface	No. of samples	No. of agar plates on which coliforms were detected	% Samples positive	Maximum no. of coliforms detected on a single plate
Walls	54	11	20	5
Floor	120	31	26	>100
Seat, toilet	70	27	38	15
Rim, toilet	35	10	28	>60
Flush handle	9	1	11	2
Bathtubs, sinks, cabinets, etc.	125	6	5	>100

[a] Rodac plates of EMB agar were used.

Table 10. Another table showing the detection of naturally occurring coliforms on bathroom surfaces [5]

Microorganism	Concentration g^{-1} ml^{-1}	Reference
Faecal coliforms	10^6–10^9	Haas *et al.* (2014)
Escherichia coli		
Salmonella	10^4–10^{10}	Haas *et al.* (2014)
Campylobacter jujeni		
E. coli 0157:H7		
Shigella	10^5–10^9	Haas *et al.* (2014)
Enterovirus	10^3–10^8	Pepper *et al.* (2014)
Hepatitis A	10^8	Pepper *et al.* (2014)
Rotavirus	10^{10}–10^{12}	Pepper *et al.* (2014)
Norovirus	10^{10}–10^{12}	Pepper *et al.* (2014)
Adenovirus	10^{11}	Haas *et al.* (2014)
SARS-CoV-2	10^1–10^3	Xiao *et al.* (2020)
Cryptosporidium	10^6–10^7	Pepper *et al.* (2014)
Giardia	10^1–10^6	GWPP (2020)
Ascaris	10^4–10^5	Haas *et al.* (2014)

Appendix E: Project Management Plan/Schedule and Meeting Minutes

Workday Meeting Minutes 1:

Header — April 1st, 2022, 3:00 – 4:00 PM, In class meeting with Andrew, Nick, and Landon attending
Objective statement — The purpose of this meeting is to figure out which parts of our prototype need to be laser cut, which pieces need to be 3d-printed, and which pieces don't need either. The dimensions that we will be using also need to be determined to make the prototype.

Completed tasks from previous week:

- DD1 Project Management – Nick, Andrew, and Landon
- R2 Conceptual Design Review – Nick, Andrew, and Landon
- P2 Grand Concept & Prototype Plan - Nick, Andrew, and Landon
- Entire Mock SolidWorks Drawing - Nick
- Our status is that we are doing good so far. We are behind on the individual parts drawings as we need to hurry up and order the parts to be able to have the prototype completed in time. Both the DD1 and R2 assignments went well as both assignments were completed with time to spare. We believed that our P2 presentation was good as well.

Tasks to be completed for the upcoming week:

- SolidWorks Drawing for lid (dxf file) - Nick
- SolidWorks Drawing for seat (dxf file) - Nick
- SolidWorks Drawing for acrylic portion (dxf file) - Andrew
- SolidWorks Drawing for bottom connector -Landon
- SolidWorks Drawing for top connector - Landon
- Ordering parts from the library (motion sensor, FE controller, wires) - Andrew

Project timeline:

So far, we are on task for our project timeline. The meeting minutes have been completed. The next big deadline is April 3rd as we need to have our SolidWorks models made by that day so they can be ready to order.

Decisions:

The group has decided that the top of the toilet lid, the bottom of the toilet lid (in acrylic), and the toilet seat need to be laser cut. This was decided because we realized each of these parts are flat pieces and they would not be good for 3D printing because of this. The connector pieces are planned to be 3D printed as they are curved in shape and would be good for 3D printing. It was also decided that the FE controller would be used for the lighting. We the Arduino, we can set the lights on a timer as well as being able to connect this Arduino to a motion sensor which would be perfect for our UV-C toilet lid.

Workday Meeting Minutes 2:

Header — April 11th, 2022, 3:00 – 4:00 PM, In class meeting with Andrew, Nick, and Landon attending
Objective statement — The purpose of this meeting is to finalize our backup plan in case our parts cannot be 3D printed. We need to figure out how we are going to go about woodworking our 3D printed part that cannot be printed and the code for the Arduino for the lighting.

Completed tasks from previous week:

- DD1 Project Management – Nick, Andrew, and Landon

- R2 Conceptual Design Review – Nick, Andrew, and Landon
- P2 Grand Concept & Prototype Plan - Nick, Andrew, and Landon
- Entire Mock SolidWorks Drawing – Nick
- User Validation Plan - Nick, Andrew, and Landon
- Our status is that we are still doing pretty good, we've just been having difficulties with getting our stuff printed and laser cut, and we just need to finish up a backup plan. We have been coming up with lots of different ideas and it's been long and frustrating, but we have pretty much come up with a final back up plan that we have all decided on, so the finish line is near.

Tasks to be completed for the upcoming week:

- P2.2 - Initial Verification "Mini" Presentation Nick, Andrew, and Landon
- DD3 - Social and Economic Value Nick, Andrew, and Landon
- 2nd Part for Arduino Code Safety Feature Nick
- Rear toilet seat connector wood worked Andrew, and Landon

Project timeline:

So far, we are still on task for our project timeline. The meeting minutes have been completed. The next big deadline is April 13th as we must prepare for the mini presentation and have our code done and finish our DD3 Social and Economic Value assignment.

Decisions:

The group has decided that we would be woodworking a back connector for our toilet seat since we need a backup plan because it doesn't look like we are going to be able to get it 3D printed from all the times it got denied. We have also decided on presenting our model with the full light in there to show what it would look like and then presenting our model with the Arduino outside of the toilet seat and the wires going in to it kind of as a rough model to show that our code works, but since the Arduino can't power the whole LED light strip that we originally brought we are just going to power a LED to show that the code works even though it won't look exactly like the final product, we have decided on doing this since we are in a major time crunch and some things did not work accordingly to the original plan. Our user feedback helped us make the decision to sacrifice aesthetic and looks for functionality, according to our user experience chart, so we have made a simpler model for our project to be not only less expensive but better functionality wise.

Workday Meeting Minutes 3:

Header — April 15th, 2022, 3:00 – 4:00 PM, In class meeting with Andrew, Nick, and Landon attending

Objective statement— The purpose of this meeting is to finalize a plan for our presentation and how we are going to go about doing the final presentation with our new prototype. We also need to share information on the new prototype that was wood worked.

Completed tasks from previous week:

- A20 – Workday 1 Meeting Minutes

-DD2 – User Validation Plan

- A22 – Workday 2 Meeting Minutes

- P2.2 – Initial Verification “Mini” Presentation

- Plan B Prototype Model

- Arduino prototype code
- Our status is that we are still doing good. We have completed our plan b model, and the code needed. We just need to come up with a plan for the final presentation.

Tasks to be completed for the upcoming week:

- DD4 – Detailed Design and Manufacturing, Nick, Andrew, and Landon

- FD1 – Prototype Working Drawings Packet, Nick, Andrew, and Landon
- FD2 – Final Verification Testing, Nick, Andrew, and Landon
- FD3 – Final Pitch, Nick, Andrew, and Landon

Project timeline:

So far, we are a little off task for our project timeline. Although we are getting everything we need to complete, we had some setbacks with the 3D printing and laser cutting orders and communication. We have finished our plan b prototype to the best we can, and we have also finished the code for the Arduino for our prototype to clearly present what our project is meant to do. We need to start getting back on track with this progress and start communicating a little more clearly.

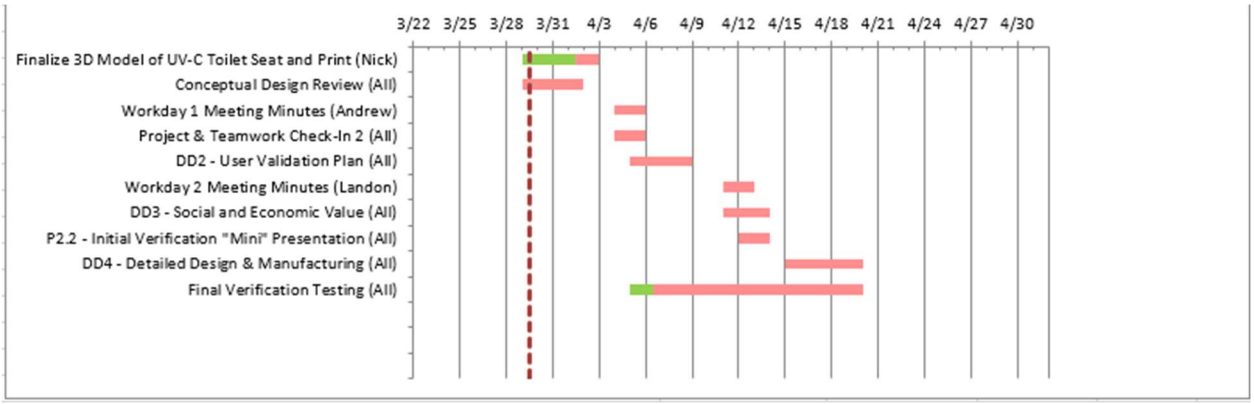
Decisions:

The group has decided to present the backup plan since it was clear that the 3D printed order and some laser cutting would be too late coming in or not coming in at all. We have taken that into charge by creating the final prototype out of woodworking materials, as well as continuing with the code on the Arduino that we will present separately with a light model showing what the original prototype would look like, then separately showing how the code will still work if we had the materials, we were told we would've had. We may come up short in the aesthetic of our presentation but that was a given when we realized that we would not be able to get our 3D printed materials, and our laser cuttings we have ordered. The next steps are to just use what we have and still try our best to stay on top of things with our new prototype without letting these things get to us.

Table 11: Gantt Chart. A detailed schedule plan for P20 through P25.

	Project Start Date	Project End Date	Today's Date
	3/22/22	5/2/22	3/29/22
Task Name/Description	Start Date	End Date	% complete
Finalize 3D Model of UV-C Toilet Seat and Print (Nick)	3/29/22	4/2/22	70
Conceptual Design Review (All)	3/29/22	4/1/22	0
Workday 1 Meeting Minutes (Andrew)	4/4/22	4/5/22	0
Project & Teamwork Check-In 2 (All)	4/4/22	4/5/22	0
DD2 - User Validation Plan (All)	4/5/22	4/8/22	0
Workday 2 Meeting Minutes (Landon)	4/11/22	4/12/22	0
DD3 - Social and Economic Value (All)	4/11/22	4/13/22	0
P2.2 - Initial Verification "Mini" Presentation (All)	4/12/22	4/13/22	0
DD4 - Detailed Design & Manufacturing (All)	4/15/22	4/19/22	0
Final Verification Testing (All)	4/5/22	4/19/22	10

Table 12: Project Management. A detailed project management plan for P20 through P25.



Appendix F: Team Working Agreement

Ohio State Engineering
First-Year Engineering
Team-Working Agreement

1. Group Information

Lab Section #: 26545
Table Letter: I
Instructor: Lang Qin
GTA: Tyler Milburn

2. Contact Information

Preferred Method(s) of Contact: Through text or Email
Expected Response time(s): Within an hour or whenever message is first seen
Table with Name and Contact Information:

Name	Cell Phone #	OSU Email
Andrew Neate	(419) - 706 - 0355	neate.14@osu.edu
Ladon Muhlenkamp	(937) - 621 - 3494	muhlenkamp.74@osu.edu
Nick Webber	(614) - 226 - 5651	webber.147@osu.edu

3. Team Goals

Our expectations of quality level are to get at least B's and much more preferably A's on every assignment that involves the entire team. Our top goals are to become better communicators with each other overtime and to work hard enough to obtain A's in this class. The minimum acceptable goals are to learn though each other this semester and to work as a quality team.

4. Meetings

We plan on meeting once a week to plan our goals. This may change depending on how much teamwork there is coming later in the semester whether there are more team assignments or fewer team assignments.

Primary Meeting Day/Time/Location:
Sunday/8pm/Zoom or Thompson Library

Secondary Meeting Day/Time/Location
Monday/8pm/Zoom or Thompson Library

Individual in charge of agenda(s): Landon
Individual in charge of reminders(s):
Andrew
Individual in charge of minutes(s): Nick

5. General Team Member expectations

- Our expectations are for each member to be at every single class and every single lab barring sickness or something important.
- Team members are expected to treat each other respectfully and to pay attention to the lectures that our instructors give.
- Team members are expected to stay on task during the working portion of the meetings, but when meetings first start, we may talk about other classes, homework, common interests, etc. to get to know each other better
- Unacceptable interactions would be sharing answers to homework or making fun of or disrespecting other group members. Acceptable interactions would be interactions that involve getting group members to get to know each other better
- Team members are to get ready and prepared for class and lab in between classes so each member comes prepared and ready to work
- To keep the team on track, team members should keep their phones put away and should only have documents related to the assignments at hand open
- Documents are expected to be shared via mainly OneDrive, but they can be shared via Google Docs if need be
- Each group member should have their portion of the assignment done at least the day before the assignment is due so the morning before class can be used to review
- If a group member is struggling, they should notify the group immediately so that they can be helped

6. Individual Team Member Responsibilities/Deadlines?

- Roles will change with each new project. Roles change from project to project. If a member of the group has a strong understanding of a project or assignment, they can take the lead for that assignment

asking the other members to then work on certain sections of the project
- The leader of the project is tasked with deciding to split the work evenly amongst the three of us and which part each of us will be doing. The other members can give input and overrule the leader at any point if they agree.
- The leadership role can change depending on the project or how the group becomes comfortable over time. They can rotate with each new project if need be

7. Conflict Resolution

Once the team goals, general member expectations, and individual team member responsibilities have been established, candid, non-threatening discussion must be held when the group or individuals are not meeting the agreed upon terms.

- When there is a disagreement amongst team members, the members disagreeing will have a chance to share both sides of their argument and then a vote will be made to decide what to do, or a better option will be made.
- Team members will be held accountable by their other team members. Other members will constantly remind each member of their assignment, and if that assignment is not done and the other members must do it for them, then there must be a very good reason, or it will be brought up to the professor
- Team members that are not meeting expectations will be given the ultimatum to either start meeting expectations after having a meeting with the other group members to talk about why the expectations were not met, or the professor will be informed.
- Team members that are not interacting appropriately with other members will be given a warning at first, but if disrespect continues, then the professor will be notified. If the member has a change of heart and wants to make amends, then they will be doing the 'bulk' of the next project/assignment.
- It is ok to redefine goals, expectations, and responsibilities at any time if some sort of change is drastically needed for the group to perform better. The instructor will become involved if the group completely falls apart and communication between group members completely stops.

8. Expectations of Faculty and GTAs

If a team member fails to live up to this agreement, the situation may be reported to the staff, but the team will still be responsible for submitting a completed assignment. Staff will be available to meet with teams to resolve issues.

9. Signatures:

Andrew Neate

Landon Muhlenkamp

Nicholas Webber