Interactive Faucet:
Final Report

Requested By:
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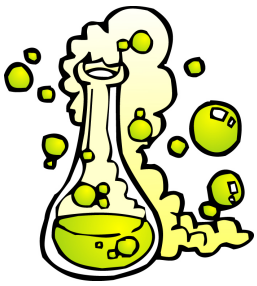
Fun Lavoratories

November 30, 2012



FUN
LAVORATORIES

November 30, 2012

Dr. Traci Nathans-Kelly
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Dear Dr. Nathans-Kelly,

In this report, we submit *Interactive Faucet: The Final Report,* delivered on the contract date of November 30, 2012.

Detailed in this report are our findings on the value of hand washing, the public's neglect on the subject, and our solution to this problem. The solution involves building an interactive sink, which provides entertainment for the user so as to compel bathroom goers to use our product instead of leaving with unclean hands. We believe this product has the potential to become widely distributed in public bathrooms worldwide, and would like your support for further research and testing.

Any questions relating to this report and the product can be directed to Benjamin Jaeger, through email at bgj9 @cornell.edu. Specific questions about materials and design can be directed to Ranjay Krishna at rak248 @cornell.edu, and questions about research and patents can be directed to Annie Cho at eac233 @cornell.edu.

Sincerely,

Ranjay Krishna,
Benjamin Jaeger
Annie Euane Cho
Fun Lavoratories

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1 Abstract

Research over the past few years has shown no change in people's behavior towards washing their hands before or after handling money, using the bathroom, touching pets, or eating food. The percentage of people who are affected by communicable diseases has not changed even though numerous ventures have been spurred by organizations including the American Microbiology Society to spread awareness. Fun Lavoratories aims to decrease communicable diseases such as Influenza, Streptococcus, and Staphylococcus by propagating proper hygiene pratices. Our objective is to increase the number of people who wash their hands after using the bathroom by providing them with an incentive. The incentive will be in the form of an entertaining light and sound show. As people use the sink, a proximity sensor will trigger a microcontroller to start the light show using an array of Light Emitting Diodes (LEDs). It will also begin an integrated sound system that will play either a soothing tune or will project excerpts from current news articles. We have built a prototype that can be installed in public restrooms above the sink and will be protected by a waterproof casing. The cost of building a unit for each sink is approximately $112, making the adoption of such a unit extremely cost effective. We project that it will decrease the spread of diseases and provide an overall fun environment for its users.

2 Executive Summary

Over the past two decades, organizations like The American Society for Microbiology (ASM) and the Center of Disease Control and Prevention (CDC) have emphasized the importance of hand washing after visiting the restroom and after completing various other activities. Research into the transmission of communicable diseases has concluded that lack of hand washing is one of the prime reasons for the spread of diseases such as Influenza, Streptococcus, and Staphylococcus. Unfortunately, campaigns to increase general public awareness concerning the risk of insufficient hygiene have had little effect on individual behavior. Surveys and tests dating back to the 90's show that the number of people who actually wash their hands has only improved from 71% to 77% of the US population.

At Fun Lavoratories, our goal is two-fold. First, we plan to design a sink product that people will enjoy using and would like to use more simply because of its fun experience. Second, we intend that the use of this faucet will reinforce proper hand washing habits. With these habits instilled in them, individuals will continue to wash their hands properly even when using other restrooms. An increased rate of hand washing will reduce the proliferation of infectious diseases and in turn benefit both those who do wash their hands and those who do not.

Our product will feature a restroom sink enhanced with a microcontroller, an array of Light Emitting Diodes (LED's), an LED driver, and a small speaker. Whenever a person places his/her hands in front of the sink, the system will start a light and sound show.

The cost of each faucet including parts and labor are estimated at $112. Fun Lavoratories has identified the specifications of the various components needed for the project. We have organized our initial release to target approximately 20 bathrooms on Cornell's main campus which are frequently used by students, followed by an installation in roughly 2000 other bathrooms. Organizations where individuals coexist in close proximity, such as universities and businesses, can benefit greatly from a product that increases overall hygiene. As a result, the number of overall sick days taken in these organizations will decrease. Weighing the difference between the marginal cost incurred by companies to install the product and the product's powerful benefits, we expect to make a significant profit even though the price of each unit will be quite inexpensive.

Based on our surveys, the students and employees who we are targetting fail to wash their hands because of lack of time. Another problem which this same group of people have in common is their need to stay connected and keep track of current affairs around the world. We will incorporate a news reader into our product instead of a music show for environments like these so that people can listen to the headlines while washing their hands. They will be incentivized to continue washing their hands in order to hear the news.

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3 Hand Washing Problem

Hand-foot-mouth disease, Hepatitis A, Shigellosis, and Giardiasis are just a few of the diseases that can be spread by those who fail to wash hands before leaving the bathroom [1, 2]. All of the above diseases occur due to fecal to mouth transference and can be greatly reduced by simply washing hands. Despite these health concerns, about thirty three percent of men and twelve percent of women do not wash their hands.

Hand washing is an effective precaution against various diseases ranging from the Common Cold to Salmonella. We found that in remote countries where hygiene is not emphasized at all, educating women about the importance of hand washing and distributing bars of soap could even help reduce death of young children by preventable diseases such as Pneumonia or Diarrhea [3].

Despite the significant benefits of hand washing, a survey by the Society of Microbiology indicated that only about 77% of people washed their hands after using the bathroom. We also found that this was a very persistent problem, one that has been monitored for over 10 years without showing much statistical improvement.

3.1 Surveys Demonstrating the Problem

Most people do not realize the importance of washing their hands while others do not know when to do so. It is imperative that people do so before and after handling food, petting animals, coughing, sneezing, using a public restroom, and touching money. As *figure 1* by The American Microbiology Society shows, the percentage of people who actually wash their hands after these activities is quite abysmal [5]. A 2010 study by the American Society for Microbiology and American Cleaning Institute found that fifteen percent of adults do not wash their hands when using a public restroom [4].

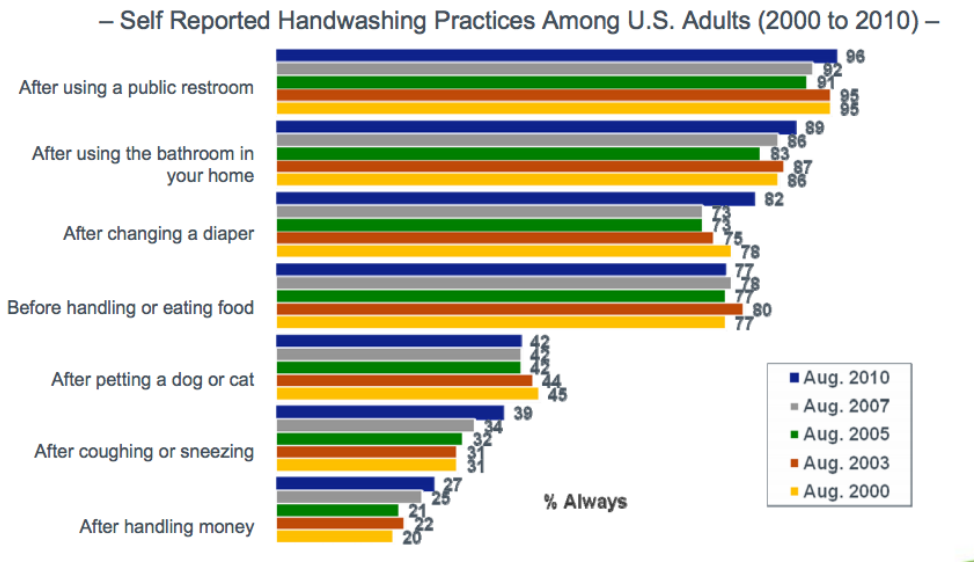

Figure 1: **Self Reported Hand Washing:** `A survery conducted by the American Microbiology Society starting at year 2000 until year 2010, where people reported whether they washed hands after using the bathroom. The chart shows how there is almost no change in the percentage of people who do so.`

3.2 Health Concerns

As mentioned in the above section, there is a surprising number of people who do not wash their hands after using restrooms. This has a negative effect on our society's general health. As pointed out by HealthReach Community Health Center, "1 in 3 E. Coli outbreaks is caused by poor hand washing by food preparers" [7]. The Minnesota Department of Health's hand washing curriculum states that 24% fewer students suffered from the common cold when trained to wash their hands more than four times a day. The same study shows that the same method led to 51% decrease in gastrointestinal problems [6]. These statistics indicate that those who frequently wash their hands suffer less from common contact based diseases.

4 Project Scope

4.1 Light and Sound Show

We will design, build, and test an interactive faucet system that engages individuals with lights and sound with the intent of encouraging users to wash hands more frequently. For this proposal we are focusing on making a proof of concept - simply a prototype to measure whether there is a change in hand washing rates for users of our product. Business considerations such as mass production, sales, distribution, and support will be addressed in future rounds of development. If successful, we will also look into submitting our idea as a patent application.

In the first iteration of our design phase, we proposed building a complete faucet with integrated electronic components for user interactivity. After further consideration, we decided not to get involved in faucet design and manufacturing but to focus solely on creating the interactive electronics as an add-on to an existing faucet product. Our research revealed that building our own faucets would be too complex and expensive - between $500 to $1000. Additionally, we would need to invest in our own assembly line and hire employees with expertise in the area. Instead, by switching to an add-on product, we significantly lowered the cost and difficulty of implementation while still maintaining our initial vision: to increase the rate of hand washing by engaging users.

4.2 RSS Reader

Additionally, our product will include a RSS reader. We intend on launching the product in universities and companies where the use of public restrooms are inevitable. Students and employees have one thing in common. They are usually busy with work and have a hard time staying updated with current affairs. The RSS feeder will be motion activated and will read headlines from different news web sites. The headlines will be about one or two sentences. It will be long enough for individuals washing their hands to listen to. And when they find these articles interesting, they will be motivated to wash their hands longer and listen to more feeds.

5 The Fun Theory

We were inspired to design our product after hearing about the previous successes of a concept dubbed The Fun Theory. The Fun Theory, developed by Volkswagen as a marketing campaign, states that an infusion of fun to a tedious task can positively modify human behavior. Several examples are displayed on Volkswagen's website. For instance, individuals are more motivated to recycle bottles when the bottle collection machine doubles as an arcade game. In another example, a musical staircase is installed in a subway to encourage commuters to use the healthier stairs rather then the escalator.

The Theory is simply a positive application of Operant Conditioning, a field of Psychology. Operant Conditioning states that an individual's habits are shaped by the consequences of his/her actions. If the consequence of a certain action is positive, an individual is more inclined to repeat that same action again in the future.

Within the realm of our project, hand washing is the tedious task. Lights and sound generated by the product are the new, added positive consequences. If Fun Theory holds true, then these positive consequences should induce an increase in hand washing.

6 Project Goal

Our goal, at Fun Lavoratories is to increase the rate of hand washing substantially by making the process fun and entertaining. The faucet will be used not just out of a fear of infectious diseases but also for the entertainment it provides. If we can develop hand washing as a habit, then individuals will be more likely to wash hands not only in a restroom with a Fun Lavoratory installation but in all restroom facilities with various types of faucets.

Imagine the consequences of a small community replacing all their faucets with Fun Lavoratory installations. If successful, all members of the community would wash hands after using the restroom. As healthier individuals, they would become less likely to spread infections like Hand-foot-mouth

disease and Hepatitis A to their peers [1, 2]. The number of sick days taken across the community would see a dramatic decrease and as a result overall productivity would increase.

7 Related Patents

7.1 Musical and Illuminated Toothbrush

The idea to use music or light to increase interest in an activity is not a new one. One prime example that utilizes this idea is the musical toothbrush [12]. Some toothbrushes for children play music for one to two minutes so that the child will keep brushing for the duration of the music. Getting children to brush their teeth is a task that vexes most parents. Often times children are unwilling to do it at all, and even if they comply, they may only do a cursory job unless someone is there to watch over them throughout the entire process. However, by adding music to a toothbrush, this patent hopes to convert brushing teeth from a tedious chore to a good time in the minds of young children. The same idea is applied in the case of the illuminated toothbrush, which has taken form in merchandise in various ways including a light saber toothbrush [13].

7.2 Automated Faucets

To trigger our device we will be relying on the proximity detectors already installed in regular automated faucets, displayed in the *figure 2* [14]. In our original report, we proposed making improvements or changes to the existing automated faucet so that it can respond not only to the presence of the hand but also to various movements. However we have simplified this original idea to only trigger the start and end of the music and light show. Now the proximity sensor has the sole task of signalling the microcontroller while simultaneously turning the water on and off.

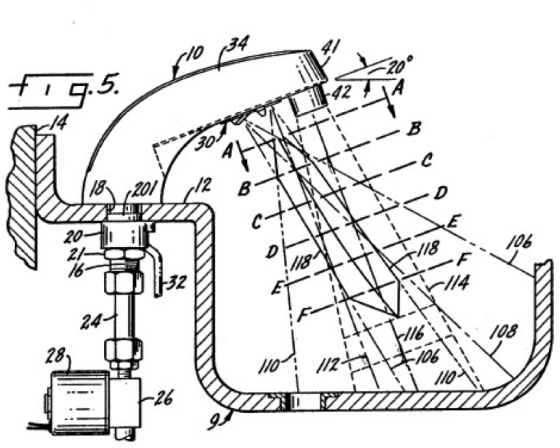

Figure 2: **Automatic Faucet:** `An example of a faucet where no physical contact is required. The faucet turns on and off when motion is sensored.`

Previously, we had considered the possibility of connecting the soap dispenser to the microcontroller as well, to integrate a command into the music telling users to lather their hands for 20 seconds. While we were considering this concept, we looked at a patent titled *Apparatus for Discharging Water with Passage Selection Sensor*. This purpose of this apparatus is to analyze the water flowing out of a sink and display the quality of water output by changing the LED light display. It accomplished this task by using various types of sensors, including temperature, flow, pressure, and pH sensors to analyze the water content [15]. This patent was significant to our research because we were considering using several different kinds of sensors when building the interactive faucet, and because both our idea and this patent dealt with sensors and other electronics around the sink, with potential threat of damage by water.

Currently, however, the idea is to simply have music that lasts for 30 to 40 seconds, which will encourage people to wash their hands for this amount of time instead of only wetting their hands.

7.3 Synchronized Light and Sound Display

While researching synchronized light and sound displays, we came across the patent *Audio Driven Synchronized Light Display* in *figure 3* [16]. This device sampled the audio output and transformed the output into 8 bit codes to be delivered to specific LEDs with specific instructions. The audio

output was fed into a light display software customized according to user preferences at 40 times a second. The signals were then divided into different frequency bands according to the number of LEDs in use, and translated into byte code to be transmitted to the circuit board. According to the type of byte signal, each LED would either turn on or off. While this device is an interesting idea, we determined that this method would not be appropriate for our project. Our goal can be accomplished in a more concise way by simply directing the microcontroller to piggyback off of the signal from the faucet's proximity sensor to determine when to activate both the audio and visual devices. The details of our own design will be discussed in section 10, *Product Design.*

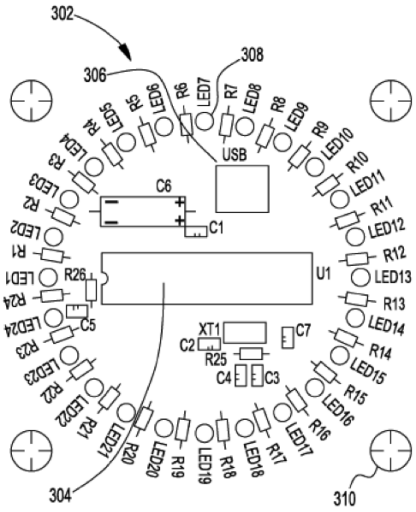

FIG. 3

Figure 3: **Synchronized Light Display:** `A product that inputs sound and outputs a synchronized light display.`

7.4 Illuminated Waterfall

The initial design was to have a faucet with a wide opening, and have the lights shine on the cascading sheet of water. This idea was similar to that of an illuminated waterfall. Patent number 9/451,335 describes a version of an illuminated waterfall [17]. It includes LED bulbs connected to a controller that activates the lighting sequence of the LEDs. These parts are cased in a clear tube so as to separate the electronics from the water. This design would have required us to build our own faucet from scratch, to install an encased LED bulbs and controller set. While this would also

have led to an interesting design worth pursuing, we moved away from this idea in favor of a less expensive design, because we wanted our product to be as widely distributed as possible. However, this product still has some similarities to our product in the method used to control the lights with a control board.

8 Music Research

Based on the research carried out by the Center of Popular Music, people universally appreciate classical music over all other forms of music [19]. Also, people tend to enjoy songs with more instrumentals and less vocals. We conducted beta testing on different groups of people and came to the same conclusion (see *table 1*). The majority of testers preferred "Stairway to Heaven" over the other songs. This fits our premise as this particular song has more instrumentals and not much vocals. Our product will focus on intrumentals and classical music including the smoothing tunes of "Beethoven's 9th Symphony" and "Classical Gas."

Genre	Number of Votes
Classical Music	28
Classical Rock	14
Hip Hop	2
Pop	4
Rap	0
Punk	7

Table 1: `Statistical data from research on music taste - 55 participants surveyed.`

9 Product Components

9.1 Hands Free Faucet

As mentioned previously, we will integrate our electronics around an existing hands free faucet. Based on our research, we have chosen the Speakman S-8810 AC Powered/Plug-In Lavatory Faucet. This durable, vandal-proof faucet provides an excellent foundation for our product [8]. We have noticed that the product is already in widespread use and is easy to operate.

There are two main reason why we have chosen to design a hands free system. First, shared

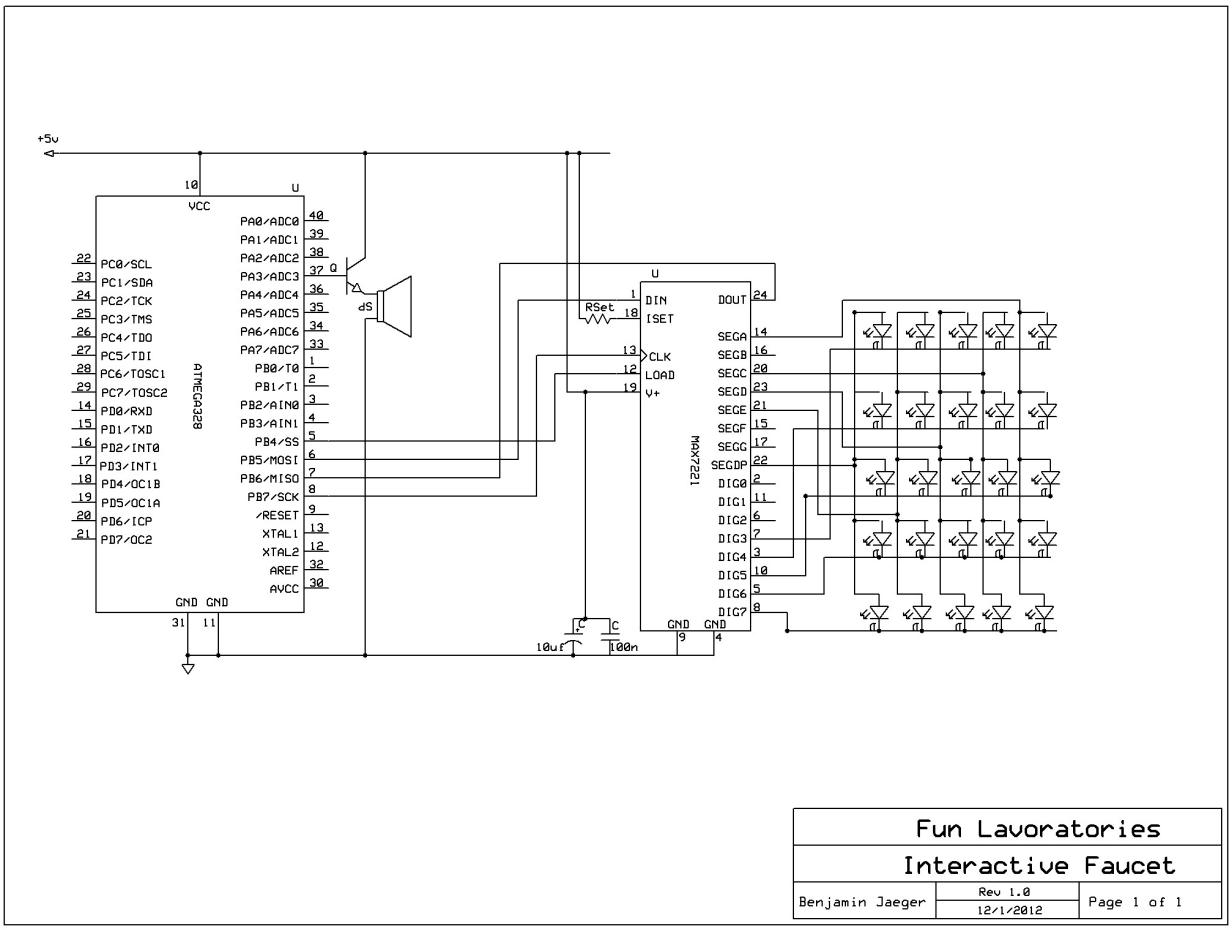

Figure 4: **Circuit Diagram:** `Shows connections between ATmega328, MAX7221, speaker, and LEDs. The microcontroller is on the left and it connects to the speaker as well as the LED array handler on the right.`

surfaces, such as the knobs on "traditional" faucets, can help spread infectious diseases [11]. Hands free is safer. Second, we can use the proximity sensor in the faucet to activate the lights and sound of our system only when the user is washing hands. As such, our microcontroller will piggyback on the signal coming from the faucet's sensor. A side consequence is that our product requires a trained electrician for installation. We will sell our product both as a stand-alone kit to be installed on existing Speakman faucets and as a package with the faucet included.

9.2 PCB Board

All the electronics will be soldered onto a printed circuit board (PCB). In recent years, the difficulty of creating a custom PCB boards has decreased immensely. Previously, customization was only available for very large scale orders. Now websites such as ExpressPCB offer all the necessary assistance for low quantities. A client first designs a board using software downloaded from the ExpressPCB website. Next, the client sends over the design to the site, and a few weeks later, the printed boards with all the components soldered on will arrive in the mail.

9.3 Microcontroller

The brain of our system is the Atmel ATmega328 microcontroller (see *figure 4*). This popular, high performance, low power chip has a 1.8V - 5.5V operating range, 32kB Flash program memory and a crucial Master/Slape SPI Interface [10]. The 32kB memory is sufficient to store a number of different musical tones which will be on the order of 3kB each. The three wire SPI Interface will be used to control the LED driver, described in the next section.

In order to operate the microcontroller a few additional components are required. A crystal clock, a power regulator, and a few capacitors will be included in the design. Additionally, electricity will come from the faucet's power supply.

9.4 Lighting

The product will feature thirty 5mm light emitting diodes (LEDs) of various colors. LEDs are cheap, long-lasting, bright, and energy efficient when compared to other electronic lighting types. 5mm is the most common LED bulb shape.

Despite the energy efficiency of LEDs, they still draw too much current to be run directly from the microcontroller. Instead we will utilize the Maxim 5V MAX7221 LED Driver which is capable of running 64 LEDs individually [9]. To save energy, the chip switches each LED on and off faster then the human eye can detect.

The MAX7221 also supports the SPI Interface. In our design, the microcontroller is the master, telling the LED driver which lights to turn on. The LED driver is the slave, executing the microcontroller's instructions.

9.5 Speaker

The speaker will be fairly small since it only needs to play simple tones. An example product is the 0.5W, 8Ohm COM-09151 sold by SparkFun. The speaker will be controlled directly by the microcontroller through a transistor. The speaker draws too much current to be wired in series with the microcontroller.

9.6 Surface Mount Wifi-Module

The final component in our product is a surface mount wifi-module by Microchip that will connect our product to the local wifi network. Using this we can collet RSS feeds from multiple websites and play them instead of the sound show [18].

10 Product Design

10.1 Software Application

The ATmega328 runs on C code which is written and compiled on a computer and then transferred via a serial connection. The compiled binaries will be loaded onto the controller during manufacturing. The client will not need to make any software adjustments.

When powered on, the microcontroller will wait on a continuous loop until it receives an interrupt from the faucet's proximity sensor indicating that the faucet is engaged. The microcontroller will activate both the LED Driver and speaker to start the light and sound show. Eventually, the microcontroller will receive another interrupt indicating that the faucet is off. As such, it will turn off the lights and sound.

Each time the microcontroller is engaged it will play a different sequence. We expect to have 10 different sequences. Future iterations of the product may allow the user to upload custom sequences.

10.2 Physical Appearance

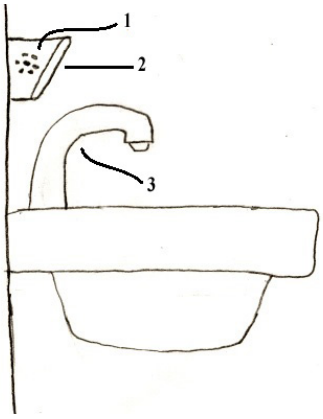

Figure 5: **Exterior Mockup:** `This is a sketch of the product exterior design with labeled parts. (1) represents the speaker, (2) is the LED light board, and (3) is the faucet with embedded proximity sensors.`

Just above the faucet, there will be a board with embedded LED bulbs, tilted downward to point at the sink. This board will be small so as not to intrude on the space for a mirror. When activated, the lights from the LED board will shine on to the sink, where the user's hands will be. Behind the board of LEDs, there will be a small speaker used to project music in the bathroom. This design was created to be as unobtrusive as possible to the existing bathroom.

The currect design is for a single sink bathroom, or a multi-sink bathroom in which only one sink has our product installed. Modifications may need to be made for a bathroom with multiple installations of our product, so that using multiple sinks at once will not result in a cacophony of different sounds being played at the same time. For this situation, a method must be found to either have only one speaker for all faucets, or have all speakers synchronized to play together.

11 Budget Table

The individual cost of each of the items in *table 2* are based on individual purchases. The actual price of production will be a lot less since we will be purchasing in bulk.

Items	Cost($)
Microcontroller	1.00
LEDs	10.00
Batteries	31.00
Speakers	20.00
Installation	30.00
Wifi Module	20.00
Total	**112.00**

Table 2: `Estimated budget for materials needed to build a prototype of the product. The production cost will decrease drastically once development begins in bulk.`

12 Progress Report

12.1 Phase 1: Brainstorming (Week 1)

During the first phase of this project, we identified a problem that we saw around us and brainstormed an easy solution for it. We noticed multiple people who would run out the bathroom in a hurry without washing their hands. After conducting some basic research, we realized that it is a problem that has been known for over a few years but the past solutions had not been successful in getting people to wash hands. We decided to approach the problem through a different angle, using Fun Theory.

12.2 Phase 2: Designing (Week 2-4)

After we had decided upon a strategy for tackling the issue, we had to break it down. During this phase, we segregated the product into its various components and estimated its prodution cost. Next, we searched for similar past projects that have aimed to address this problem. The main purpose of this phase was to understand the space that we are exploring. We wrote a proposal for the project and outlined its core elements. We laid out a schedule for developing the product.

12.3 Phase 3: Researching (Week 5)

We realized that we didn't necessarily have to build a new sink to tackle the issue during this phase and we underwent a number of changes. We decided that a small water proof component that could be installed to sinks would be cost effective. We identified the suppliers that would be able to provide us with the components in bulk after distinguishing the properties that we wanted

to optimize for the microcontroller, LEDs, proximity sensors, etc.

12.4 Phase 4: Optimizing (Week 5-8)

In the final phase of our development, we added additional features such as the radio news broadcast. We honed in on our target market and considered strategies for customer aquisition of our product and its market validation.

13 Team Functionality

Our team consisted of three individuals:

- Ranjay Krishna: B.S. Electrical and Computer Engineering
- Benjamin Jaeger: B.S. Computer Science Engineering
- Annie Euane Cho: B.S. Operations Research and Information Engineering

14 Conclusion

With more than 20% of adults not washing their hands after using the restroom, improper exercise of personal hygeine is a major issue. This widespread negligence can result in serious and dangerous diseases such as Hand-foot-mouth disease, Hepatitis A, Shigellosis, and Giardiasis. These diseases can spread to others in the community resulting in sick days taken and loss of productivity.

Our goal, at Fun Lavoratories is to increase the rate of hand washing substantially by adding fun to the tedious hand washing process. We have designed an interactive faucets featuring a light and sound show that engages users. We believe that this infusion of fun will develop hand washing as a habit so that individuals will continue to wash hands no matter what facility they are using, even if only traditional style faucets are present.

Finally, the addition of a wifi-based RSS syndicator will keep busy individuals up to date with

current affairs during a restroom break. This unique and innovative feature is just one example of the numerous ways in which the idea of an interactive faucet can be expanded to further engage the user.

15 Acknowledgements

We would like to thank multiple people for making this project so much "Fun". First off, thank you to Dr. Traci Nathans-Kelly for allowing us the oppotunity to put on our creative hats and find an elegant engineering solution to a problem that we all face all around us.

We would also like to thank B.F. Skinner for formalizing the concept of Operant Conditioning and Volkswagen for utilizing operant conditioning and molding it into "The Fun Theory".

Let's not forget to keep our hands clean.

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