2019

Automatic Pill Dispenser and Reminder

Lyndsay Castle
University of Rhode Island

Kyle McKenna
University of Rhode Island

Brian McDonough
University of Rhode Island

Joe Jacobs
University of Rhode Island

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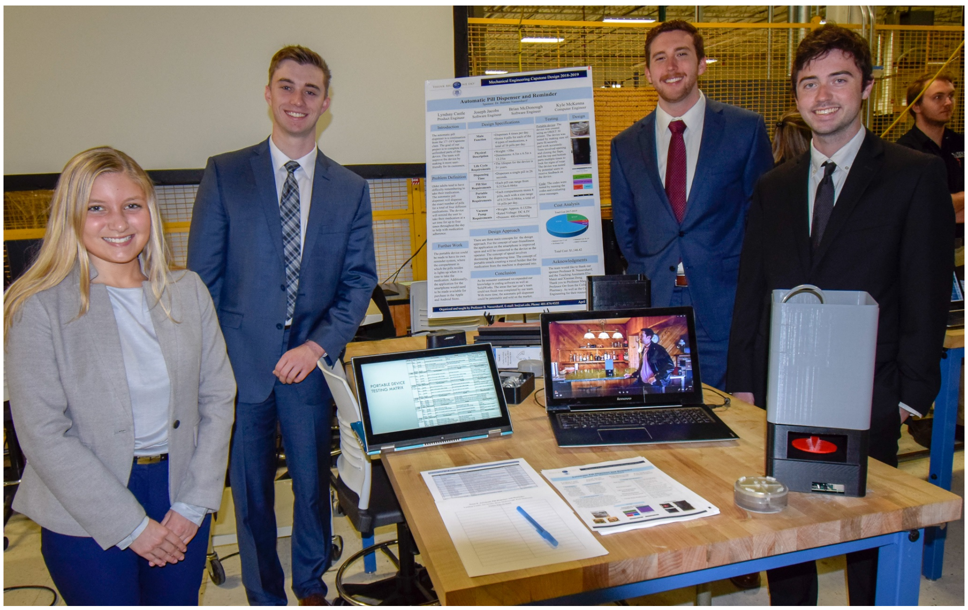
Final Design Report
The Dr. Pill
Team 8



Team Members:
Lyndsay Castle - Product Engineer
Kyle McKenna - Computer Engineer
Brian McDonough - Software Engineer
Joe Jacobs - Software Engineer

Sponsors:
Bahram Nassersharif
Faculty Advisor:
Bahram Nassersharif

Department of Mechanical, Industrial, and Systems Engineering
University of Rhode Island

2018-2019 Academic Year
May 6, 2019

Abstract

The Automatic Pill Dispenser is a device which dispenses medications and reminds users when and which one to take, helping with medication adherence. Ideally, this machine will hold four different types of medications, which will be dispensed into a portable device, which the user can take with them throughout the day. When it is time, an integrated app will notify the user when they should take a specific pill. The main focus of work this year is to improve and refine the progress made from the previous group, while meeting the requirements of the design specifications. This year, the group is focused on making the Automatic Pill Dispenser more user friendly by creating a smart phone app which connects with the device and serves as the main operator. The portable device in which the pills are dispensed to is redesigned from the previous group, and is able to be used with the smart phone app. The device has also been made faster, which was accomplished by cutting out redundant sections and optimizing different aspects of the code, decreasing the overall dispensing time.

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List of Acronyms

APP Application

BOM Bill of Materials

CDR Critical Design Review

FDA Food and Drug Administration

GPIO General Purpose Input Output

LCD Liquid Crystal Display

PLA Polylactic Acid

PMMA Polymethylmethacrylate

POC Proof of Concept

PDS Product Design Specifications

QFD Quality Function Deployment

UI User Interface

3D Three-Dimensional

a Acceleration due to gravity (m/s^2)

A Area of contact area (m^2)

F Force (N)

m Mass (g)

P Pressure (Pa)

r Radius (m)

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1 Introduction

Older adults tend to have difficulty remembering to take their medication, the Automatic Pill Dispenser will dispense the exact number of pills and remind them to take their medications at a set time throughout the day to help with medication adherence. This device will hold four different types of pills and will dispense the correct number of each pill throughout the day, up to four times, while reminding the user when to take each dose and how to take it (i.e. If the dose needs to be taken before eating, or with water, etc.). The device will also remind users when their prescription is close to being finished in order for the user to refill their medications before they run out. Interaction with the Automatic Pill Dispenser is through the use of an Application, which will also act as a database, keeping track of the users medical records, such as vaccinations or previous medications. With this app, the user can add information about their prescriptions, research information about their medications, or keep track of the different medications they are taking.

This year the project is focused on the refinement of the previous groups work, who finished with a functioning model, but was far from a practical product. The main focus of this year is to bring the previous design closer to a product that can be used in the average household with the average user. One design which has been improved has been the portable device. Before, the design required the user to open all four compartments at once, which could lead to accidental spilling of pills. The new design has lids built into the top section, allowing the user to open each compartment separately from one another, reducing the chances of spilling. The design of opening and closing the portable device was also altered, making it more user-friendly for it users. The app has also had a major improvement since last year. The focus of the group from last year was to get a working prototype of the device, and less about the design of the interface. This year the group is able to devote more time into the app and its integration with the device. Additionally, the code for the automatic pill dispenser was optimized to reduce the total dispensing time. Keeping the design specifications set for the device in mind, the team has made a great amount of progress for both the fall and spring semester.

2 Patent Searches

The patent search is important to the design criteria of the automatic pill dispenser and reminder. The patent search gives a better idea of the overall design of the pill dispenser, and the features that should be included, and how they are implemented into the design. The patent search began with the focus on the portable device, since it was one of the proof of concepts. The patent searches also focus on the vacuum pump, and the automatic pill dispenser as a whole, as a way to get ideas for improvements in the device.

Document Identifier: US 20170087059 A1
Publication Date: Mar 30, 2017
Inventor(s): Rodriguez, M., Reyes, C.

Abstract:A system and method for the dispensing of medication in the form of pills and also to monitor health parameters is disclosed. The system comprises a modular system having a main control module; a plurality of pill dispensing modules in communication with the main control module; and optionally sensors to measure health parameters in communication with the main control module. The main control module can store information and also can communicate information over a communications network.

Relevance: A patent used to help come up with the idea of the portable device is the pillbox [7]. In the design of the pillbox there are separate compartments for each medication based on time. The pills are arranged in order of taking first, time wise. The design of the pillbox also includes an opened top as the opening, a bottom, and side walls, and comprises of an actuator for opening the cover and mounted on the side wall where the compartment is connected to the preceding compartment; and the cover is pivotal and can be locked to the compartment. From this design of the pillbox, the portable device for the automatic pill dispenser is created. From this design the idea of the top opening and being able to lock was used in a similar way for the portable device. A few differences from the portable device, is the portable device is manually closed and opened. As well as there is not a locking mechanism that is fully functional at this point in the design.

Document Identifier: US 20060086641 A1
Publication Date: Apr 27, 2006
Inventor(s): Priebe, R.N., Noble, T.O.

Abstract:A pill container assembly that includes first and second main body members each defining a plurality of separate compartments and having at least one locking feature. The at least one locking features of the first and second main body members are configured to lock to each other with a twist lock connection thereby coupling the first and second main body members together.

Relavance: Another patent used in the design is the detachable pill container [8]. In this design the bottom surface is positioned opposite the top surface. There is a lid member for each of the compartments, where the lid member is secured to one of the first and second main body members with a hinge connection. This design was useful in getting ideas of how to attach the lid compartment to the base of the portable device. A hinge feature with a pin was implemented into the portable device as a way to open an close the lid.

Publication Number: US 2010/0219198 Al
Publication Date: Sep. 2, 2010
Inventor(s): Goldman, K.N.

Abstract: The apparatus and method of the present invention provide for the simple and accurate dispensing of articles, particularly solid oral medication. The apparatus of the present invention according to one embodiment comprises a holder device, in which said holder device comprises a bottom surface, a sidewall engaging said bottom surface, a pair of radial walls adjoining a center of said bottom surface and said sidewall, and a sloped slide adjoining said pair of radial walls. In a preferred embodiment, the holder device further comprises seven pairs of radial walls to correspond with each day of the week. The present invention also includes a plurality of compartments within each pair of radial walls, which correspond to the time periods during which medication must be taken during a single day. Each compartment according to this embodiment contains a sloped slide. The present invention further provides a method for loading the apparatus whereby a filling tray with wells is placed on the holder device, the filling tray is arranged so that each well empties into a compartment, a number of articles are poured onto the filling tray, and spread over the tray so that the desired number of articles fall into each well. The embodiment of the present invention further describe methods for administering and storing articles.

Relavance: The last patent used for the design of the portable device is the Daily Dose Personal Pill Dispenser [9]. For this device the pills are dispensed into a holder device, where the holder device is arranged into days of the week. Also within each of the seven compartments there are four more individual compartments to separate the medication into times for each day. Each individual compartment is sloped so it it easier fort the pill to be taken out of the compartment. In this design the idea of using separate compartments was used in the portable device. For the automatic pill dispenser, the portable device has four compartments for a single day, assuming the person will return the portable device to the machine at the end of each day. By doing this each morning the user will get a fresh set of medication for that day. Additionally, the idea of making it easier for the user to take their pills out of the holder was used. There are separate lids for each of the four compartments, so the user only needs to open the compartment in which the pills that need to be taken at that time reside in. A difference between the holder device and the portable device for the automatic pill dispenser is the holder device is not meant for travel, the holder device acts as a platform that the medication can be dispensed into. Therefore the holder device can be made larger for it is not used for travel purposes

Document Identifier: US 6,510,692 B1
Publication Date: January 28, 2003
Inventor(s): James, L.

Abstract: A device that can be loaded with appropriate pills and programmed to automatically dispense the proper amount(s) and proper type(s) of pill(s) at the proper time(s) each day. The device includes a system for alerting the pill taker that pills have been dispensed, a system for providing voice messages to coach the pill taker to use the device and consume the pills, and a system for alerting an off-site caregiver when the pill taker has not responded as required or when there is a problem with the operation of the device. Major components of the device include a programmable timer (41), a pill-storage wheel (21), a cabinet (11), a compartment for storing bottles of pills (13), a push button to stop the alarm and release the pills (34), a pill-release gate (61), a compartment indicator template (51), an index gear (92), a battery (500), a pill-storage wheel actuation circuit (504), a pill alert LED and buzzer driver circuit (506), a voice message record and playback system (514), and an automatic telephone dialer system (510).

Relevance: The specific patent that was used as a reference in the project is Patent 6,510,962 Programmable automatic pill dispenser [10]. The concept behind the device is a great idea. This device has all the features, that are going to be to included into the automatic pill dispenser. It can be loaded with the appropriate pills and programmed to dispense a certain amount at a certain time. The device also has voice messages to alert the user the pill has been dispensed and needs to be taken. It also has a system to alert a relative/care-giver of the user that the pill was not taken or if there is an issue with the device. The design for the device needs to be changed however the overall ideas of how the device will operate is a great user-friendly technique and serves a great purpose.

Document Identifier: US 6,330,957 B1
Publication Date: Decmeber 18, 2001
Inventor(s): Bell-Greenstreet, D. L.

Abstract: The present invention is an automatic medication dispenser that is capable of distributing medication according to at least one prescribed time schedule, such as daily or weekly. The dispenser is capable of signaling to the patient the appropriate time for taking the next dosage of medicine by the activation of appropriate alarms. The dispenser has a housing with a removable cap, the housing adapted to receive at least one circularly shaped medication cassette, the at least one medication cassette being rotatable within the housing; a medication exit slot in the housing which allows medication contained by the at least one medication cassette to be distributed from the at least one medication cassette; a drive system contained by the housing which rotates the at least one medication cassette within the housing and a medication detector which is contained by the housing and detects the distribution of the medication, in combination with at least one removable circularly shaped medication cassette. Each of the at least one circularly shaped medication cassettes further comprises a circularly shaped backing plate with an axially located, cam-shaped aperture having a cam-shaped edge, a cam-shaped partition located along the cam-shaped edge and projecting perpendicularly from backing plate, a circularly shaped partition that is co-axial with the cam-shaped aperture and also projects perpendicularly to the backing plate, and a plurality perpendicularly mounted fins extending radially from the center of the backing plate. The medication detector has a transmitter that emits light, and a light detector that detects the light emitted from the transmitter.

Releavnce: This patent will also be used in the design criteria is Patent 6,330,957 Automatic medication dispenser [11]. The design/look to this dispenser will be taken into consideration when designing the capstone project. One of the main focus in the design criteria is the height, this device entails a circular shaped medicine cassette, and the design is circular. Making the shape of the device the same shape as the shaft reduces wasted space within the device.

Document Identifier: US 9,841,653 B2
Publication Date: November 14, 2017
Inventor(s): Lehmann, C., Brittelli, J., Chen, C.H., Kehoe, T., Barnikel, R.

Abstact: A portable self medication management system and method of provided. For example, the system may include a removable tote and docking station. The removable tote including a plurality of receptacles, communicating section for transferring data to and from a docking station and a power reception station for receiving power from the docking station. The docking station including a scanner, a display screen, a controller, a storage device, communicating sections for transmitting data to the removable tote and other external devices and a power transmitting section for transferring power to the removable tote.

Relevance: The home medication manager is a similar approach to the design for the automatic pill dispenser. The main focus of the automatic pill dispenser is to design something that would be for home use but also travel purposes. Also the communication feature is a great idea of being user-friendly. For example, the docking station includes a scanner, a display screen, a controller, a storage device, communicating sections for transmitting data to the removable tote and other external devices and a power transmitting section for transferring power to the removable tote [12].

Document Identifier: US 9,980,880 B1
Publication Date: May 29, 2018
Inventor(s): Litton, L.J.

Abstract: A pill dispenser is configured to receive a plurality of different pill types into discrete pill reservoirs, whereby a dose of different pills may be provided to a user in a dispense reservoir. A vacuum manifold may be configured with a vacuum tube for removing pills from the discrete reservoirs and placing them into the dispense reservoir. In one embodiment, a pill dispenser is part of a pill dispenser system that utilizes a remote electronic device having an application software program for setting, managing and displaying the dosing regimens for pills loaded into the pill dispenser. The application software program may be coupled with a prescribing pill database, whereby prescription pill information, including dosing regimens may be loaded onto the application software program to ensure compliance with the prescription.

Relevance: In this patent, the function of the vacuum is used similarly in the Automatic Pill Dispenser and Reminder design. In the patent, the device has a motor that is coupled to the turntable. A vacuum tube is configured with a vacuum tip designed to attach to a pill. A vacuum pump is configured to draw a vacuum to create a suction though the vacuum tube. The tip is comprised of an elastomeric material having an opening to draw vacuum, or air. A vacuum manifold is configured with an actuator, such as a linear actuator, to move the tube down into a reservoir and up out of a reservoir. An actuator may be driven by a motor, pneumatic cylinders or any other conventional means to actuate the vacuum tube up and down [13]. The workings of the device is similarly created to the automatic pill dispenser, however the vacuum for the automatic pill dispenser is extremely loud. This design was used to compare how the vacuum pump was set up and controlled to help improve the noise volume on the automatic pill dispenser.

Publication Number: US 7,753,229
Publication Date: July 13, 2010
Inventor(s): Hutchinson,Kevin ; Self,Anthony ; Inabnet,Joseph ; Milton,Monroe ; Bergeron,Mike

Abstract: A counter is disclosed for use with a medication storing and dispensing cassette. The counter is comprised of a loader for receiving a cassette, a sensor for sensing whether a cassette is in the loader, means for moving the loader into an operative position, a vacuum unit for applying a vacuum to the cassette, a drive unit for driving a driven portion of the cassette and a counter for counting medication within a portion of the cassette. Methods of operating the counter are also disclosed.

Relevance: This patent of the Vacuum pill dispensing and counting cassette [14] is very similar to the automated pill dispenser in the way it is looking to dispense the pills. This patent is far larger that the design for the automated pill dispenser and far more expensive. This patent also does not have app integration. However, it is a good reference since it uses a very similar dispensing method. It proves the the vacuum pump is a viable way to dispense pills.

Publication Number: US 7,624,894
Publication Date: December 1, 2009
Inventor(s): Gerold, William Olin ; Gerold, William Jason

Abstract: A pill-dispensing apparatus for automatically dispensing solid pills includes a plurality of storage units and a pill dispensing module. The storage units store pills in bulk and each include a hopper and an auger movably positioned with respect to the hopper. An inlet of the auger is positioned to receive pills from the hopper. The pill-dispensing module includes: a dock for receiving and holding a selected one of the storage units, a drive unit for rotating the auger to motivate the pills along the auger, a pill counter for counting pills dispensed from an auger outlet, and a lift for tilting the hopper to control flow and to assist in motivating pills to fall from the hopper and move along the auger.

Relevance: The automated pill-dispensing apparatus [15] is similar to what the automated pill dispenser will do. The pills will be loaded in from the top and the dispense from the bottom. This patent compared to the automated pill dispenser uses a much different dispensing mechanism. This patent uses an auger/hopper system which is will likely make it far less accurate when compared to automated pill dispenser. This patent was good to get a baseline for the automated pill dispenser design. It shows that the overall concept is sufficient and desirable.

3 Evaluation of the Competition

Multiple products were compared to the Automatic Pill Dispenser to determine how it will hold up against other products. The products compared are ones that are currently sold in the market to a similar target audience. One of the biggest comparisons to be made is the price point at which a user can buy these products. The Automatic Pill Dispenser should be a competitive product against other products in the market while also keeping price low. Prices and subscription costs are listed below in Table 1.

Table 1: Cost comparison between the Automatic Pill Dispenser and other products

Company	Doses	Upfront Cost	Monthly Fee
MedaCube	20x/Day	$1,500	$59.00 for 36 Months
Philips	6x/Day	$0	$59.95
MedReady	4x/Day	$149	$16.00
Livi	24x/Day	$2,000	$79.00
E-Pill Accutab	3x/Day	$39.95	$0
Automatic Pill Dispenser	4x/Day	$100	$0

When comparing the automatic pill dispenser to all of the products available on the market, the MedReady compares similary. The automatic pill dispenser dispenses up to 4 times per day dispensing one per each of the four medications. For on the go purposes, the automatic pill dispenser can dispense one time per day, dispensing all 16 pills, four pills for each medication at once. Comparing the upfront cost, the automatic pill dispenser is lower in cost by $50. Also the automatic pill dispenser does not have a monthly fee, saving a total of $192.00 a year. The automatic pill dispenser also stands about from the MedReady for the automatic pill dispenser includes its own portable device in which the pills are dispensed into. The user does not have to spend additional money to purchase a travel medication holder. The automatic pill dispenser also comes with the smartphone application which does not include a monthly fee to use. The smartphone application is used to have notify the user of their medication time, as well as stores additional medical information for their own personal records or to be shared with their doctor/pharmacist. The automatic pill dispenser is more technological advanced when compared to the MedReady. When comparing the other products on the market to the automatic pill dispenser, having similar features and with a lower upfront cost and no monthly fee sets the automatic pill dispenser apart from its competition.

4 Specifications Definition

Table 2: Product Design Specifications Table

Product Name	Automatic Pill Dispenser and Reminder
Main Functions	- Holds up to 4 types of medications - Stores a total of 4 pills for each of the 4 medications - Stores a total of 16 pills per day. - Dispenses up to 4 times per day.
Physical Description	- Volume: < 560in3 -Dimensions: 6.5in x 6.5in x 13.25in -Weight: < 5lbs
Target Market	The target market is older adults.
Dispensing Time	- Dispenses a single pill in 26 seconds - Total of 2 minutes for all 4 pills - Maximum of 10 minutes for all 16 pills
Pill Size Requirements	Each pill can range from 0.315in-0.984in
Vacuum Pump Requirements	- Rated Voltage: DC 4.5V - Pressure Range: 400-650mmhg - Weight: Approx. 0.132lbs
Service Environment	-Typical household bathroom, kitchen, and/or bedroom. -Average Room Temperature (20 °C). -Pills will be protected in the device from water vapor given off from a hot shower in the bathroom.
Training	-One-time set up of the device will take a maximum of 30 minutes. -User will only have to learn and enter information into the android application.
Portable Device Requirements	- Each compartments stores 4 pills, each with a size range of 0.315in-0.984in - Stores a total of 16 pills
Life Cycle Requirements	The lifespan for the device is 5+ years
Manufacturing Requirements	Prototype: -3D Printed -Mechanical parts purchased -Design of Android application interfaced to product Final Marketable Product: -Mass produced mechanical parts
Financial Requirements	-Target Marketing Price : $100.00 -Allowed Budget for Research/Prototyping: $300.00
Legal Requirements	Dealing with medication, a product that will be sold to consumers must be regulated and approved by the FDA.

The design for the Automatic Pill Dispenser was generated based on the design specifications given as a requirement for the project, as seen in Table 3. Using the requirements of the customer, these requirements were then transcribed into engineering requirements that is listed as the design specification requirements that are used in the development of the device.

The service environment for the automatic pill dispenser and reminder is it to be used for home use. The device is designed to be on a counter-top in either the kitchen or bathroom, or in the bedroom on top of a nightstand or dresser. The average household temperature is 20 degrees Celsius [16]. If the device were to be placed in the bathroom, the pills will be protected in the device from vapor that might occur from a hot shower.

The dimensional requirements of the device is for it to be no larger than a typical home coffee maker. The volume will be less than 560 in^3 and will weigh less than 5lbs. The process behind picking the material of choice to use in the device is dependent on the cost and temperature. The team is given a budget of $300 with an estimated market price of $100, and to make a considerable profit from the device, the material will be made out of PLA. PLA can withstand temperatures lower than 90 degrees Celsius to 100 degrees Celsius. However, if the household temperature passes 100 degrees Celsius, the PLA will begin to melt and/or deform which will be noted in the warning section of the user manual.

The target market for device is older adults. The focus market is older adults for they are more likely to need assistance in taking medication, or forget to take their medication. This device is designed to be made user-friendly, for the market in which the device will be sold to, the device will need to be made simple, and easy to use. The device will be made to have limited repairs, and has a life cycle of at least 5 years. Since most older adults are retired, the device will be sold at $100 which when compared to other products is well below the average cost. The devices available on the market today range from $150-$6000, which the hope is the cost of the device will be appealing enough to sell to this market, when compared to the other devices.

The key features for the device is for it be automatic and have a reminder feature. The device will hold at least four pills for each of the four types of medications, a total of 16 pills per day, as well as dispense these medications automatically. The prescription will be dispensed into a portable device, that the user can take and use on the go. The portable device has four compartments for each of the four medications holding up to four pills in each compartment, all with a pill size range of 0.315in to 0.984in, totalling 16 pills per day. Since the device is dealing with medication, the device needs to be accurate on every dispense of the medication. To avoid possible law suits the device needs to be programmed correctly to avoid glitches in under and over-dosing of the medication. To ensure accuracy, the pill dispenser takes a maximum of 10 minutes for all 16 pills to be dispensed into the portable device. That is a time of 26 seconds per pill to be dispensed into the portable device. With the target market of older adults in mind, the alarm function and inputting the prescriptions into the device needs to be simplistic. To do this a smart-phone application has been created. The user can download the application on their smart phone, and from there they can input the quantity, type and special instructions, as well as the alarms for each of the four types of pill. The smart phone application will automatically sync to the device and will be the way the device is programmed to operate. The reminder function will be a feature within the smart phone application, which when the alarm goes off, a notification will be sent via wifi. For the training, the user will learn how to dispense the medication into the device, and how the smart phone application is used to operate the device.

5 Conceptual Design

Thirty designs were generated by each member of Team 8. Each design was then analyzed and evaluated to find the best concept generated that the team could use as a prototype.

5.1 Kyle McKenna List of concepts generated

The concepts generated were mostly changes to the prototype that was created by the prior team. In these designs, particular components were either added or changed. In some cases, there was a complete redesign of the entire prototype.

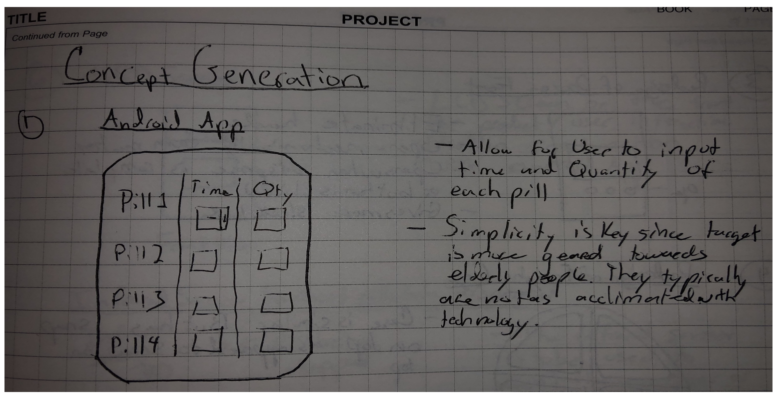


Figure 1: Kyle McKenna Design 1

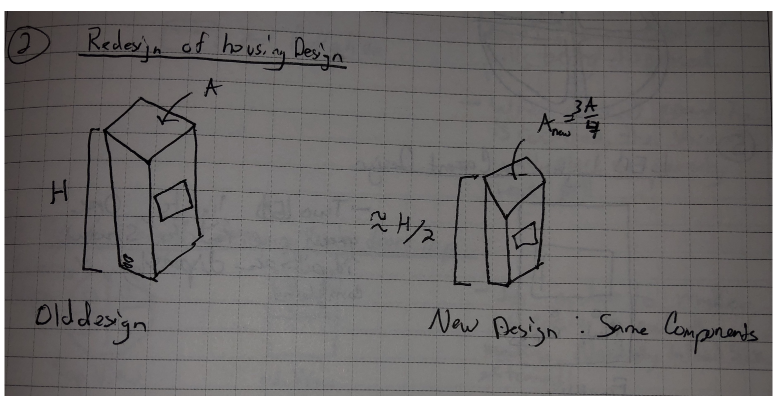


Figure 2: Kyle McKenna Design 2

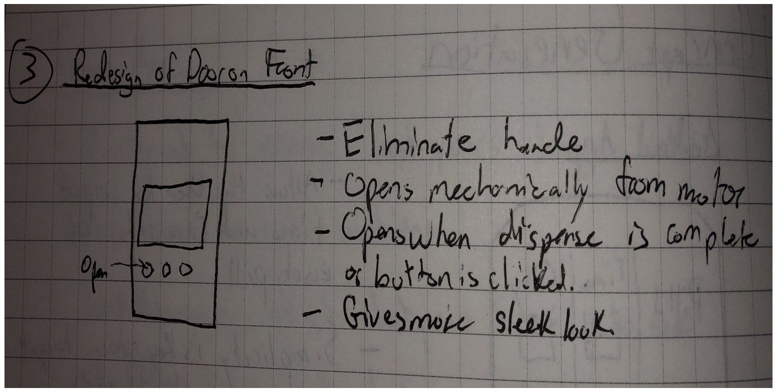
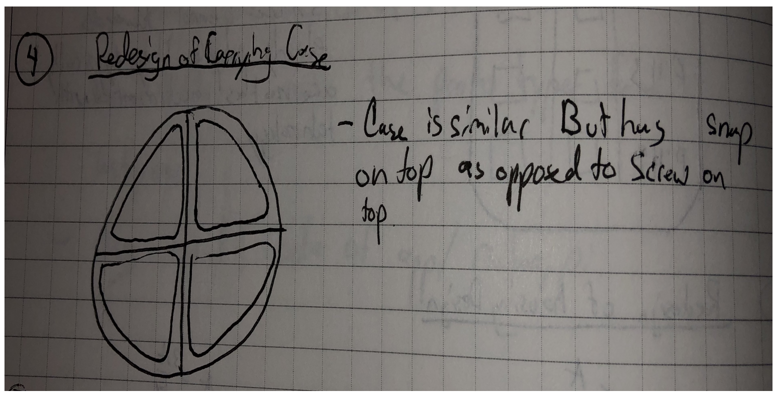


Figure 3: Kyle McKenna Design 3



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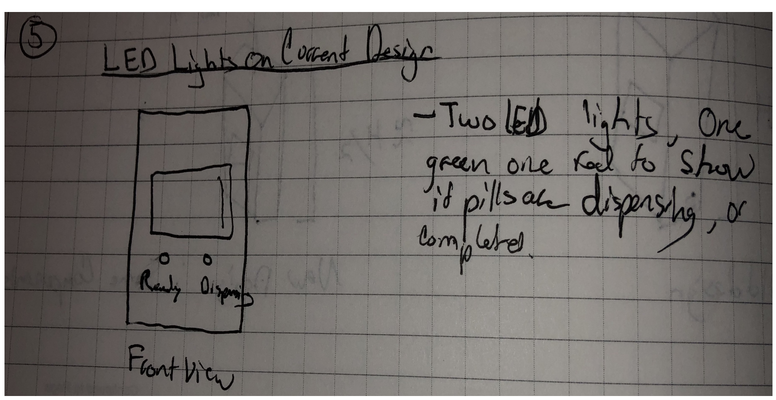

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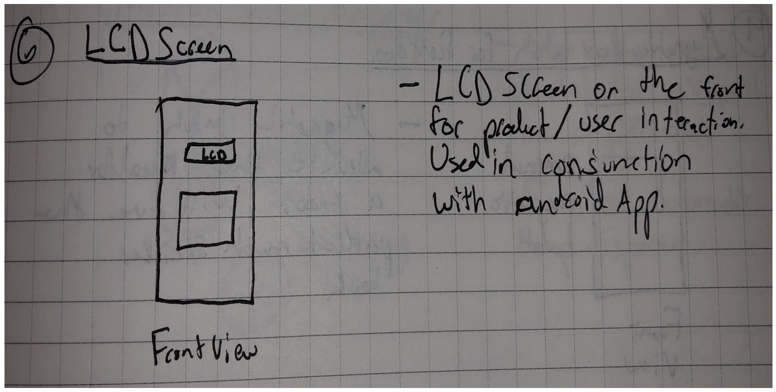


Figure 6: Kyle McKenna Design 6

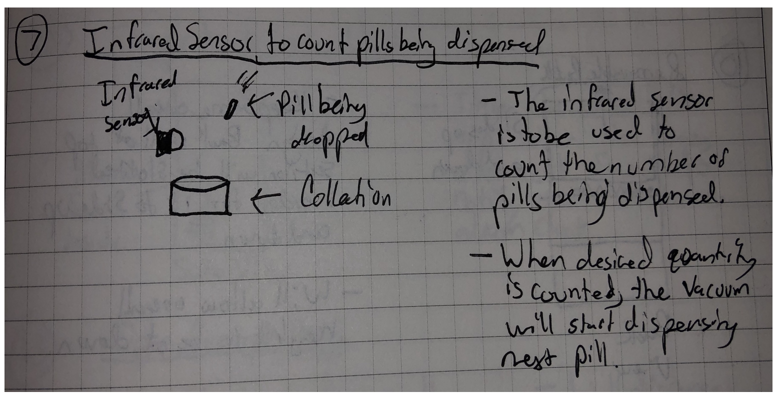


Figure 7: Kyle McKenna Design 7

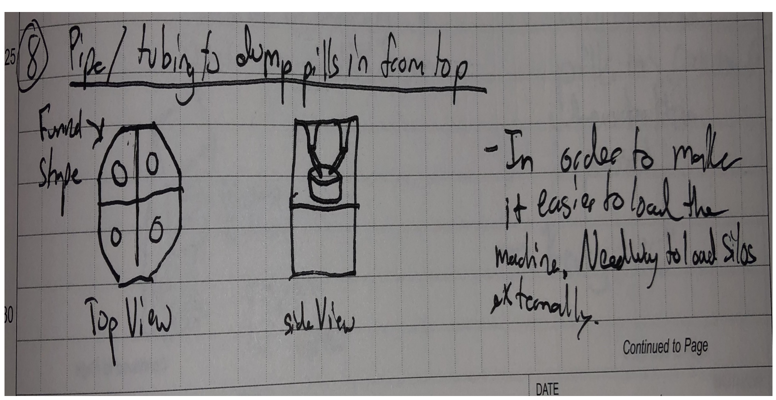


Figure 8: Kyle McKenna Design 8

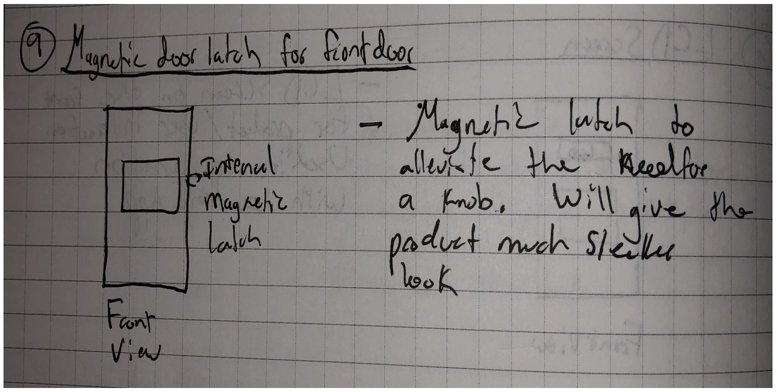


Figure 9: Kyle McKenna Design 9

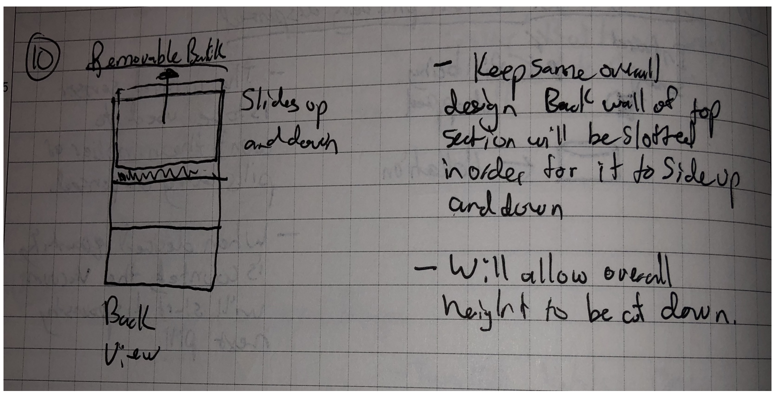


Figure 10: Kyle McKenna Design 10

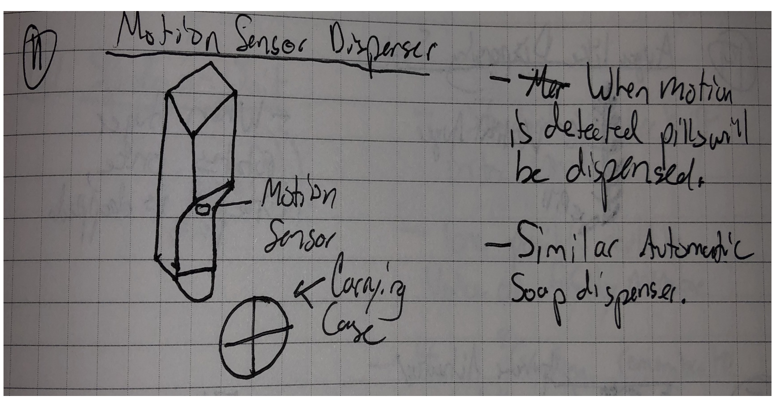


Figure 11: Kyle McKenna Design 11

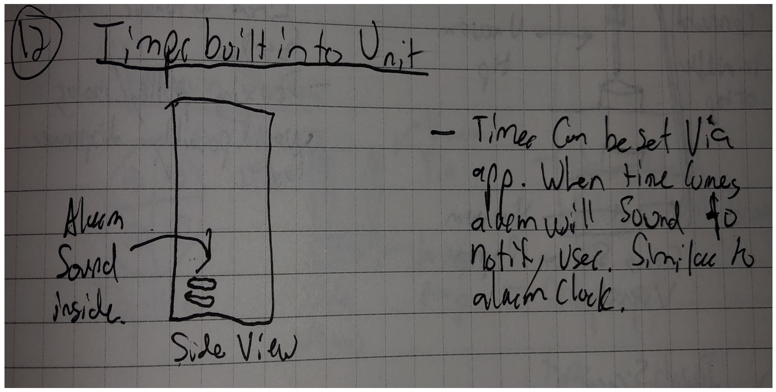


Figure 12: Kyle McKenna Design 12

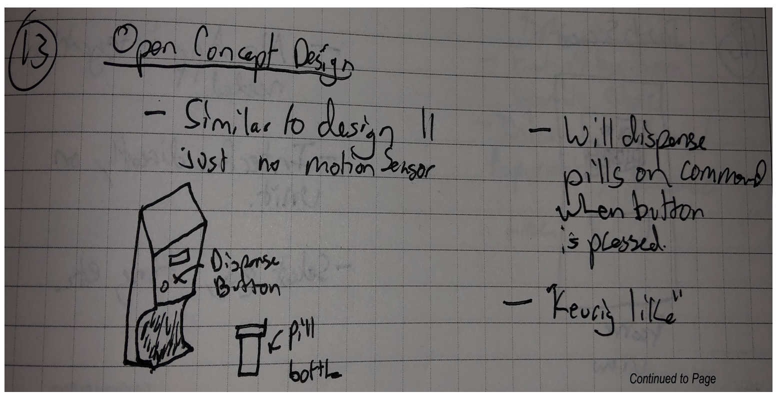


Figure 13: Kyle McKenna Design 13

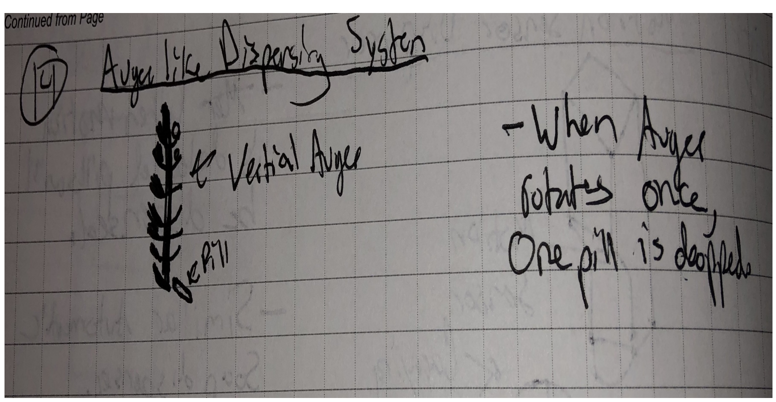


Figure 14: Kyle McKenna Design 14

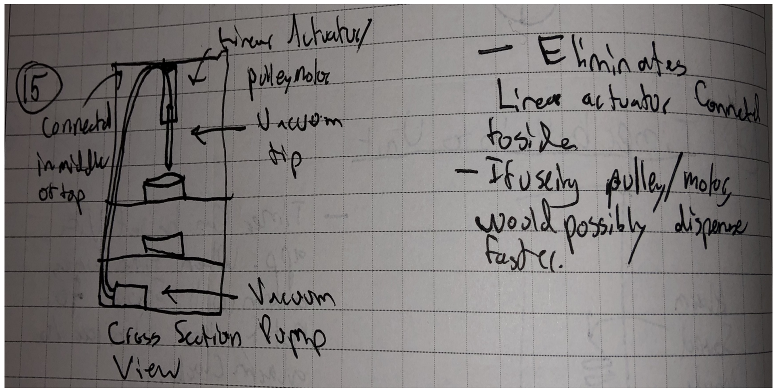
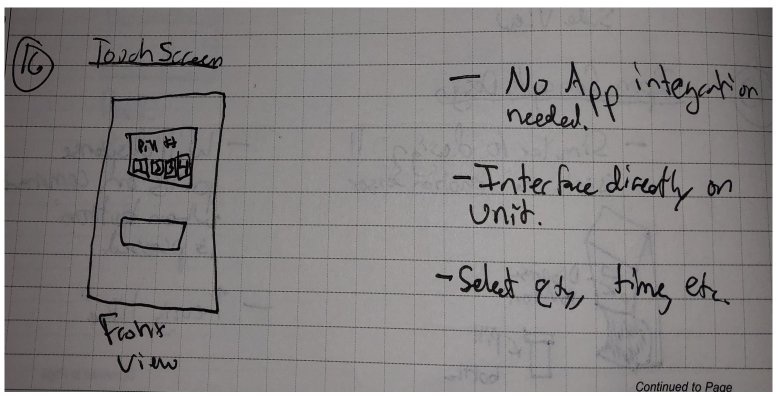


Figure 15: Kyle McKenna Design 15



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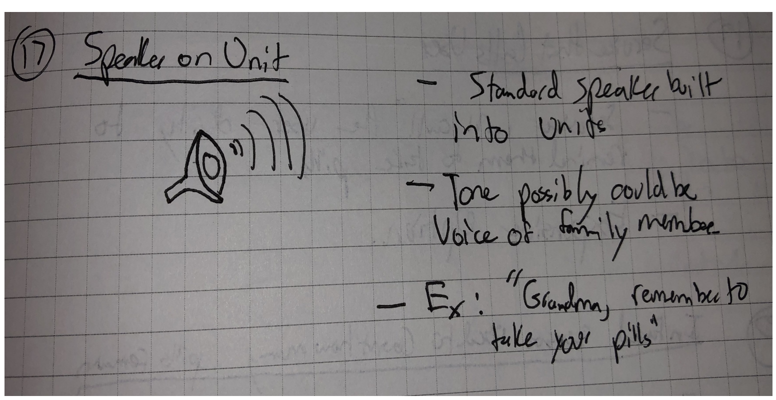

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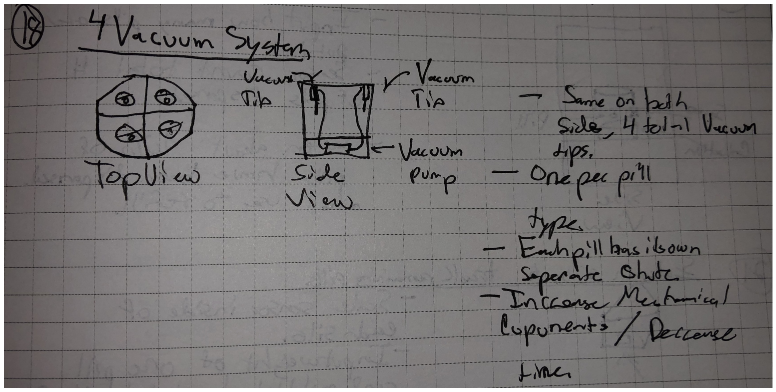

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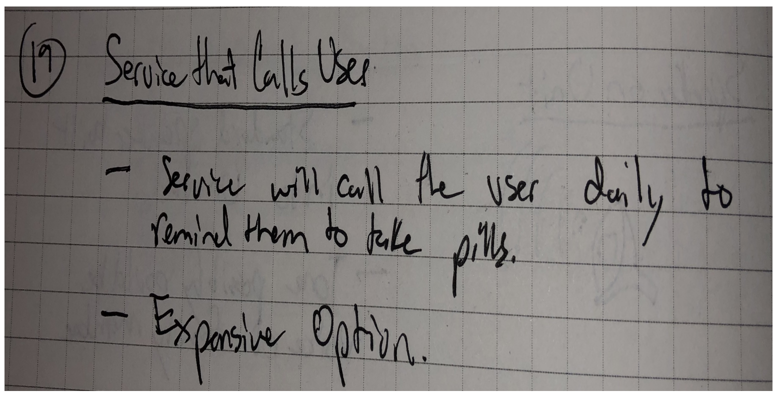

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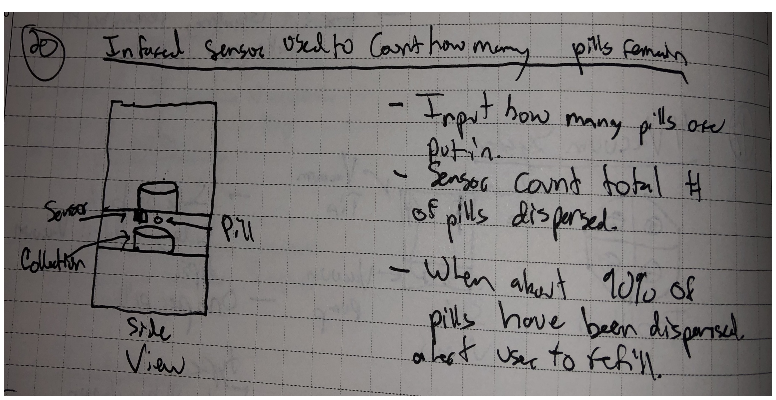

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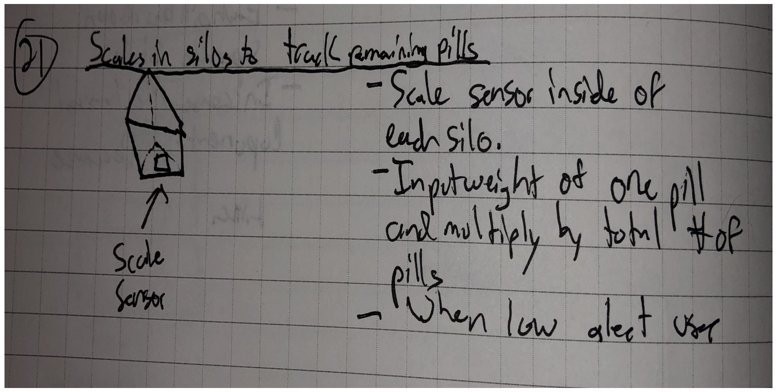

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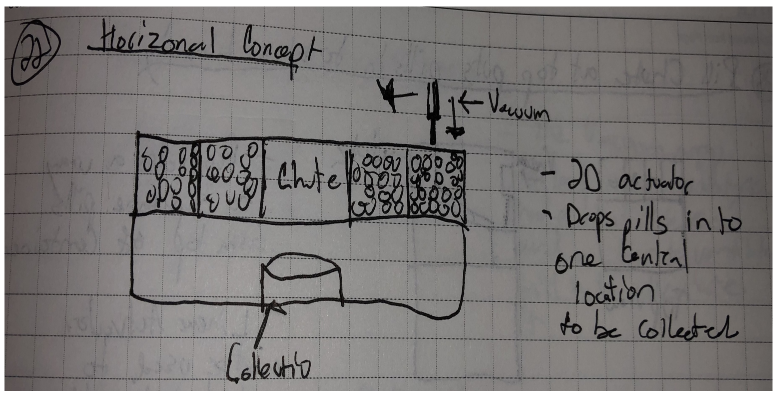

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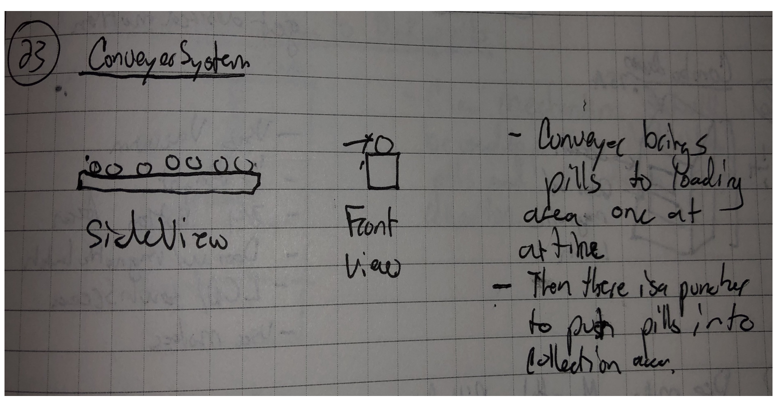

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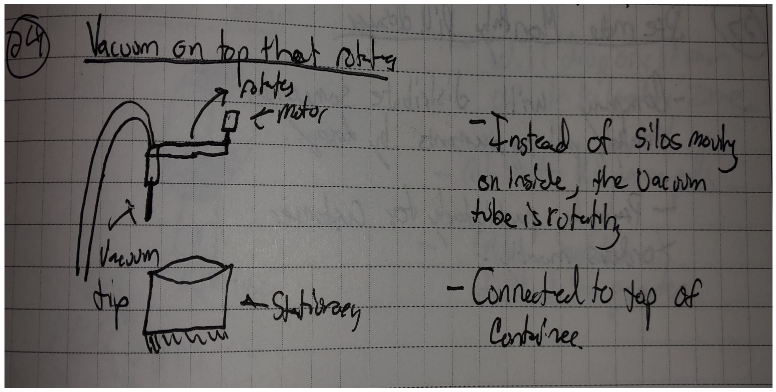

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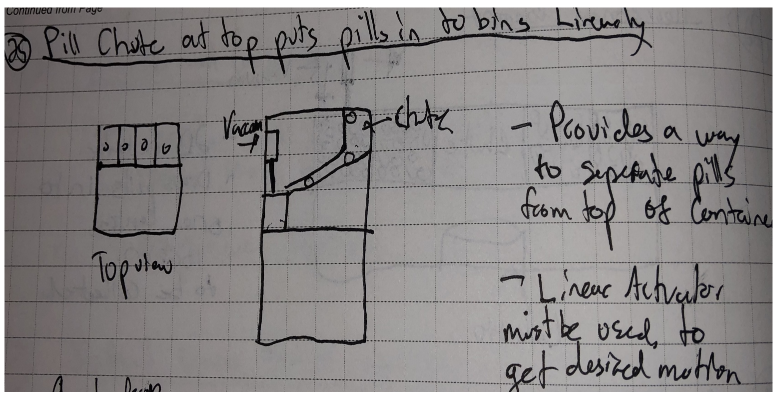

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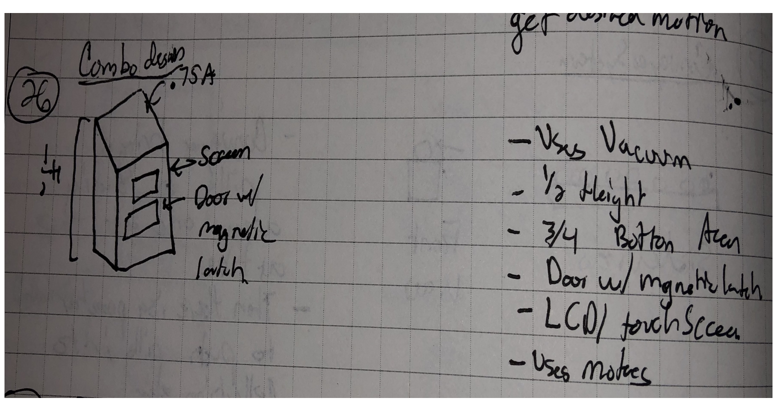

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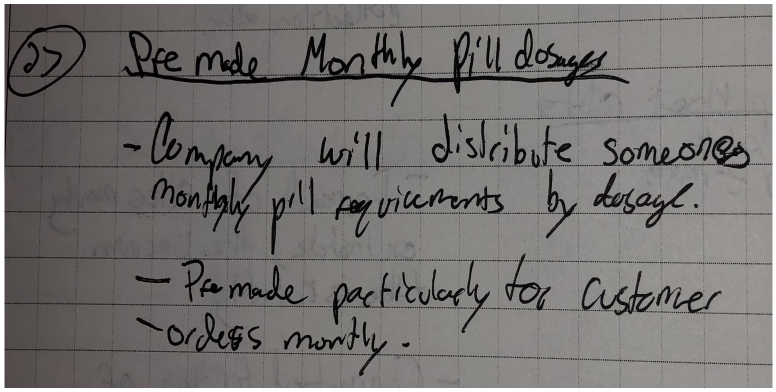


Figure 27: Kyle McKenna Design 27

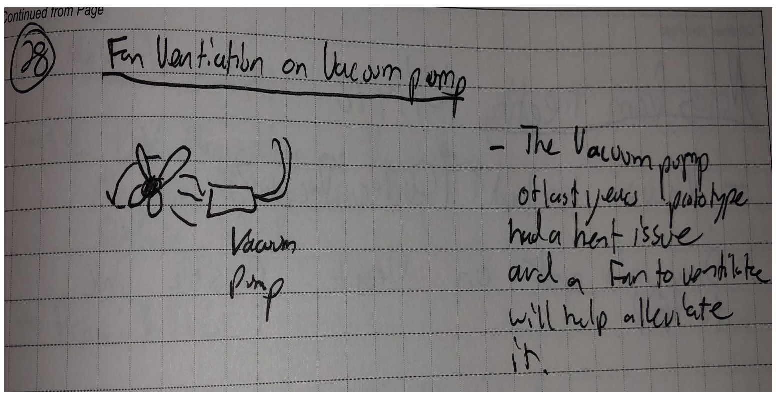
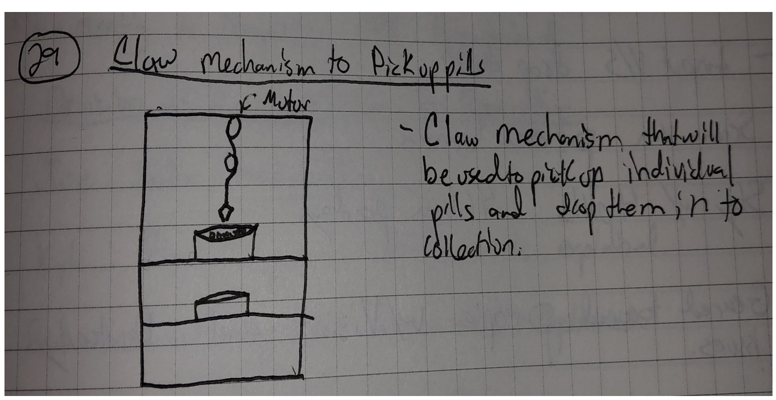


Figure 28: Kyle McKenna Design 28



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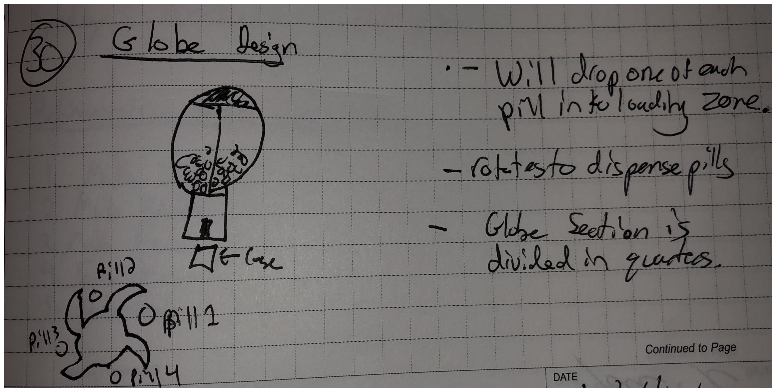


Figure 30: Kyle McKenna Design 30

5.2 Kyle McKenna Evaluation of each concept

Design 1: The first design was a concept design of the android application that will go along with the dispenser. The new app allows for the users to input the time to take each pill and the quantity needed of each pill. The goal of the app was to make it as simple as possible, while making it as effective as possible.

Evaluation: This redesign of the android application increases the quality, overall performance, user friendliness, and total number of functions when comparing to the previous android application.

Design 2: The second design was a redesign of the housing of the original prototype. This keeps the same components on the inside of the prototype but the height will be cut in half and the footprint of the base will be approximately 75% of the prototype.

Evaluation: This redesign on the housing of the original prototype increases the aesthetics, decrease weight, decreases the height, and decreases the volume of the original prototype.

Design 3: The third design was a redesign of the door on the front of the prototype. The new door will be able to open with the push of a button. There will be a gear and motor system inside the housing that will open the door on the front with the touch of a button. This will give the prototype a more aesthetically pleasing look.

Evaluation: This design of the door opening mechanism will increase the aesthetics, the user friendliness, the technology used, increase the number of mechanical aspects, and increase the total number of functions. This will also increase the target cost, increase the weight, and decrease the lifetime of the product.

Design 4: The fourth design was a redesign of the lid on the carrying case. This design will have a snap top compartment for each of the four pills, allowing for one of the four bins to be dumped out without the others falling out. This will alleviate the need to unscrew the top off whenever the carrying case would like to be opened.

Evaluation: This redesign of the lid on the carrying case will decrease the weight of the overall product and increase the overall quality.

Design 5: The fifth design is the addition of LED lights to the prototype. There will be two lights, one will illuminate green when the pills have been dispensed, the other will illuminate red when the pills have yet to be dispensed.

Evaluation: The addition of LED lights will increase the reliability, increase the aesthetics, increase the overall performance, increase the user friendliness, increase the technology used, and increase the total number of functions. This addition will also increase the target cost and decrease the lifetime.

Design 6: The sixth design is the addition of an LCD screen to the front of the prototype. This will allow for more product/user interaction. The functions of the dispenser will be able to be accessed directly from the screen. The screen will be used in conjunction with the android application.

Evaluation:The addition of the LCD screen will increase the aesthetics, increase the overall performance, increase the technology used, and increase the total number of functions. This will also increase the target cost, decrease the reliability, increase the weight, and decrease the lifetime.

Design 7: The seventh design is a system that uses infrared sensors to count the number of pills being dispensed. Each time the infrared beam is broken by the the pill, it counts how many pills have been dropped. When the desired number has been reached the system will either stop or move to the next pill.

Evaluation: The addition of the infrared sensors will increase the aesthetics, increase the mechanical aspects, increase the overall performance, increase the technology used, and increase the total number of functions. This will also increase the target cost, increase the weight, and decrease the lifetime.

Design 8: This design is a solution to making it easier to put pills in the machine. There will be four funnels/tubes that run from the top cover of the prototype and lead directly into the pill bins. The cover of the product will stay on the entire time.

Evaluation: The design of adding in funnels/tubes will decrease reload time, increase reliability, increase efficiency, increase aesthetics, increase overall performance, and increase user friendliness. This will also increase the weight.

Design 9: This design is similar to design 3 except it limits the number of mechanical components needed. The front door on the prototype will be a push activated magnet latch. Simply push the door in, and it will open up. This will give the prototype a sleeker look.

Evaluation: The addition of the magnetic push latch will increase aesthetics, increase mechanical aspects, increase overall performance, and increase total number of functions. This will also increase the target cost.

Design 10: This design will add a sliding back cover to the prototype that will slide vertically. This will eliminate the need for a removable top and allow for easier loading of the pills into the silos.

Evaluation: The design of the sliding back cover will decrease reload time, increase efficiency, and increase the total number of functions.

Design 11: This design will be a motion sensor oriented dispenser. There will be a motion sensor near the dispense location. The user will have a cup or something to catch the pills in. They will put the cup under where the pills dispense. When the sensor senses motion, the pills will dispense.

Evaluation: The addition of the motion sensor dispensing mechanism will increase efficiency, increase aesthetics, increase number of mechanical aspects, increase overall performance, increase technology used, and increase the total number of functions. This will also increase target cost and increase weight.

Design 12: This design concept is the addition of a timer component to the already existing prototype. The existing prototype must have everything selected on Raspberry Pi and then hit the go button. The timer will allow the user to set a time to dispense and when it has reached that time the pills will automatically dispense. The timer will trigger an alarm and make noise when the pills have dispensed to alert the user.

Evaluation: The addition of the timer component will increase mechanical aspects, increase overall performance, increase user friendliness, increase technology used, and increase the total number of functions. This will also decrease lifetime.

Design 13: This design concept is similar to design concept 11 however, there is no motion sensor. The housing will be exactly the same but there will be either a touch screen or an LCD screen that controls when the pills are dispensed. Simply hit the dispense button and the pills will dispense into the users cup.

Evaluation: This design will increase the target cost of the product while increasing the overall performance of the product. This trade off is one that will be considered. If the product performs better at a higher cost that may have to be done to appeal to more buyers.

Design 14: This design concept is a design for the method that the pills are dispensed. There will be a vertical auger system that the pills will sit in. Each time the auger rotates, a certain number of each pill will be dispensed to the user.

Evaluation: This design will decrease the number of mechanical aspects. It will completely eliminate the need for a vacuum pump. However, this dispensing method is far less accurate than the vacuum pump.

Design 15: This design is similar to the prototype that the team has however, the vacuum tip will be in the middle of the top cover instead of on a side wall of the housing. This design will also use a pulley/motor system instead of a linear actuator. The use of the pulley/motor system will hopefully make the dispensing method faster.

Evaluation: This design will hopefully decrease the time it takes to dispense the dose of pills, however it will increase the number of mechanical aspects which will ultimately decrease the lifetime of the product.

Design 16: This design concept is the addition of a touch screen to the current prototype. The interface for the device will now be directly on the unit itself. This will eliminate the need for app integration. The touch screen will have all the same functions that the app has but serve as an alternative to the app. The user will be able to select the quantity, time, etc. of each medication.

Evaluation: This design concept will increase the user product interaction and also increase the number of functions of the dispenser. This will also increase the target cost while decreasing the lifetime of the product. That is an undesired relationship when creating a product.

Design 17: This design concept is the addition of a speaker to the current prototype. This will allow for the unit to produce sound to alert the user that it is time to take their pills. The speaker will be a standard manufactured speaker that will play a tone. It would even be able to have a function to record sound. The user could have their grandchild record their voice so that was the tone that alerted them. For example it could say, ”Grandma, remember to take you pills!”

Evaluation: This design will increase the overall function of the dispenser and also increase the effectiveness of the product. If the dispenser itself can alert the user to take the pills there will be a greater adherence. However, this will increase the number of mechanical aspects which will also decrease the lifetime of the product.

Design 18: This design concept uses the same vacuum dispensing method as the prototype. This concept will have four vacuum/actuator systems, one for each pill. This will allow each pill to be pick up at the same time, decreasing the dispensing time significantly.

Evaluation: This design concept will decrease the time it takes to dispense the pills significantly. However, it will also significantly increase the number of mechanical aspects of the product which will significantly decrease the lifetime of the product.

Design 19: This concept is not a product design. It is more of a service design. This service will call the user on their cell phone several times each day to remind the user to take all of their pills. However, this service is likely very costly.

Evaluation: This design will significantly increase the target cost of the product while keeping all other aspects of the dispenser the same. Customers will not want to pay the increased price for this product.

Design 20: This design is exactly like design concept 7. The difference is the use of the infrared sensor. The infrared sensor in this design will be used to count the total number of pills that have been dispensed. The user will input the starting number of each pill and the infrared sensor will compare to the number that it has count so far. When each pill is getting low, it will alert the user that it is time to refill their prescription.

Evaluation: This design will increase the overall performance and accuracy of the dispenser. However, it will increase the overall number of mechanical aspects but decrease the lifetime and increase the target cost.

Design 21: This design concept is an alternative to design concept 20. There will be scale sensors placed in each of the four silos. This will take the total weight of the pills in the silos and alert the user when there is only a few doses left.

Evaluation: This design concept will increase the effectiveness and overall performance of the product. However, the addition of the scale sensors will increase the number of mechanical aspects and decrease the lifetime of the product. This will also increase the cost to create and sell the product.

Design 22: This design concept is a complete redesign of the prototype. The housing will be rectangular and have a chute in the middle with two silos on either side of it. Inside the housing will be a 2D actuator that use a vacuum tip to pick up the pills. The pills will be picked up and dropped into the middle chute. The pills will fall into a little catching area that they can scoop the pills from.

Evaluation: This design will likely increase the time it takes to dispense the pills. However, it will significantly increase the cost of the product. A 2D linear actuator is very expensive and complex. This will also decrease the lifetime of the product.

Design 23: This design concept is a new dispensing method design. The pills will sit on a conveyor belt and will be brought to a ”loading” area. While sitting on the loader area, a puncher will hit the pill in to a collection area.

Evaluation: This dispensing method will decrease the time to dispense the dosages of pills. It will significantly decrease the accuracy of the product because it will be difficult to manage how many pills are on the conveyor belt at once. Accuracy is the most important aspect when dealing with medications.

Design 24: This design concept is similar to the prototype that was created. It has the exact same dispensing method as the prototype, the only difference is that the carousel that the silos sit on will be stationary. The vacuum tip will be mounted to the top of the dispenser on it's own carousel. The vacuum will be rotating instead of the pill silos.

Evaluation: This design is a good alternative to the current prototype. The only issue is that the vacuum tube may interfere with the carousel on top of the dispenser. This will decrease the effectiveness and accuracy of the dispenser. This method could increase the efficiency of the product.

Design 25: This design concept addresses the issue of loading the pills from the top of the dispenser. There will be four chutes from the top of the dispenser to the silos. The silos will be linearly aligned along one of the walls inside the dispenser instead of in the center of the dispenser.

Evaluation: This design will make the time it takes to load the pills significantly less and far more user friendly. This addition may add some weight to the product but increase the overall performance of the product.

Design 26: This design is a combination of all the best designs presented so far, and is what the team will likely look to produce. This design uses the vacuum pump, is 1/2 the height of the prototype, 3/4 the base area, uses magnetic latch for front door, has an LCD/Touch Screen, and also uses motors.

Evaluation: This design is by far the best design presented. It will address all of the major issues that the orginal prototype has. It will increase the aesthetics of the prototype, decrease the weight, increase the overall performance and function, and increase the technology used. The only issue is that it may increase the target cost of the product and decrease the lifetime. This design does have far more positives than negatives though.

Design 27: This design isn't necessarily a design of a dispenser, it is more of a way to get people to take their pills. A company will prepackage a users daily pills months at a time. The packages are then delivered to the user, broken up by day. The user simply opens up a certain days pills and takes them.

Evaluation: This design decrease the technology used and will increase the target cost significantly. There are little to no mechanical aspects which means the lifetime is essentially the lifetime of the company.

Design 28: This design will be used to alleviate a problem that the prototype has. The vacuum pump tends to get very hot, and this design will uses a fan to cool the pump. The fan will either blow cool air onto the pump, or it will suck the hot air out of the system and dissipate it to the environment.

Evaluation: This design will increase the overall performance of the original prototype by cooling the system down. This increases the quality and efficiency of the product. The addition of the fan does increase the number of mechanical aspects which will decrease the lifetime of the product.

Design 29: This design concept is a new dispensing method. A claw-like mechanism will replace the vacuum tip. The claw will be used to pick up each pill and drop them into the collection area. The claw will use a pulley/motor system which is typically more user friendly than a vacuum pump. This concept was inspired by the claw machines that are seen at arcades.

Evaluation: This design is an alternative to the vacuum pump. However, it will increase the number of mechanical aspects and decrease the accuracy of the product. The use of the claw mechanism could decrease the target cost since a motor/pulley system would be cheaper to manufacture than a vacuum pump.

Design 30: This design is a complete redesign of the prototype. The pills will all be poured in from the top of the ”globe”. The pills will then drop into a loading zone where there will be a rotating gear with arms that will move the pills into the collection area. The biggest downfall of this design is finding a way to make it as accurate as possible.

Evaluation: This design will be far more aesthetic than the original prototype. This design will also take far less time to reload the pills. However, the reliability, accuracy, and efficiency will likely decrease.

5.3 Lyndsay Castle List of concepts generated

In this section, team member Lyndsay Castle's 30 designs for the concept generation and analysis are illustrated. The evaluation of each design is under each design concept figure.

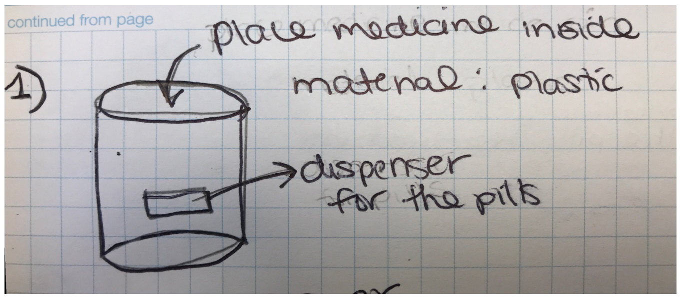


Figure 31: Lyndsay Castle Design 1

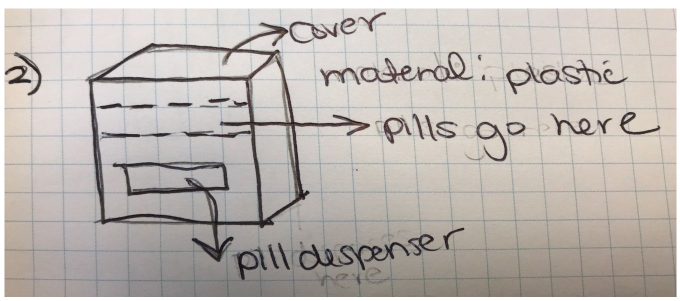
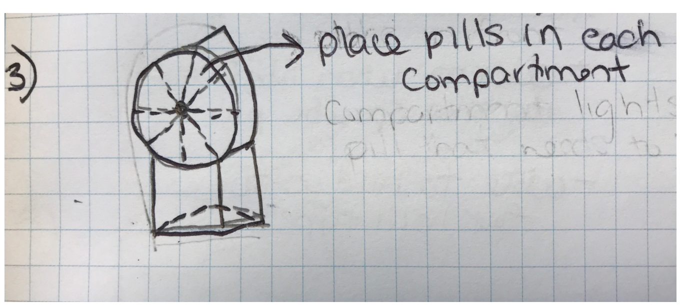


Figure 32: Lyndsay Castle Design 2



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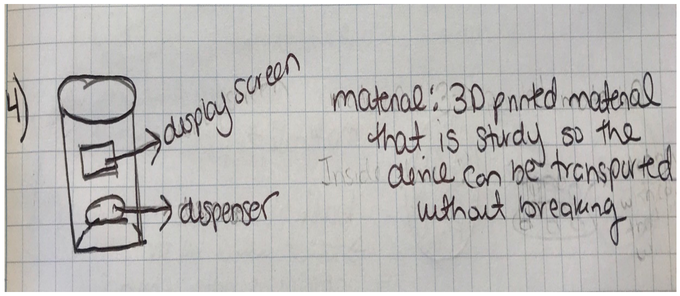

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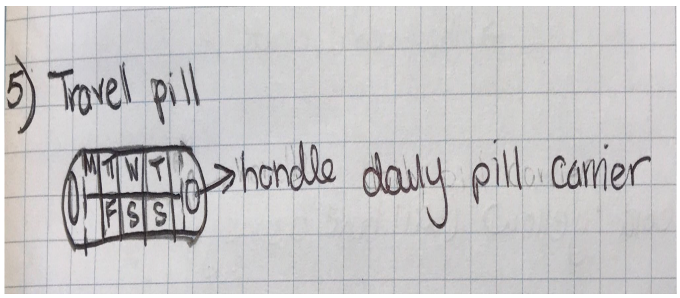

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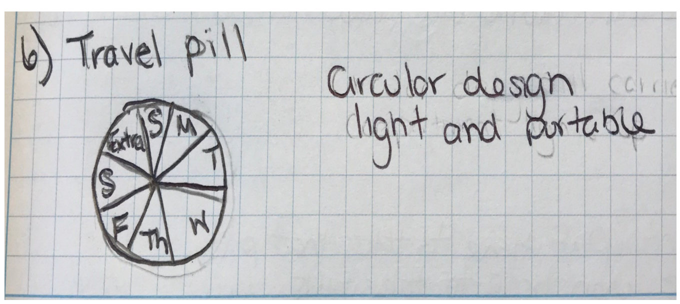

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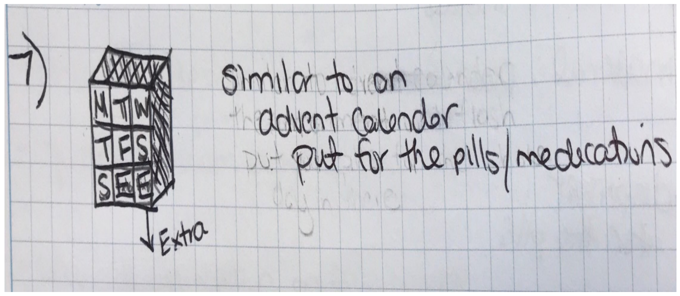
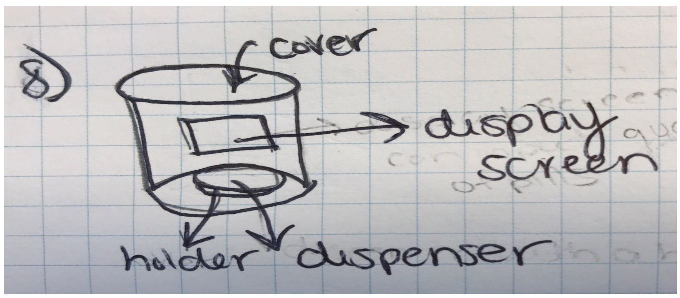


Figure 37: Lyndsay Castle Design 7



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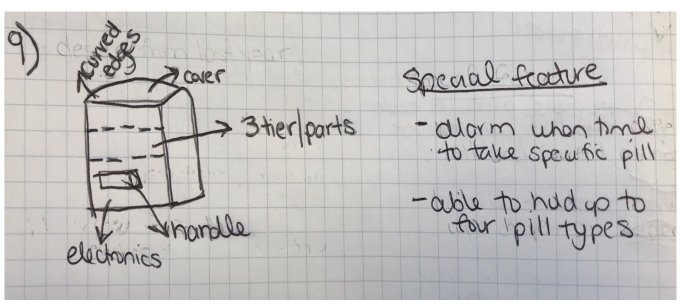
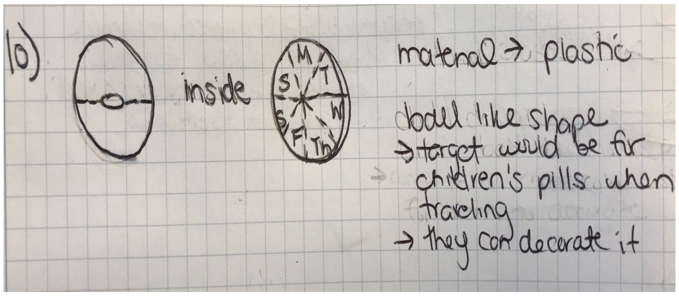


Figure 39: Lyndsay Castle Design 9



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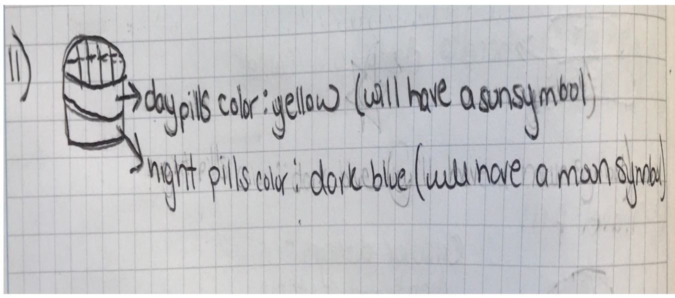
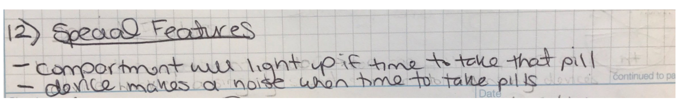


Figure 41: Lyndsay Castle Design 11



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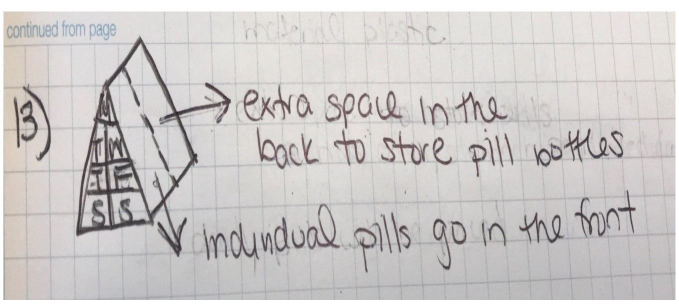

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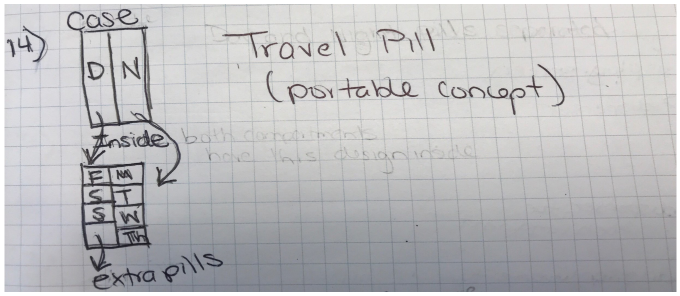

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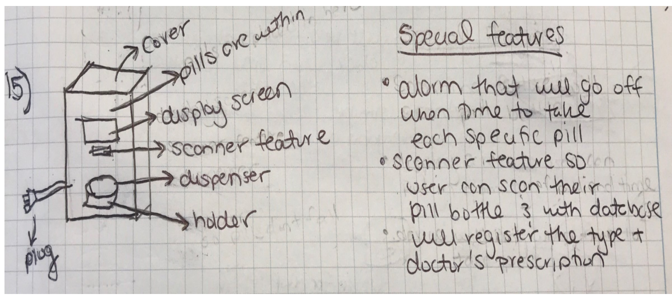

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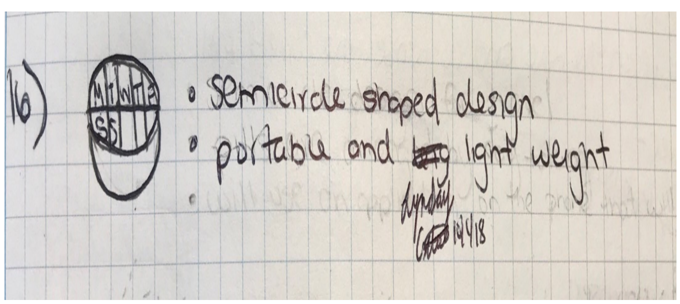

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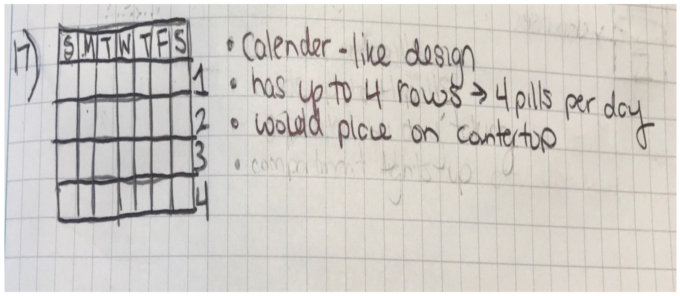


Figure 47: Lyndsay Castle Design 17

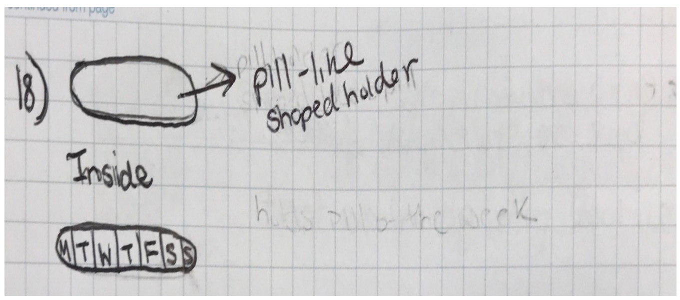


Figure 48: Lyndsay Castle Design 18

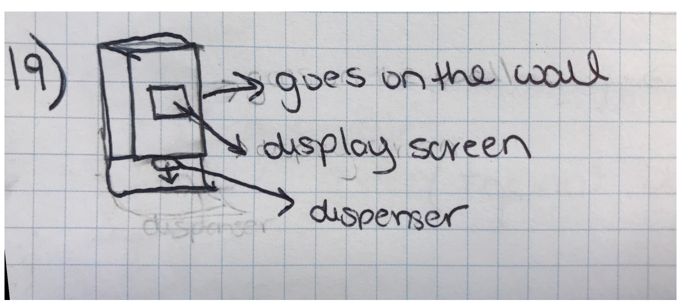


Figure 49: Lyndsay Castle Design 19

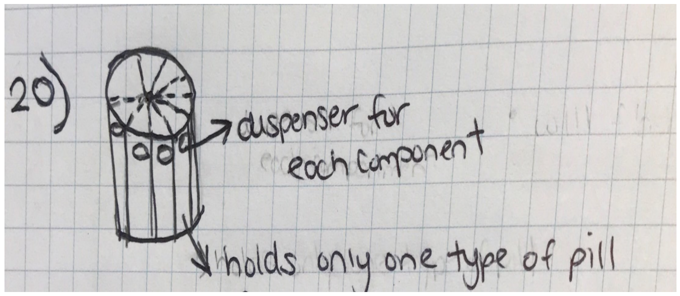


Figure 50: Lyndsay Castle Design 20

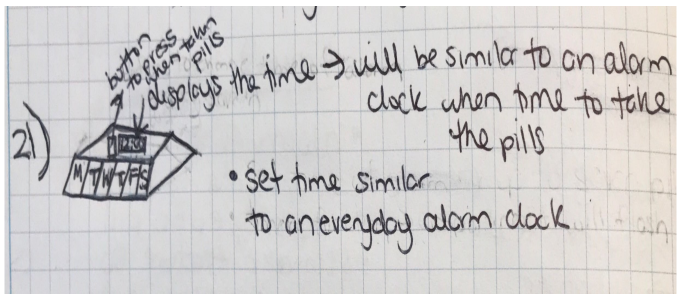
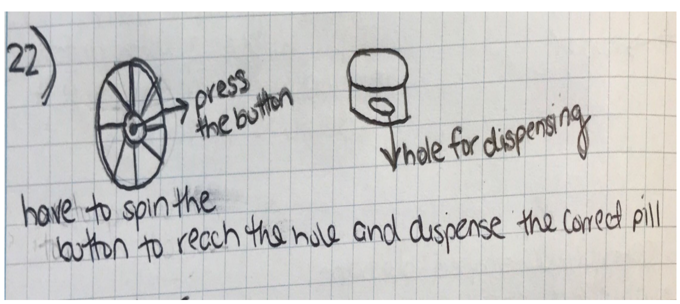


Figure 51: Lyndsay Castle Design 21



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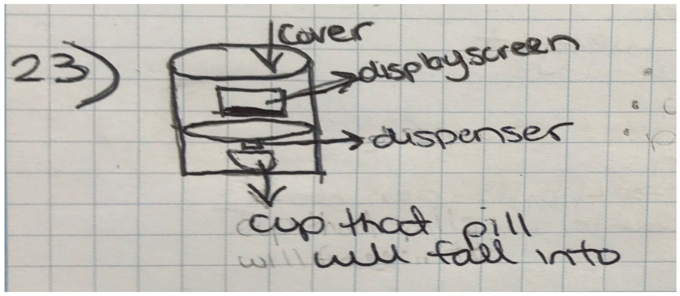

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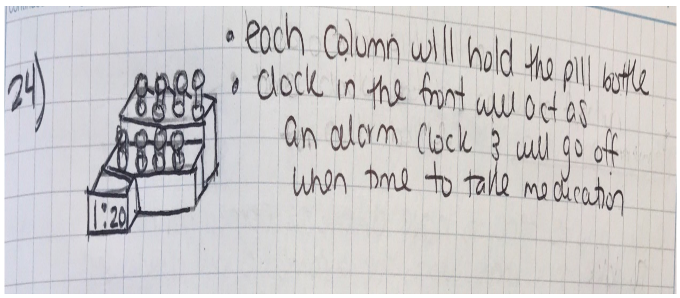
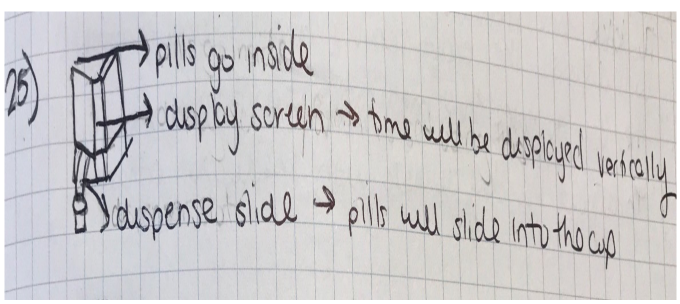


Figure 54: Lyndsay Castle Design 24



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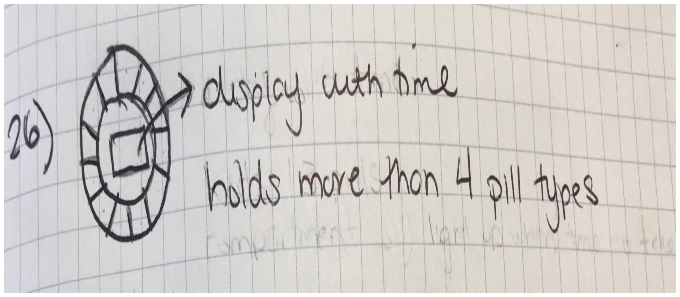

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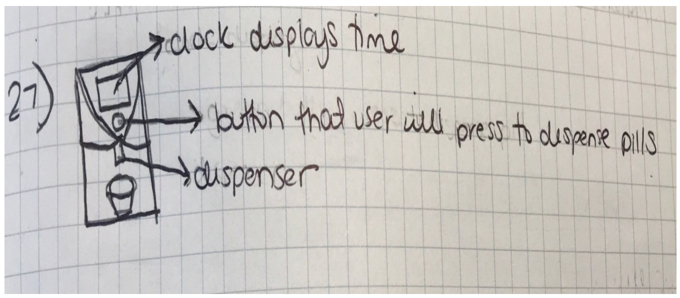

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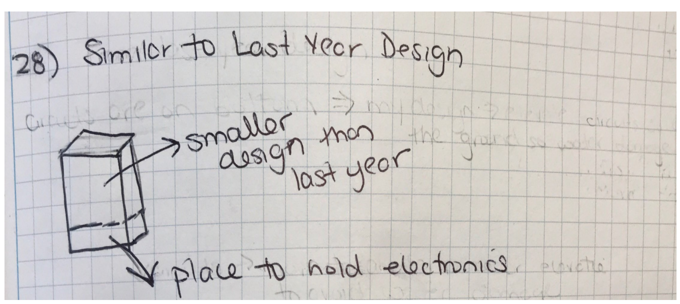


Figure 58: Lyndsay Castle Design 28

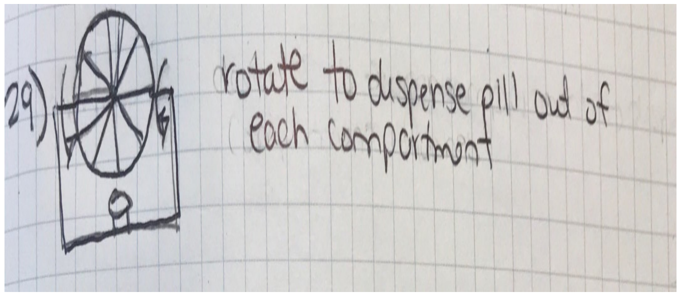


Figure 59: Lyndsay Castle Design 29

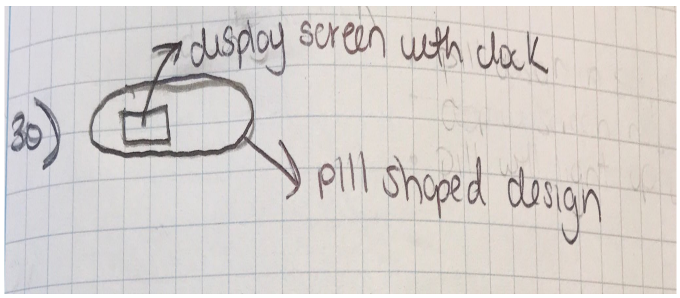


Figure 60: Lyndsay Castle Design 30

5.4 Lyndsay Castle Evaluation of each concept

Design 1: In this design the medicine will be placed from the top, where inside there will be columns where the pill bottles will reside in. The dispenser is similar to a vending machine. The material of the dispenser will be plastic.

Evaluation: Comparing this concept to the engineering criteria, it meets most of the criteria. This design will be more sturdy, however it does not hold up to four different pills.

Design 2: In design two the pill dispenser is rectangular shape, and there is a cover on the top. The cover can be lifted and that is where the pills can be placed. The pills are dispensed from the lower part of the device, and is made out of plastic.

Evaluation: When comparing to last year design it will be more sturdy, however will be larger in size due to the rectangular shape, and can not hold more than four pills.

Design 3: For design three, the pills are placed in separate compartments. The top part rotates and when it is time to take a certain pill the compartment will light up. This design is manual, for it does not automatically rotate when placing and taking pills out of the device.

Evaluation: This design has major improvements when compared to the automatic dispenser that the team has now. This design has a light up/ ringing function, as well as an alarm function. This design can also hold up more than four pill types.

Design 4: For design four, the pills are placed in separate compartments. The top part rotates and when it is time to take a certain pill the compartment will light up. This design is manual, for it does not automatically rotate when placing and taking pills out of the device.

Evaluation: This design is lower in cost due to it having less automatic features. This design also has a display screen as a way for the user to communicate with the device. This makes the device overall more user-friendly. Also the design will be more sturdy since it does not have a three-tier design.

Design 5: In design five it is for the portable device. The travel pill will have a handle at both ends to make it easier for the user to hold. It will also be arranged by day of the week. The individual will store all their pills for each day in the compartment for that day.

Evaluation: This design is for the potable device, so when comparing to the previous portable device it is more user-friendly for it is easier to hold with the handles at both ends. This design will also be more sturdy, and can hold more than four types of pills.

Design 6: In this design, another portable device is evaluated. The design is a circular shape which makes it light and portable to use and store. The case is broken into compartments that are labeled by days of the week, with an additional compartment for extra medications or instructions.

Evaluation: This design is also compared to the portable device, in design six it can hold more pills than the portable design used now. This design is also more appealing to the user for it can hold prescriptions for the entire week, as well as an additional compartment for extra medication, or directions for the medication that need to be stored in it.

Design 7: This design is similar to an advent calender where it is rectangular shape, and each medication/pill bottle is stored in each compartment. The compartments are arranged in order of the week, with two extra compartments at the end. Each compartment is opened by an opening door, and held shut with a magnet.

Evalution: This design is larger in size, as well as does not have a power supply. This design does not make use of a software and does not automatically dispense. This design does not meet the design specifications of the automatic pill dispenser and reminder.

Design 8: In design eight the device is cylindrical shape to make more use of counter space. There is also a holder at the end of the dispenser, so if any pills fall they will fall into the holder rather than on the floor. There is also a display screen that tells the user what it is dispensing. The display screen will also light up with a pop up message alerting the user that it is time to take their medication.

Evaluation: This design is smaller in size than the automatic pill dispenser used now. However, this design has a display screen to communicate the user, as well as a reminder feature which is key to the design of the automatic pill dispenser and reminder.

Design 9: In this design the edges are curves so if it were to be picked up or moved the edges will not hurt the user. Also the design has three tiers, on for where the pills are placed, another for where the pills are dispensed, and the last tier is where the electronics of the device sit. Some special features of this design is an alarm when it is time for the user to take their medication. The device can also hold up to four different pills.

Evaluation: This design is larger in size, as well as less sturdy since it has the three tier design concept. Improvements is this design does have an alarm feature, and can hold four types of pills.

Design 10: The design is for the portable device, where it is ball shaped. The ball shape will make it easier for the user to find. It has an outer shell, and the inside has seven compartments marked for each day of the week. The material of this design is plastic.

Evaluation: When comparing design ten to the portable device that the team has now, this design is much more sturdy user-friendly. It is more user-friendly for it can hold up to seven different pills, or can be used to hold the pills for each day of the week. This design is made for travel purposes.

Design 11: This design is for the portable device where there is two tiers for the device. The top half of the device is for morning pills. The color of the top half will be yellow to symbolize a sun, and will also have a sun on the top half. The bottom half is for the pills taken at night. The bottom half will be colored dark blue to symbolize the night and will have a moon on it.

Evaluation: This design when compared to the last year's portable device is larger in size for it has two tiers to hold both day and night prescriptions. This design can hold more than four types of pills, and is categorized by morning and night pills, avoiding confusion making this design more user-friendly.

Design 12: This design consist of special features of the device. One special feature will be that the compartment will light up when that specific pill needs to be taken. Another feature is the device will make a noise or have a song that it plays when it is time to take the medication.

Evaluation: When comparing the special features, to the features the device now offers, design twelve has more to offer. This design has a reminder feature which is in the design specifications, more so the device light up as well as makes noise.

Design 13: In this design it is triangular shape to make more use of counter space. The compartments in the front are arranged in days of the week. In the back of the device there is another opening where the user can store their prescription bottles.

Evaluation: This design is smaller in size for it it is triangular shape. Also this device is lower in cost for it is not automatic, and the cost of the device is mainly from production cost rather than electronics/software cost. This design can also hold more than four pill types by it can hold up to prescriptions for the entire week and has extra storage.

Design 14: This design is for the portable device. The case has two opening doors that are split into day and night. Under each door there will be seven compartments for each day of the week. This device is meant for travel in that it incorporates all seven days of the week.

Evaluation: Design fourteen is larger than the portable device at this time. However, this design can hold more than four types of pills, and is categorized by night and day pills, as well as day of the week.

Design 15: This design is rectangular shape, and has a cover where the pills will be inserted into the device. There is also a holder at the dispenser, so if the pills were to fall out the dispenser they will fall into the holder and not the floor. This device also includes special features. One special feature is an alarm will go off when it is time to the medication. There will also be a scanner feature, where the user can scan the pill bottle and it will automatically sync into the device.

Evaluation: This design is roughly the same size as the device now. This design includes more key features that are listed in the design specifications. This design has an alarm feature which is required in design of the automatic pill dispenser and reminder. Making the device more user-friendly it has a scanner feature that will automatically sync the prescription into the device, avoiding manually inputting the prescription and possibly making a mistake.

Design 16: In this design the device is semi-circle shaped. The device has a compartment for all seven days of the week. Also this design is portable and light weight making it easier to travel with.

Evaluation: This device is larger than the portable device at this time for the semi-circle shape increases the volume. This device can hold more than four type of pills.

Design 17: This design is similar to a calender. It can be placed on a counter or installed on the wall. There are four rows that medication can be placed into for each day of the week. This design is not automatic, the user has to manually input the medicine into each department and dispense it. This design is more of a holder for medication/ pill bottles for each day/week.

Evaluation: This design is larger as well as heavier than the automatic pill dispenser at this time. Design seventeen does not have a power supply for it is manual, not automatic. This design can also hold more than four types of pills.

Design 18: This design is focused on the portable device. The device is shaped like a pill, to symbolize it is a pill holder. Inside the pill there are seven compartments for each day of the week. Each compartment is also labeled with the first letter of each day, to avoid confusion and taking the wrong medication.

Evaluations: This design is larger in size for it is resembles a pill. The device can hold more than four types of pills, and all of the compartments are labeled making it more user-friendly. However, this device does not have a reminder function.

Design 19: This design is meant to be installed on a wall. The device has a display screen that notifies the user what pills are dispensing, and when they are. There is also a dispenser and a holder that is curved shape so the pills do not fall on the floor. This device is not portable for it will be installed into a wall with nails.

Evaluation: This device does not take up counter space for it will be installed on the wall. The device however is roughly the same length and height, but smaller in width for it does not want to bulge out on the wall. This device is also more user-friendly for it has a display screen that can communicate with the user.

Design 20: The dispenser is not automatic and is a way for the user to hold and dispense their medication. Each column has a dispenser at the end of it which is opened and closed by a sliding door. Each column holds one type of pill, so the user will have to manually open and close each sliding door of the column in which the pill that they need to take at that time resides in.

Evaluation: This device does not meet the design specifications for it does not have an automatic function. The design also does not have a reminder function, therefore the design can not be used for the final prototype.

Design 21: Design twenty-one is similar to an alarm clock, where the time is displayed on the top of the device,and an alarm will go off when a medication needs to be taken. The clock on the top has an alarm function where the user can set up to three alarms per day. The medication resides in the compartments on the side which are organized and labeled by days of the week.

Evaluation: This design meets some of the requirements for the automatic pill dispenser. This design has an reminder function that is set up similar to an alarm clock, where the user manually sets the time the alarm needs to go off at. This design is more user-friendly for the device is organized by day of the week, and the compartments are labeled.

Design 22: This design is similar to a salad spinner. The user will input their pills into each compartment and will have to press the button on the spin the device. There is only one opening so the user will have to spin the device until the compartment that has the pills that need to be taken reach the dispenser.

Evaluation: This device does not meet the requirements for the design specifications for it is not automatic, and does not include a reminder feature. This design would not be worth the cost to produce.

Design 23: In this design there is a display screen where the user can communicate with the device and type in how many and the kind of pills that are being placed in the device. There is also a cup that will come with the machine, that the medication will be dispensed into. The pills are inserted from the top of the device. The cover can be removed and there will be columns inside the device, where the user will dump their medication into.

Evaluation: This device has a larger volume, as well as weighs more than the automatic pill dispenser at the time. The device, however does automatically dispense the medication, as well as has a display screen where the user can input the quantity and type of medication inserted making it more user-friendly.

Design 24: This design has a several columns exposed to the environment but are all attached to the device. The actual prescription bottle will be placed in each column. An alarm clock feature will notify the user when it is time to take the certain medication, and the pill bottle will light up to designate the specific one to take. There will be a light at the bottom of each column, so when the timer goes off, it will appear as though the pill bottle will be flashing.

Evaluation: This concept does not automatically dispense, however does include a reminder feature. This device meets most of the design criteria but the main focus it is being automatic which this design does not offer.

Design 25: The device is automatic for it automatically dispenses the medication.The medication is placed inside the device. There is a display screen on the device that will show the time, and the user can input the quantity and type of medication inputted into the device. when the alarm functions goes off the display screen will flash, and a pop-up message will be displayed of the type of medication being dispensed. The medication will then be dispensed down a slide into a cup.

Evaluation: This design does meet all of the design criteria for it automatically dispenses and reminds the user. This design would be worth the production cost to produce for it meets the majority of the design criteria.

Design 26: This design is focused on the portable device. The device has a time function in the center, and will be like a watch with an alarm function. This device can hold more than four pill types. The compartments are not separated by days of the week but by the type of pill that resides in each compartment.

Evaluation: This design is larger than the portable device the team is using at this time, however it include a reminder function which the device at this time does not include. The organizer is equivalent in user-friendly for the compartments are not labeled.

Design 27: The device has a display screen where the time is displayed. Also the device does not automatically dispense the medication. The alarm will go off to what time the user set it to, and the button will flash telling the user to press the button so their medication can be dispensed into the cup. The device does not automatically dispense, as a way to force the user to get up and take their medication. Also so if the user is not around the device will not continue to dispense medication for each time set and end up mixing up the different medications.

Evaluations: This device is roughly the same dimensions as the the device at this time. However, this device does not automatically dispense prescription but doe shave a reminder feature. This device has half of the design criteria, if the design included an automatic feature it would be worth the production cost.

Design 28: This design is similar to last year's device. Some differences is it is only two tiers rather than three. By making it two tiers the dimensions of the top tier is reduced in size. Also the electronics will be placed in the bottom compartment but will be built up by 5 inches. This to avoid water getting into this compartment, and destroying the entire device.

Evaluation: This device is smaller in size, as well as more sturdy due to the two-tier design concept. This device does include a power supply and due to possible damage will save money in repair cost by building up the electronics by 5 inches, so water can not seep into the openings for air circulation.

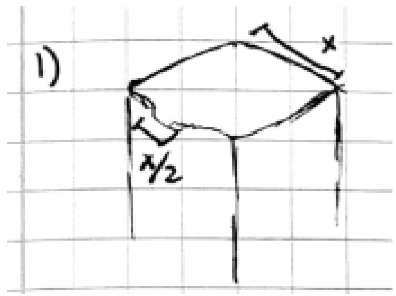
Design 29: In this design it is not automatic, but instead the user has to manually rotate the device to dispense the medication. Each compartment is shut close by an opening door and secured with a magnet. The user will have to open up the smaller sliding door that is apart of the opening door to dispense the medication in that compartment.

Evaluation: This design does not meet the design criteria of the automatic pill dispenser and reminder. The design is not automatic, and does not include a reminder feature. This design will not work when building the final prototype.

Design 30: This device is the design for the portable device. The design is pill shaped to symbolize it is a medication holder. There is a display screen on the device, that displays the time. There is an alarm function that will go off to the time that user set. The entire pill will light up when the alarm goes off, however it will not designate which medication, or the compartment of the medication that needs to be taken.

Evaluation: The design is larger in volume than the portable device at this time due to the pill-like shape. This design does meet one of the design criteria for it has an alarm function. This design would be a great concept for the portable device, and would be worth the production cost. An improvement would to make it smaller, by making the top part of the pill flat, decreasing the surface area.

5.5 Brian McDonough List of concepts generated



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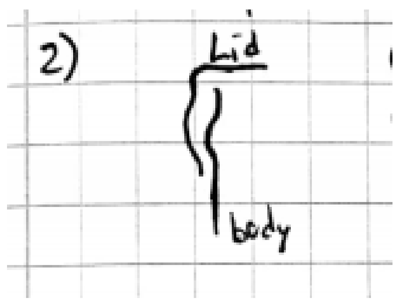

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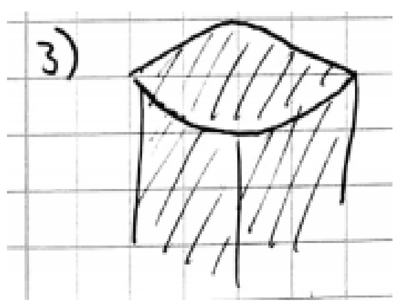

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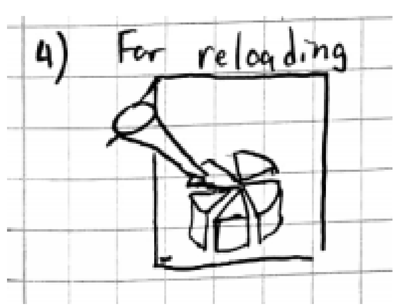

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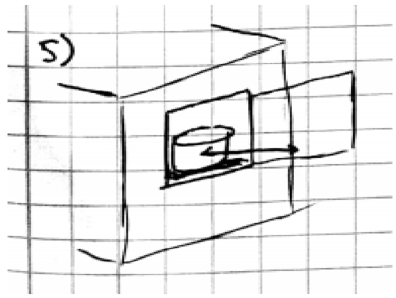

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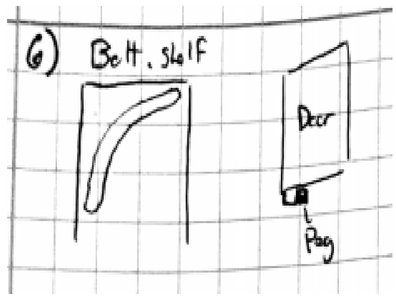

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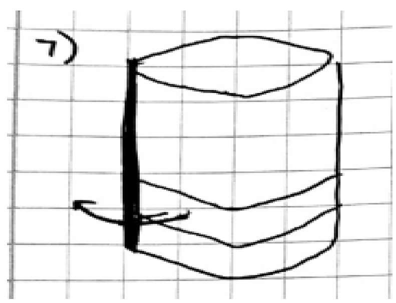

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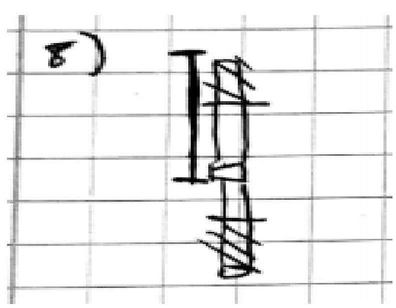

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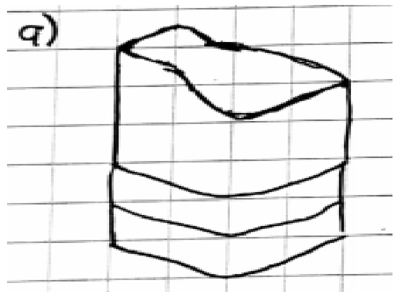

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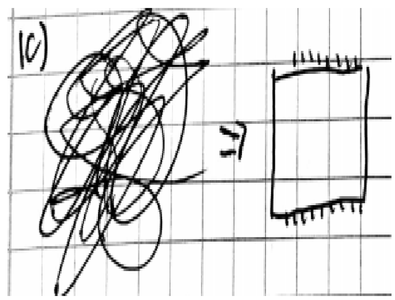

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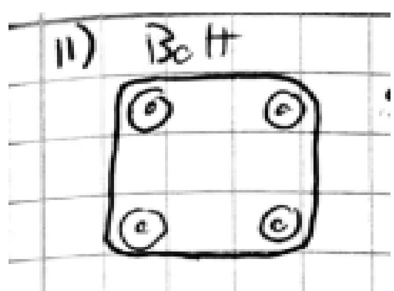

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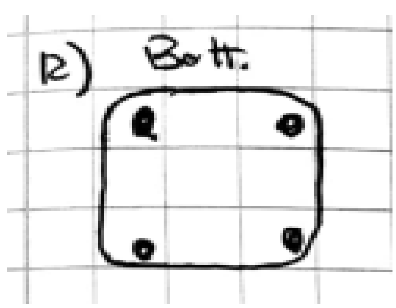

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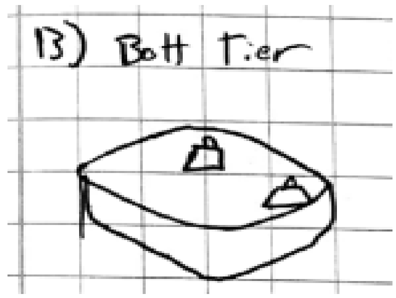

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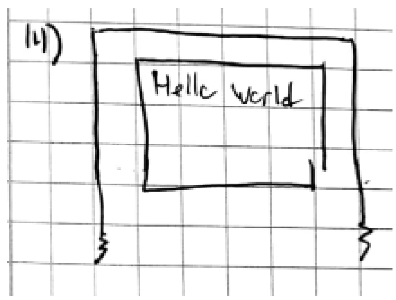

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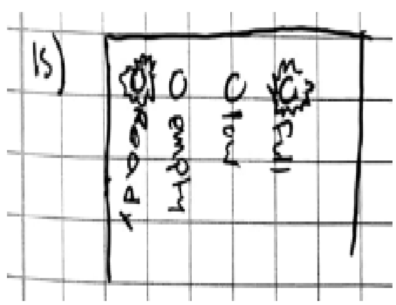

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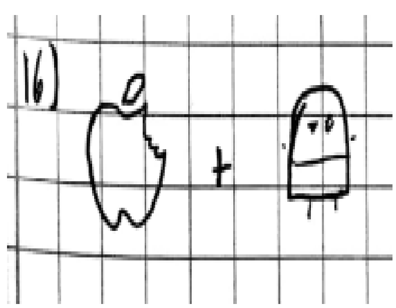

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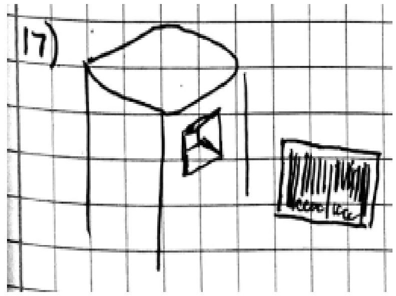

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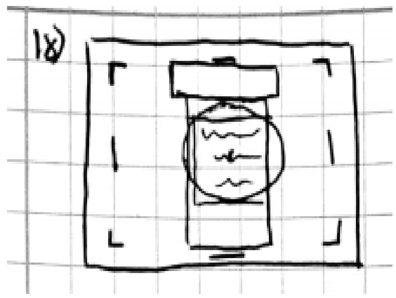

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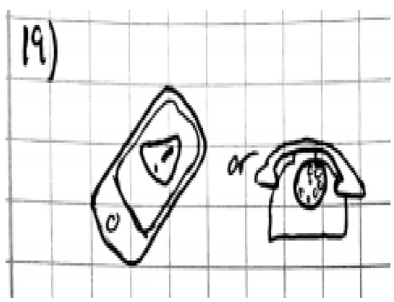

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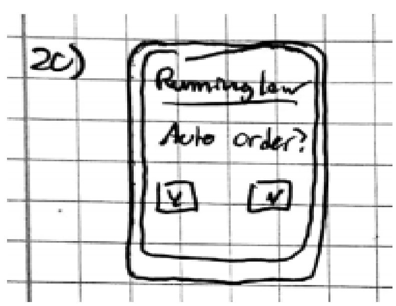

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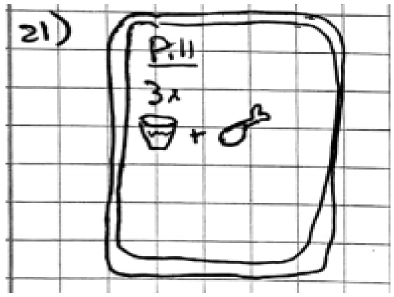

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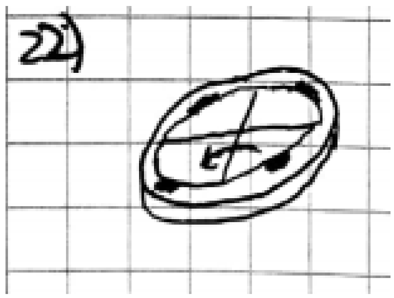

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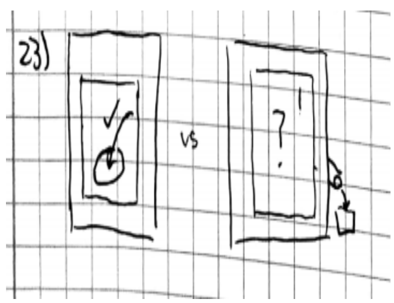

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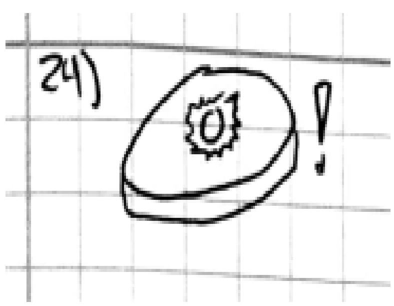

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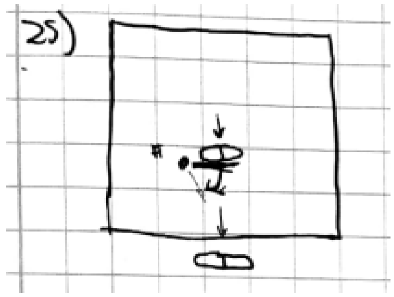

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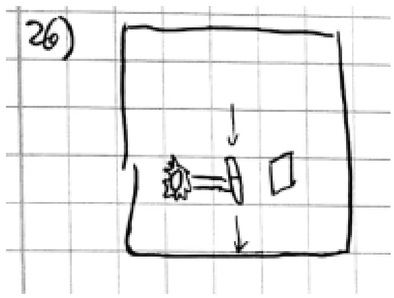

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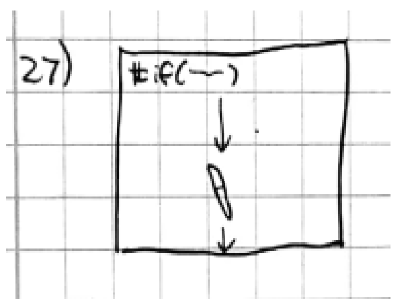


Figure 87: Brian McDonough Design 27

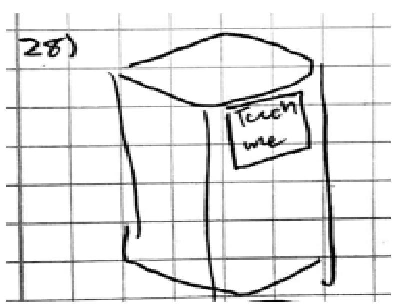


Figure 88: Brian McDonough Design 28

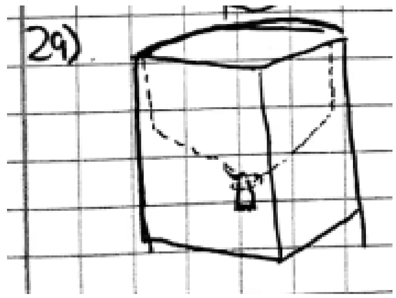


Figure 89: Brian McDonough Design 29

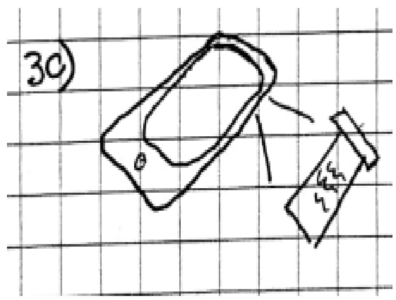


Figure 90: Brian McDonough Design 30

5.6 Brian McDonough Evaluation of each concept

Design 1: Figure 61 is a redesign of the lid to the Pill Dispenser. This redesign of the lid will make for easier access to the inside of the machine, while also protecting it from any outside influence, such as water vapor or dirt and dust.

Evaluation: This design will increase the cost, due to it requiring the an extra print or mold for production but will simultaneously increase the ease of access for the user.

Design 2: Figure 62 shows a method of connecting the lid to the rest of the machine. An bump in the body and a matching bump in the lid will create a mating seal, in some ways like any plastic food storage container. This design will protect the pills inside the storage area from any outside contaminants.

Evaluation: This design increases the user friendliness of the device and also increases the cost, due to needing specific, more complex designs for each product.

Design 3: Figure 63 redesigns the top of the Pill Dispenser to have no lid at all. Out of the first three designs, this will be the most secure in terms of contamination prevention, but will also be the most difficult to refill the pill silos. The following designs, Figures 64 - 66 show how the reloading of the machine can be optimized.

Evaluation: This design would decrease the cost of manufacturing due to the simplicity of the design, but would decrease the user accessibility.

Design 4: Figure 64 shows a method of reloading. Currently, the user must either take out the desired silo in which they want to refill, or blindly pour their medications into the silos. Both of these methods require much concentration and a steady and accurate hand. Design 4 eliminates the problem of accuracy, as the silos will spin until the correct silo is under the funnel, allowing the user to simply pour their medication into the funnel.

Evaluation: This design greatly increases the user friendliness of reloading the machine, but will also increase the complexity of manufacturing and the cost of production.

Design 5: Figure 65 shows another method of reloading the silos. Instead of a funnel, all silos would slide out on a tray, which the user can move themselves. This method of reloading still requires an accurate hand to pour the medications, but it eliminates the problem of pouring blindly into the machine.

Evaluation: This design will increase the accuracy of refilling the pill silos due to them being easily accessible, but can also become less user friendly, as a user could accidentally place the pills into the wrong silo.

Design 6: Figure 66 is a redesign of 65, but the displaying of the pill silos in done by the action of opening the access door. The user must simply open the access door, and a mechanism will pull the tray out with it. This design makes the process of reloading much easier.

Evaluation: This design has the same problem with the previous one, in that the user is still responsible for putting the pills into the correct silo. It also increases the cost of the device.

Design 7: Figure 67 has one corner of the Pill Dispenser hinged, allowing each tier to swivel open and closed. This creates very easy access to the different tiers of the machine, but it also makes it very unstable.

Evaluation: This design greatly reduces the stability of the device, especially if the device is printed using plastic, and it will also increase the cost.

Design 8: Figure 68 shows the vacuum tube housed in the top tier of the Pill Dispenser. In the final design from last year, the top tier is mainly empty space. The main component preventing the top from being shorter is the vacuum tube. This component seems to be long for no apparent reason, so a simple solution which would reduce the height of the top tier would be to shorten the length of the vacuum tube.

Evaluation: The change in design does not affect the cost, due to it being a change in a previous piece, but this design will greatly reduce the volume of the top tier, which is one of the goals for this year.

Design 9: Figure 69 is another way to solve the issue in which the top tier is too large. This design would simply get rid of the empty space, reducing the total volume taken up by the device. This, however, does not solve the problem of reloading the device.

Evaluation: Design 9 decreases the volume of the top tier of the device, which as stated earlier, is a goal for this year. It will also decrease the cost of production, due to the reduction in material needed to make the top tier.

Design 10: The Pill Dispenser is currently many wires tangled with one another, so Figure 70 is showing a migration from wires taking up the bottom tier to a neat and organized central board, in which most if not all of the wiring can be accomplished.

Evaluation: This design could potentially increase the cost of the device, but will also increase the stability of the device, since wires wont be broken if the user moves the device around too much.

Design 11: Figure 71 shows the bottom of the Pill Dispenser. Attached to the bottom of the device would be suction cups, preventing the device from moving while it is dispensing. The suction cups, however, would prevent the user from moving the device around the counter-top without having to pick the device up, which could be problematic.

Evaluation: Design 11 will greatly increase the stability of the device. Since most users will most likely keep their device in one spot, needing to move the device around wont be much of a problem.

Design 12: The design in Figure 72 is a workaround to the problem described in Figure 71, in which the user would struggle moving the device if they wanted to. Instead of suction cups on the bottom, Figure 72 has rubber pads, similar to those found on the bottom of most laptops. The rubber pads would prevent sliding during normal operation, but would allow the user to move the device significantly easier than with the design in Figure 71.

Evaluation: This design increases the stability of the device, but not as much as in Design 11. As a trade off, the design allows the device to easily be moved to and from, on a counter top, for example.

Design 13: Figure 73 shows a design in which the bottom section is weighted. This design would prevent the device from tipping over, and would prevent the device from moving during normal operation, but would significantly increase the weight of the design.

Evaluation: This design greatly increases the weight of the device, due to the addition of pure weight, which will increase the stability.

Design 14: Figure 74 shows a design for a display screen to be integrated into the Pill Dispenser. This Screen will tell the user information such as the amount of pills they have left, when the next dispensing will be, and other similar information.

Evaluation: This design increases the user friendliness of the device. The user can easily see information given by the device. The disadvantage, however, is that the screen will increase the cost of producing the device.

Design 15: The design in Figure Figure 75 is a display on the Pill Dispenser, but instead of a screen display, lights will indicate different statuses of the device, such as ”Low on Pills”, ”Empty”, and ”Ready”, to name a few.

Evaluation: This simple display will increase the cost of production, but not nearly as much as it would increase with Design 14. This design increases the ease of access and the user friendliness.

Design 16: Since the group from last year only had an app working on Android platforms, Figure 76 would be apps working on both iOS and Android.

Evaluation: This design would double the amount of users able to the device, and since developing apps is free on both platforms, the only cost increase would be the time taken to make each app.

Design 17: The design in Figure 77 shows a bar code scanner that would be integrated into the device. This scanner would read the bar code off of the pill bottle and store information to the app and device. Such information would be things like the name of the medication or any information about the medication itself. This will let the device take care of input of information, in case the user is not able to accurately input information into the device.

Evaluation: This design will greatly increase the cost of the device, but will also greatly increase the accuracy and the adherence.

Design 18: The design in Figure 78 is similar to that of Figure 77. A picture of the pill bottle would be taken, and the information would be read from the label. Devices are able to read text from pictures, such as Google Translate or Keep Notes. This method of input would make sure that all special instructions on the bottle are taken into consideration.

Evaluation: Design 18 will increase the price and complexity of the device, but it will also increase the accuracy and adherence to medications, the major goals of this device.

Design 19: Figure 79 shows a design which would either call or notify a user and their family or caregiver if the user missed a medication. This design allows not only the user to keep up to date with their medications, but a doctor, for example, will know if their patient is adhering to their prescriptions.

Evaluation: This design is a simple implementation to the app, which will increase the accuracy of the device, without having to increase the cost too much.

Design 20: Figure 80 shows part of the app which would allow users to reorder their medications if they are running low. The dispenser would keep track of their medications via Figure 85,86 or 87, and would alert the user when they are running low.

Evaluation: Again, this is another implementation to the application which would not increase price by much, but would increase the accuracy of the device.

Design 21: Figure 81 is another design of the app which would tell users any special instructions they need to know when they take their medications. Some medications require that they are taken before or after a meal, with water, or many other conditions. This design would remind users not only which pill to take, but also the specific instructions that accompany the pill.

Evaluation: This is another design which will not increase the cost of the device, but will greatly increase the accuracy of

Design 22: Figure 82 is the portable section which users can take with them out of the home base. The previous design had only one cap to the entire portable component, so all four sections were open at once. If a user accidentally tilts the portable section too far, all pills will fall out The new design in Figure 82 allows each section to be opened individually, ensuring the least amount of loss during an accident.

Evaluation: The design in Figure 82 will decrease the chances of any medication falling out unintentionally. This design would also increase the portability and user friendliness, while increasing cost at the same time.

Design 23: Figure 83 asks if the device should have a mode to dispense pill to a separate location if the portable section is in the base. If the user is not going out that day, it would not make much sense to dispense the pills into the portable section, and instead dispense them into a separate, at home, container.

Evaluation: Design 23 increases the cost of development, while not increasing much else in terms of user friendliness.

Design 24: Figure 84 represents some form of notification on the portable section of the device, alerting the user when to take their medication. This would work in tandem with the notification function of the app, working as a fail safe in case the user does not have their phone on them.

Evaluation: Design 24 would increase the medication adhereance of the user, but would also increase the cost. Due to the extra components added to the portable section, it would increase the weight of the unit substantially.

Design 25: Figures 85 through Figure 87 are all different methods of counting pills. This would allow the device to remind the user they are running low on a medication, as described in Figure 80. The method described in Figure 85 would be a mechanical counter, using hoppers or something similar to keep track of the pills.

Evaluation: This design would increase the cost of development and the weight and cost of the unit, and is an inefficient way to keep count of the medications.

Design 26: The design in Figure 86 would count the pills using a light source. When a pill breaks the light source to the receiver, the counter would decrease.

Evaluation: This design is a very complicated way of counting medications, increasing the cost significantly for doing a relatively simple function.

Design 27: Figure 87 is a counter based solely on coding. The user would input the amount of pills and the frequency of these pills, and the code would subtract the total count based on this information. Out of the three designs to count the amount of pills, this would be the most logical, as there is no extra parts needed.

Evaluation: Of designs 25 and 26, this design is the simplest way to count the medication. The design does not add to the cost at all, since a code which counts is one of the simplest codes to make.

Design 28: Figure 88 shows a touch screen integrated into the Pill Dispenser, which would be the main interface the user would interact with. They would be able to input all information using the touch screen, and all information would be shown using the same screen.

Evaluation: This design add a large cost to making the device, and since the user will be interacting with the machine via smart-phone, the touchscreen is redundant.

Design 29: The design in Figure 89 is a way to know if the pill in the silo is the last one. A sensor would lay on the bottom of each silo, and a pill would interact with the sensor. If the silo is empty, the sensor would notify the unit that the silo is empty, which in turn would tell the user they need more pills.

Evaluation: This design could be accomplished with methods such as in Design 27, so adding this design is not cost effective and would add weight to the final design.

Design 30: The design in Figure 90 is similar to Figure 78, except this design is a function of the app instead of the device. The app would take pictures of the pill bottle and transfer the information to the unit allowing the user to easily input their information into the device.

Evaluation: This design does not add any weight to the device, and could potentially integrated for little cost, if there are sites with open source code which have this design coded.

5.7 Joe Jacobs List of concepts generated

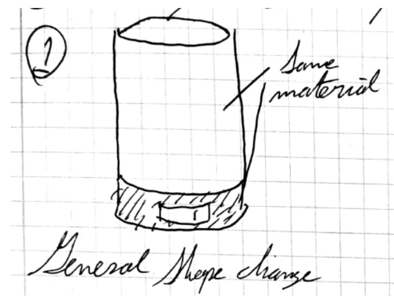


Figure 91: Joe Jacobs Design 1

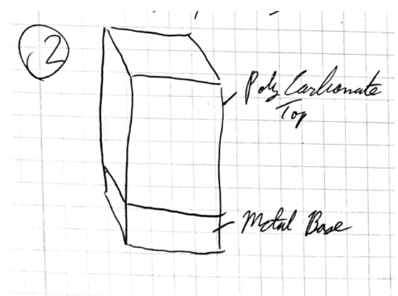


Figure 92: Joe Jacobs Design 2

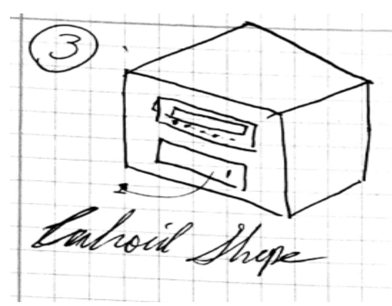


Figure 93: Joe Jacobs Design 3

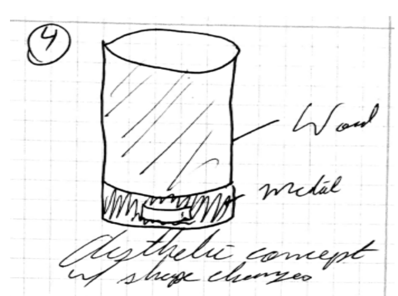


Figure 94: Joe Jacobs Design 4

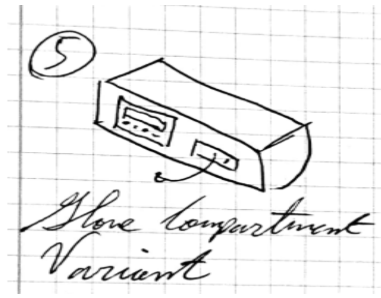


Figure 95: Joe Jacobs Design 5

Figure 96: Joe Jacobs Design 6

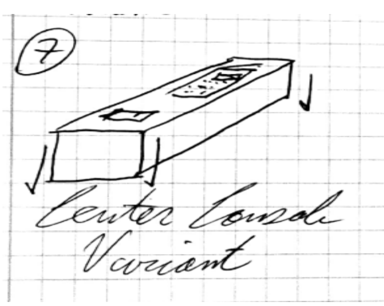


Figure 97: Joe Jacobs Design 7

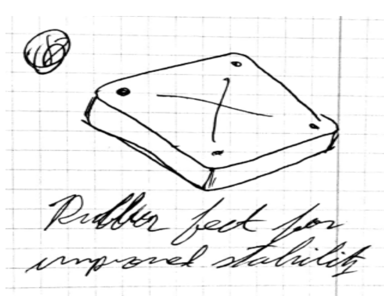


Figure 98: Joe Jacobs Design 8

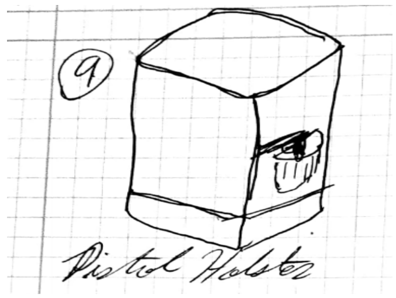


Figure 99: Joe Jacobs Design 9

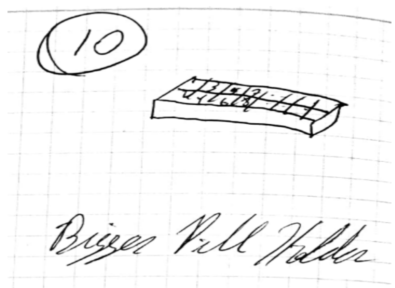


Figure 100: Joe Jacobs Design 10

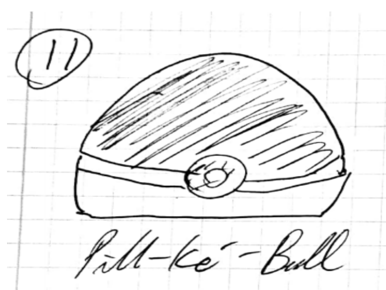


Figure 101: Joe Jacobs Design 11

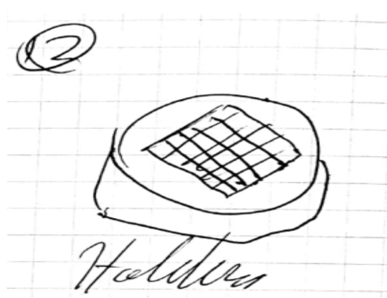


Figure 102: Joe Jacobs Design 12

Figure 103: Joe Jacobs Design 13

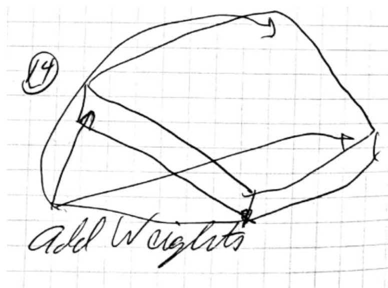


Figure 104: Joe Jacobs Design 14

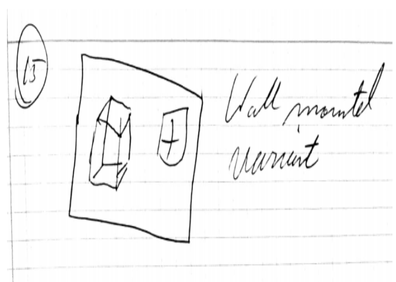


Figure 105: Joe Jacobs Design 15

5.8 Joe Jacobs Evaluation of each concept

Design 1: In Figure 91, an overall shape change was conceptualized. Instead of the rounded edge rectangular prism in the original design, a cylindrical body shape would be used.

Evaluation: This is more aesthetically pleasing and would provide more storage, but would increase cost, weight, and overall size.

Design 2: In Figure 92, the proposed design sought to leave the overall shape the same but have a change in material. The poly-carbonate top would remain (maintaining a light weight) but the bottom would be made out of metal. An Aluminum alloy most likely.

Evaluation: A metal base would increase production cost and weight (in this case, a positive due to it lending to more stability), but it would improve product life.

Design 3: In Figure 93, this design would see an overall change in shape of the product. The product as is is quite cumbersome and oddly shaped.

Evaluation: A cuboid shape would maintain total volume but make it easier to work with. The shape makes better use of space therefore would have a positive impact on storage capacity, plus the shape is simpler therefore making manufacturing cheaper.

Design 4: In Figure 94, this concept sought a total redesign. With a wooden upper section, a metallic base, and instituting the shape redesign as mentioned in Figure 91.

Evaluation: The metal base is sturdier and provides needed weight to improve stability. The wooden top would be aesthetically pleasing, lightweight, and environmentally friendly. The wood would reduce humidity resistance which is important for pill storage.

Design 5: In Figure 95, a design concept for a glove-compartment variant. The idea was to have a pill dispenser model that could be installed in an automobile.

Evaluation: This would require complete redesign of the dispenser and would most likely not function well in shock-prone environment of an automobile. The strange shape would also increase production costs. As mentioned before, if this machine was inserted into an automobile the reliability/accuracy would plummet.

Design 6: In Figure 96, this design would simply increase the height of the silos within the machine.

Evaluation: The original pill silos within the machine are quite stout and do not posses exceptional storage space. This concept sought to increase the silo capacity within the machine. This would require an increase in height of the entire unit, but overall storage capacity would be increased.

Design 7: In Figure 97, this design is similar to the one in Figure 95 except it would be inserted into the center console of an automobile. It would be more of a rectangular-prism shape.

Evaluation: Similar to the other design it is completely impractical. It would require a complete redesign and must be able to withstand the shock of automobile travel. Reduced reliability and storage, but increased ease-of-access.

Design 8: In Figure 98, this concept sought to improve general design stability. Rubber feet would be added to base to increase grip between the device and an surface on which it stands.

Evaluation: This design would increase stability and reliability with almost no other negative effects aside from a minuscule increase in production cost.

Design 9: In Figure 99, this concept was not so much a change to the original but sought to add an addon to it. One may be vulnerable whilst awaiting pill dispersion, so in order to improve the customer's defense posture a pistol holster would be attached to the side of the machine.

Evaluation: Since defensive posture is not a criterion within our design criteria this concept is quite useless. It would increase the cost and weight.

Design 10: In Figure 100, this concept sought to increase total pill capacity of the to-go container. It shares the same shape as most modern pill organizers. This concept is utterly superfluous and would require extensive redesigns.

Evaluation: This design would increase size and the cost of having to redesign the entire machine utterly outweighs the benefit of increased storage capacity.

Design 11: In Figure 101, this concept sought to have an entire exterior redesign and the implantation of a popular franchise's symbol: the Poke-ball. This design would increase overall storage space. The glaring issue would be copyright infringement. Overall, the costs of this concept outweigh the benefits.

Evaluation: The ease-of-access and aesthetic criterion would be improved with this design, but the cost, weight, and size would also increase. As already mentioned the trouble of designing something after a trademarked item would be deplorable.

Design 12: In Figure 102, this concept shows the interior of the concept in Figure 101. There would be a large tray of pill holders which would provide an exceptional level of storage capacity.

Evaluation: Similar to the evaluation for Figure 101, this concept relies on the previous concept. It would have a large increase in storage capacity, but the costs of redesign and getting permission for using trademarked media would be terrible.

Design 13: In Figure 103, this concept sought to create a twin-layer to-go pill container. It could be flipped to either side in order to be filled up or used.

Evaluation: This concept would increase storage capacity of the to-go container, but would make it more cumbersome to store in a bag or purse.

Design 14: In Figure 104, this concept would have metal weights added to each corner of the internal assembly in order to increase stability.

Evaluation: Naturally, this would increase the weight which in this case would be positive as a top-heavy product is not good. There would be a small increase in production cost to add these weights.

Design 15: In Figure 105, the concept would become wall-mountable. This would be done making sure the entire assembly is attached to itself and then addition of wall-mounting holes in the case.

Evaluation: This would increase the cost, but increase the aesthetics as the machine would not be restricted to only sitting on top of counters.

Design 16: Magnets to secure the pill holder. This concept would have the to-go container modified slightly. While the container sits and spins in the machine it is held by a triangular bump in the device which corresponds to a similar triangular groove on the container. Magnets would be attached to the assembly and the pill container to ensure a strong bond.

Evaluation: This would increase ease-of-access as the container need only to be placed on top of the assembly instead of turning it to make the groove lines up. This would slightly increase the cost due to the need for magnets as well as the container needing to be slightly modified.

Design 17: Sliding Bay Door. Instead of a hinge assembly for the access door, a sliding door would be added.

Evaluation: The hinge door is quite flimsy and cumbersome to close correctly. A sliding door would improve ease-of-access, aesthetics, as well as the option to seal the container which would improve humidity resistance for the device.

Design 18: Hinges for the top cover. The top cover would have hinges added in order to easily open and close the device and perhaps sealing capabilities.

Evaluation: This would improve ease-of-access and if a locking system was added, then the device could be hermetically sealed to improve the humidity resistance of the machine.

Design 19: Make the entire assembly out of metal.

Evaluation: This would increase the weight and cost of production significantly, but would greatly improve longevity, aesthetics, as well as the environmental impact as metal is recyclable. If a lightweight strong Aluminum alloy was used the production cost may not rise as much.

Design 20: Make entire exterior out of wood. Similar to design 19, but instead of metal the entire outer assembly would be made of wood.

Evaluation: This would improve the aesthetics and the environmental impact, but may greatly reduce humidity resistance and increase cost as machining wood can get expensive.

Design 21: Aluminum Pill Holder.

Evaluation: The use of an aluminum alloy for the to-go container would indeed raise the cost of production, but it would increase the longevity, aesthetics, and humidity resistance. Reliability and the environmental impact would also be improved as metal is much more durable than plastic and more recyclable.

Design 22: Rubber seal for pill holder. A rubber seal would be used on the cap of the to-go pull container in order to ensure humidity control.

Evaluation: This would naturally increase humidity resistance and reliability, but would increase the cost slightly. The cost increase would be quite minuscule for the payoff of having a properly sealed container.

Design 23: Light sensor added to dispensing pipe to count pills dispensed. A sensor would be added within the machine that would monitor the dispensing tube and would send a signal for every pill dispensed.

Evaluation: This would improve the accuracy and reliability as the pill-dispersion-accuracy would be greatly increased, but the cost of added electronic components as well the man-hours needed to ensure correct integration of the new hardware could be high.

Design 24: LCD screen added to front. An LCD interface would be added to display information.

Evaluation: This would improve aesthetics and ease-of-access, as a phone would no longer be needed to program the machine, but it would raise costs due to the materials and man-hours needed to integrate the new part.

Design 25: Computer Components to increase programmability. Instead of a RaspberryPi a formal circuit arrangement would be installed and custom-tailored to the product.

Evaluation: This would be a massive increase to cost due to man-hours and new components, but it could increase accuracy and reliability of the machine.

Design 26: Weights added to pill silo's to increase stability. The Silo's are quite light and can wobble easily. Weights would be added to bottom of the plastic silos.

Evaluation: Adding weights to four silos would increase the overall weight of the product but it would improve the reliability as there would be a decreased chance of the silos tipping over during operation.

Design 27: Magnets added to base of pill silo to maximize stability. Similar to Design 26, but to increase stability magnets would be used.

Evaluation: Similar cost-benefit trade-off to design 26. The magnets would provide a greater grip compared to the silos merely being weighted, improving reliability. There could also be a risk of magnetic-field interference if this was done.

Design 28: Make pill silos out of metal or sturdier plastic to allow them to be dishwasher-safe. Some people use fish oil pills or other vitamins that may leave gunk behind in the silos, the silos should be able to be cleaned in an average household dishwasher. Which can be accomplished by using a sturdier plastic or using a metal.

Evaluation: The new material would increase the cost, but the reliability would be improved as the parts could be cleaned and no doubt with the sturdier construction the silos would last longer.

Design 29: Battery pack power source. Instead of using a plug to receive power the device would have a battery pack.

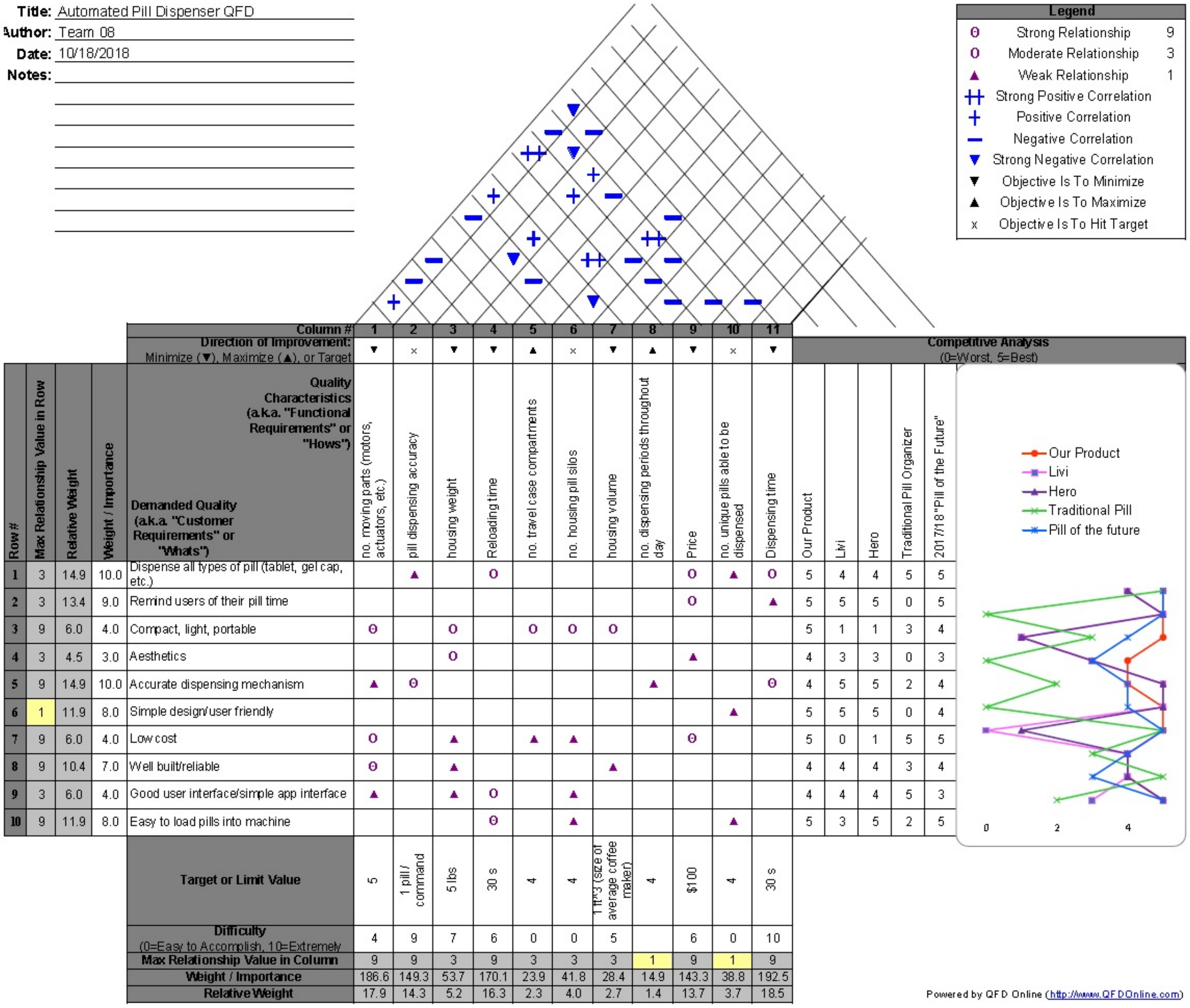
Evaluation: Utterly counter-intuitive, it would increase the weight, cost, and size as well as reducing reliability, longevity, and being more of a negative environmental impact.

Design 30: Improve vacuum pill system. A quieter vacuum pump or some other alternative. The system as-is is quite loud and slow.

Evaluation: A more advanced vacuum pump would be more expensive, but if the machine does not sound like a leaf-blower that would be a great improvement for customer satisfaction.

6 QFD

A Quality Function Deployment, or QFD, was used to compare qualities and features of the Automatic Pill Dispenser, as show in Figure 106. Many qualities used to rate the Automatic Pill Dispenser are goals set for the team. After completing the spring semester, many of the goals set for the device have been met. Two major smart pill dispensers were focused on for the QFD, as well as a traditional pill organizer (Such as a weekly or monthly organizer), and the ”Pill of the Future”, the final product from last year. In terms of competition, the Automatic Pill Dispenser is a product which is very affordable to all, the automatic pill dispenser will be sold without monthly subscriptions, which puts it to be the best product available price wise. The Automatic Pill Dispenser has many advantages over a traditional pill organizer, by reminding the user when to take which pills, and dispenses the correct number of pills automatically. As noted in the QFD, the Automatic Pill Dispenser also has advantages over both Livi and Hero, being that the Automatic Pill Dispenser is much lower in cost than the Livi, and it has a portable section, where the Livi and Hero do not. In comparison to the final product from last year, the goal for Team 8 is to improve the Automatic Pill Dispenser, which will make the improved device a better option when looking at the device created last year. After completing the spring semester, the design was altered, re-positioning the location of the opening for the portable device. Also, the vacuum pump was changed making the device quieter in noise volume. Additionally, the smart-phone application was redesigned and is fully functional with the automatic pill dispenser. Lastly, the portable device was changed allowing the device to be used by a greater target market for it is user- friendly for all ages including those who suffer from arthritis, and weakened handle muscle disorder. A full analysis of the Automatic Pill Dispenser can been seen in Figure 106. One of the main goals in terms of competition is to make the Automatic Pill Dispenser as functional as the high end pill dispensers, while being incredibly affordable in comparison. With the changes made throughout the semester, the automatic pill dispenser is a better option than the Pill of Future, and sold at an affordable price, the automatic pill dispenser sets itself apart from its competition.



Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	1: no. moving parts (motors, actuators, etc.)	2: pill dispensing accuracy	3: housing weight	4: Reloading time	5: no. travel case compartments	6: no. housing pill silos	7: housing volume	8: no. dispensing periods throughout day	9: Price	10: no. unique pills able to be dispensed	11: Dispensing time	Our Product	Livi	Hero	Traditional Pill Organizer	2017/18 "Pill of the Future"
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target	▼	×	▼	▼	▲	×	▼	▲	▼	×	▼					
1	3	14.9	10.0	Dispense all types of pill (tablet, gel cap, etc.)		▲		O					O	▲	O	5	4	4	5	5
2	3	13.4	9.0	Remind users of their pill time									O		▲	5	5	5	0	5
3	9	6.0	4.0	Compact, light, portable	Θ		O		O	O	O					5	1	1	3	4
4	3	4.5	3.0	Aesthetics			O						▲			4	3	3	0	3
5	9	14.9	10.0	Accurate dispensing mechanism	▲	Θ						▲			Θ	4	5	5	2	4
6	1	11.9	8.0	Simple design/user friendly										▲		5	5	5	0	4
7	9	6.0	4.0	Low cost	O		▲		▲	▲			Θ			5	0	1	5	5
8	9	10.4	7.0	Well built/reliable	Θ		▲				▲					4	4	4	3	4
9	3	6.0	4.0	Good user interface/simple app interface	▲		▲	O		▲						4	4	4	5	3
10	9	11.9	8.0	Easy to load pills into machine				Θ		▲				▲		5	3	5	2	5
				Target or Limit Value	5	1 pill / command	5 lbs	30 s	4	4	1 ft^3 (size of average coffee maker)	4	$100	4	30 s					
				Difficulty (0=Easy to Accomplish, 10=Extremely	4	9	7	6	0	0	5		6	0	10					
				Max Relationship Value in Column	9	9	3	9	3	3	3	1	9	1	9					
				Weight / Importance	186.6	149.3	53.7	170.1	23.9	41.8	28.4	14.9	143.3	38.8	192.5					
				Relative Weight	17.9	14.3	5.2	16.3	2.3	4.0	2.7	1.4	13.7	3.7	18.5					

Figure 106: Team 8 QFD Analysis

7 Design for X

The design for the automatic pill dispenser is broken up into four main sections. These sections include the Portable Device, Android App, Dispenser Housing, and Internal Hardware and Code. In each of these sections there includes up to five main categories. These main five categories include design for manufacturability, design for cost, design for ergonomics, design for functionality, and design for ease of use.

7.1 Portable Device

In order to make the device user-friendly, the portable device from last year needed to be redesigned to meet the needs of the customers.

Design For Ease of Use

The previous portable device had a top and a bottom that was connected by a thread assembly. Due to this assembly, the user had to screw and unscrew the top piece, which made it difficult for the users to open and close the portable device. These users are specifically people who suffer from Parkinson's disease, arthritis, or have a weak grip strength. The previous device did not meet the need's of the customer, since the people who will buy the device are ones with a disease/illness and need to take medication for it. Therefore, individual compartments were designed to the top piece that line up with the compartments on the bottom piece of the portable device. Additionally, a twist and lock design was implemented to the top and bottom pieces, replacing the threaded design.

Design for Reliability

To improve the device tremendously, individual compartments were designed to the top piece of the portable device. By making separate compartments it alleviates having to unscrew and screw on the cap numerous times, and instead the user just needs to flip up the opening door on the top piece. Furthermore, having separate compartments makes it harder for all pills stored in the device to spill if the portable device was dropped, since the pills will be enclosed into the device in four separate compartments. For the new design, there is a lip at the inner end of the opening door to avoid jamming. One could benefit from this feature by gaining additional help to open the compartment for less force is needed. To also help with opening the flap, a cylindrical pull tab was designed on the smaller edge of each flap. Additionally, the top piece connects to the bottom piece by a twist and lock design, omitting the threaded design. The twist and lock assembly of the top and bottom, allows the pills to be secure in the device and the two pieces stay locked throughout the day.

Design for Ergonomics

A major improvement from the previous device, is the individual does not have to consistently take on and off the cap of the device, whenever pills need to be taken. Overall, the new design offers a convenient feature for those who suffer from a weak grip strength, arthritis, and Parkinson's disease. The portable device also meets the requirements of the automatic pill dispenser, for the automatic pill dispenser needs to be able to hold four type of pills. The portable device was designed to meet this requirement for there are four compartments to hold each of the four types of pills in which the automatic pill dispenser will dispense into the portable device. This allows user to keep all their pills for the day stored in the device, saving time in having to re dispense their medication.

Design for Manufacture

The portable device was built in Solid Works with new dimensions when compared to the original device, while still being in the range of travel pill cases on the market. Since the device is meant to be open and closed with the use of hinges, the material VeroClear which is made out of PMMA (polymethyl, methacrylate) was used to produce the device. The Solid Works drawing was saved as an STL file and imported into the Objet Studio Software where it was then printed in the in-house Objet 30 3D printer. The new design for the portable device meets the needs of the customers, as well as satisfies the requirements of the design specifications.

Portable Device Design Requirements

In table 3, the specific design consideration that went into the design of the portable device are outlined.

Table 3: Portable Device Design

Product Name	Portable Device
Main Functions	- Each compartments stores 4 pills, each with a size range of 0.315in-0.984in - Stores a total of 16 pills
Ergonomics	- Home environment/travel - Make opening of flaps comfortable/less force required - Design of Closure is simple
Physical Description	- Dimensions: Diameter: 3.45in Height: 1.32in - Weight: < 2lbs
Target Market	The target market is older adults.
Safety Regulations	- Device is made out of PMMA - PMMA is polymethyl and methacrylate, also known as acrylic - PMMA is FDA approved [27]
Reliability	PMMA Behavior: -Flexural Strength: 75-110 MPa -Tensile Strength: 50-65 MPa
Financial Requirements	Objet 30 3D Printer: - $350 per hour - Total Cost: $750
Life Cycle Requirements	The lifespan for the device is 5+ years
Manufacturing Requirements	Prototype: -3D Printer: Objet 30 -Material: PMMA -Cleaning: Use the water jet to clean portable device of support material
Legal Requirements	Dealing with medication, a product that will be sold to consumers must be regulated and approved by the FDA.

7.2 Android App

Integrating an android app into the pill dispenser was one of the main goals while working on this project. In the design process, the team designed for areas such as Functionality, Ease of Use, and Reliability.

Design for Functionality

When designing this android app, the team had one underlying goal at hand. That goal was the functionality of the app. Some key functions that the team was looking to design into the app were the communication to the Raspberry Pi board via WiFi, being able to save information in the form of a comprehensive medical history, and having the ability to enter various information regarding the four medications being held in the dispenser. These designs were executed by writing and running XML code until all desired functions within the app worked.

Design for Ease of Use

During the design process of the android app, the ease of use of the app was always kept in mind. Knowing that our target market was Elderly adults, the ease of use of the app was a key component. Elderly people typically aren't as technology advanced as new generations are so it was important that the app was as simplistic as possible while not compromising the function that it holds. The ease of use of the app was also executed by the design of the user interface of the app. Each button in the app were made very large and bright colored to cater to a user that experiences both dexterity and vision issues. Also, all text fields within the app were made large for these same reasons.

Design for Reliability

The last design guide that the team made sure to follow may be the most important. This is the reliability of the android app. Sine this product is dealing with the distribution and adherence of medication to the user, it is imperative that the user can rely on the app to do its job. Whether it's communicating the proper quantity of each medication to the Raspberry Pi, or even reminding the user that it is time to take their pills it is extremely important that there are no reliability issues. This was done by debugging the code several times are testing to make sure all functions work as anticipated. If the app is not reliable the user could take too much medication or not enough. Either scenario could have large repercussions.

7.3 Dispenser Housing

When re-designing the dispenser housing, there were several categories that were targeted to design for. These design categories were established when analyzing the changes that needed to be made to the design of the original prototype. These categories include design for Manufacturability, Cost, Ergonomics, and Functionality.

Design for Manufacturability

During the design process of the dispenser housing, the ease of manufacture was an area that the team targeted. This was done by making the housing as simple as possible. The housing consists of three pieces; a bottom, middle, and top tier. Each tier is only one piece that sits on top of the previous tier. There are no fasteners holding the tiers together which enhances the ease of manufacture. If there were fasteners holding the dispenser together, it would be very cumbersome to assemble. In a large scale operation, it would be very inefficient and a waste of money to pay an employee to assemble these pieces with fasteners. Another feature that was changed from the prototype that enhances the ease of manufacture was the removal of the door on the front of the dispenser. In the previous design, there was a door on the front of the dispenser that was held in place by a pin assembly. When manufacturing this there would need to be someone that assembles this pin on the door. This would be an extremely inefficient manufacturing process on a large scale. For this reason, the new design completely gets rid of the need of the door.

Design for Cost

During the design process of the dispenser housing, the cost to produce was thought about. The goal in the design was to minimize the amount of plastic to produce the necessary parts. By minimizing the amount of plastic, the cost will go down. This was done in designing by making the walls of the dispenser slightly thinner than the prototype. Even though it is not much, this change will slightly decrease the cost to produce this product. Also, the height of the dispenser was kept to a minimum which decreases the amount of plastic needed. This will also slightly decrease the cost it takes to produce.

Design for Ergonomics

Although this area was not a main focus, the ergonomics of the dispenser housing were used in the design. One design aspect that enhances the ergonomics of the dispenser housing was increasing the size of the opening on the front of the dispenser. In the previous design, the opening was slightly too small. When the portable device was to be slid into the dispenser, the user had to use more effort than one would like for it to sit properly. In the re-design the opening is slightly larger to ensure the user has no issues when placing the portable device in the dispenser. Another factor that effected the ergonomics of this product was the height of the dispenser housing. By making the housing shorter, the dispenser will be able to more comfortably sit wherever the user desires.

Design for Functionality

Functionality was a main focus when designing the housing of the dispenser. This was achieved by making sure that all holes/chutes lined up for each tier. If these do not line up properly, the pills being dropped by the vacuum pump will not be able to fall into the portable device like it should. If there is an issue with this, it could cause an issue in the adherence of the medication within the dispenser. Another aspect that was designed to increase functionality was the holder for the linear actuator. In the original prototype, the linear actuator was simply taped to the inside of the top tier. This caused the actuator to vibrate while in use. This vibration would effect the function of the vacuum pump by causing the pills to not be picked up. This new design alleviated the vibration issue, ultimately increasing the functionality of the dispenser as a whole.

7.4 Internal Hardware and Code

Design for Functionality

The most important aspect of the main code and internal hardware is the overall functionality. If these pieces do not function then the machine is useless. The code runs on an internal Raspberry Pi 3B+ using GPIO outputs and connections to a breadboard, which in turn connect and provide function to all internal components. Such as the linear actuator, stepper motors, and vacuum pump. Functionality of the internal components has not been too big of an issue so far, the only issue is the stepper motor supporting the pill silos. The extra weight causes the rotation to sometimes be inaccurate. This could be offset by increasing the torque output to the stepper motor. The code for the machine runs the linear actuator fine, but sometimes the actuator will jam and cease function when there is too much weight opposing it.

Design for Manufacturing Requirements

This is a massive issue with the Raspberry Pi. Assembling the GPIO board with all the proper output wires and the breadboard would be a massive time sink. Attaching the internal components such as the motor and actuator would also be time consuming, but not nearly as much as the GPIO wiring. A dedicated circuit board would have to be created to run the whole device, which increase development costs but would reduce the manufacturing cost and most likely increase reliability.

Design for Cost

The most expensive component as of now is the Raspberry Pi 3B+ which sits at around $35.00. As mentioned already in Manufacturing Requirements this cost could be averted if a dedicated internal circuit board was developed in order to run the device. This would cost more to develop but save in the long run of manufacturing.

8 Project Specific Details and Analysis

8.1 Market Analysis

Older adults tend to take more drugs than younger people because they are more likely to have more than one chronic medical disorder, such as high blood pressure, diabetes, or arthritis. From a study, people who are age 65 years or older, 90% take at least 1 drug per week, more than 40% take at least 5 different drugs per week, and 12% take 10 or more drugs per week [17]. The only way for older adults to benefit from taking their medication, is if the medication is taken correctly. When older adults are assigned more than one prescription it becomes confusing for them, especially medications that have specific instructions. These specific instructions include taking the medication with water, on an empty stomach, in the daytime, nighttime, and so on. Older adults typically need a family member, or a home care nurse to help them with taking their medication correctly.

8.2 Demand Forecasting

In the United States, 8 out of 10 people take at least one medication and many older adults take three or more medications each day. Older adults comprise 13% of the U.S. population, but account for 34% of all prescription medicine use and 30% of all over-the-counter (OTC) medicine use [18]. From a recent study, 4,1000 North Carolina residents all above the age of 65 all participated in a medication adherence study [19]. All participants had health conditions such as poor vision, poor hearing, a history of diabetes, high blood pressure, stroke, heart attack or cancer. It was found that just over 7 percent of the seniors required help taking their medications. Three years later, 11 percent of those who did not need help at the start of the study required some assistance [19]. The research also showed, people aged 80 and older were 1.5 to 3 times more likely to require help taking medications than those ages 65-69. It was also found that men were 1.5 to 2 times more likely to need help with medications than women. [19].

8.3 Cost versus Price

When looking at the other products available on the market, selling the automatic pill dispenser and reminder at $100 is fair, and is reasonably priced for the buyers interested in the device. The devices available on the market range from $150-$2000 all having an additional monthly fee. In order to make a profit the price of the device needs to be appealing enough for people to buy the device. Our device offers similar features, but at a much lower cost when comparing to the other devices available on the market. When the device is first put on the market the device will not be making a profit. This is the case for the team last year spent $279.97 and with a total of cost of $86.05 for purchases made in the spring semester, there will be a negative profit of $266.02. However, as the number of sales increase, the negative profit will decrease becoming a positive profit value.

8.4 Surveys of Potential Users

The portable device was surveyed by potential users. The device was tested by people who range in the age of 45-75 years. The main focus of the survey was for these potential users to open and close the flaps of the device to see the level of difficulty for this age group. The device was also tested by potential users to look for signs of wear, for the device is to last for 5+ years. After the survey, the diameter of the pull tabs were increased from 0.13in to 0.25in, for there was difficulty with opening the pull tabs with a diameter of 0.13in. Also after the survey, there were signs of adhesive wear in the pins so an additional layer or a stronger material would need to be applied to the pins to avoid future wear. Lastly, a feature that users enjoyed was the twist-lock design, when compared to the threaded design of last year's portable device prototype.

9 Detailed Product Design

The project that is being worked on by Team 8 is a continuation of the automatic pill dispenser that was created last year. The team from last year created a functional product however, it was far from finished. The fall semester was not enough time to refine the prototype to the point where it was a finished product. With that being said, team 8 decided to focus on a few main aspects when creating a Proof of Concept for the fall semester. The team focused on redeveloping an android app that has far more functions, redesigning the portable device, and refining the python Raspberry Pi code. With more time in the spring semester, the main concepts worked on in the fall semester were continued to be approved upon resulting in a final prototype. Additionally in the spring semester, the vacuum pump was changed, as well as the housing of the pill dispenser.

9.1 Android Application

The android app that the team developed had two goals during design: simplicity and function. The target market for this product will likely be elderly people. Elderly people typically aren't as technologically inclined as the younger generations, which is why the team was looking to make the app simple yet effective. The android app that the team from last year created was very simplistic but had little function. The app that was redeveloped now has many more functions.

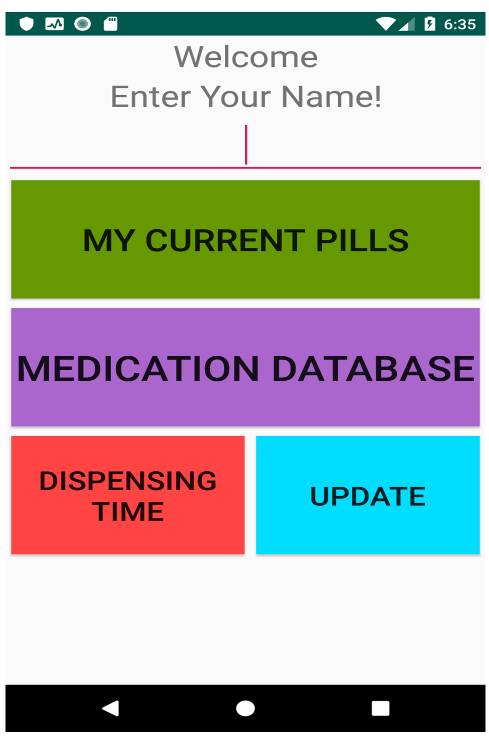


Figure 107: App Home Screen

Figure 107 is the home screen that the user will see when the application is initially opened. There is an input text bar that will allow for the user to put there name in. The goal of this was to personalize the app slightly. Bright colors and large letters/buttons were used to cater to any person with vision or dexterity issue. The Main Screen of the App features four main buttons for each of the main functions; Adding a new medication, Adding to the medication database, Setting the dispensing time and updating the pill dispenser.

Figure 108: My Current Pills Page

When the user clicks the ”My Current Pills” button, it will lead to the screen shown in Figure 108. Each button here takes the user to a new screen where they can fill out information about each medication.

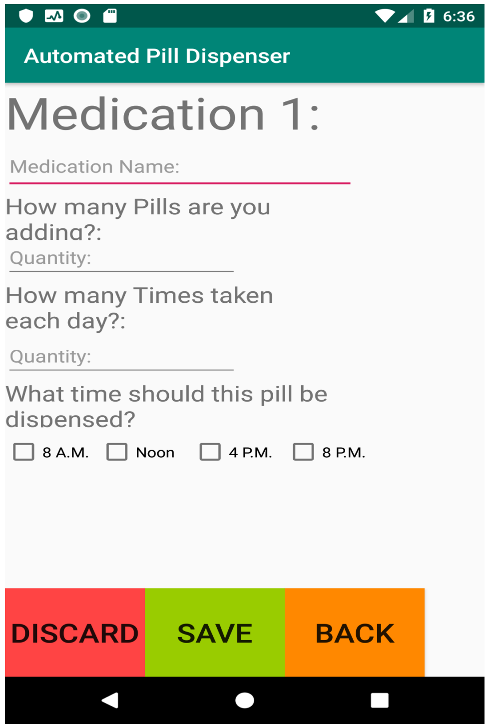


Figure 109: Default Medication Screen

The screen in Figure 109 shows the default layout when a user adds a new medication. There are areas which can be edited for the medication name, amount being added to the machine, frequency for each pill, and the time of day each pill should be taken. At the bottom are three buttons; discard, save and back. These buttons will determine if information is saved, discarded, or not manipulated.

Figure 110 shows when the information is filled out completely and correctly. All fields must be filled out in order for the information to be saved. The frequency of the pills must be a whole number between one and four due to the limitations of the portable device. The portable section holds a maximum of 16 pills. If the user inputs any information incorrectly and tries to save the medication, different error messages will prevent the user from saving the information.

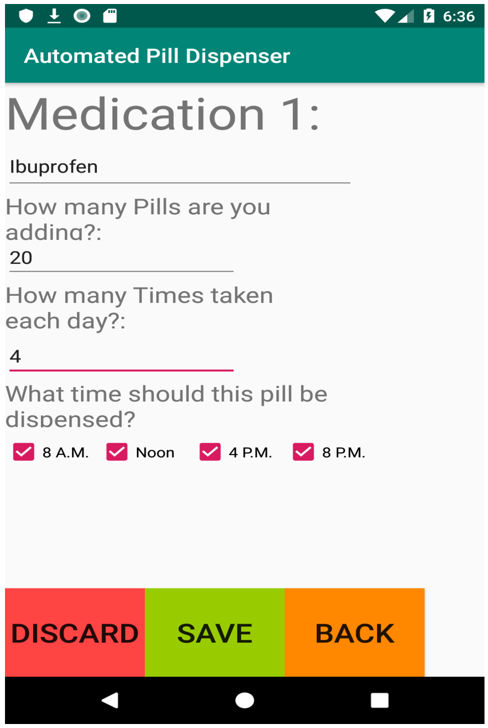


Figure 110: Information is correctly filled

Figures 111, 112 and 113 show the three potential error messages when attempting to save the information. The error shown in Figure 111 appears when any of the information fields are empty and the user attempts to save. All information is necessary for the app to work and keep track of medications, so having an empty field could throw it off. The error in Figure 112 appears when the user tries to make the daily frequency greater than four or less than one. This is due to they physical limitations of the portable device. The device has four compartments, each meant to hold one of four different medications. If a user inputs that they want to take one medication four times per day, the machine will put one pill in each compartment. If the user inputs more than four, there would not be any space for the other pills to be placed. If the user inputs a frequency that does not match with the number of times checked at the bottom, they will see the error in Figure 113. This is to match a specific pill to a specific time. If the frequency and the number of times chosen differ, the machine cannot and will not decide the discrepancy, as it is up to the user to make this determination. Therefore the error message is shown.

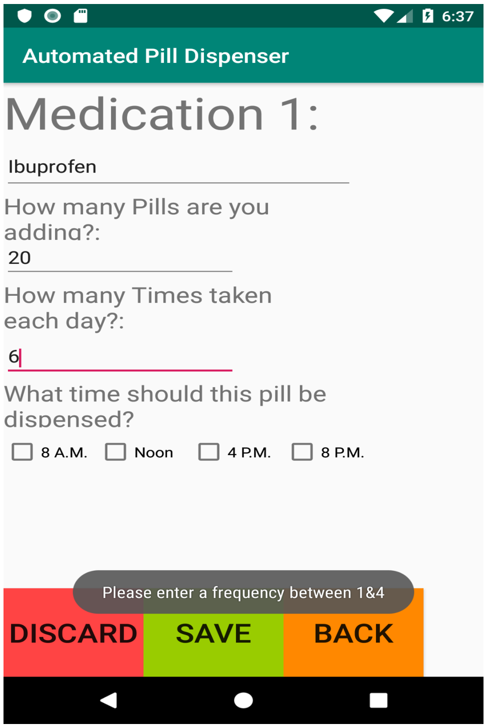


Figure 111: Error Message: Frequency is not between 1 and 4

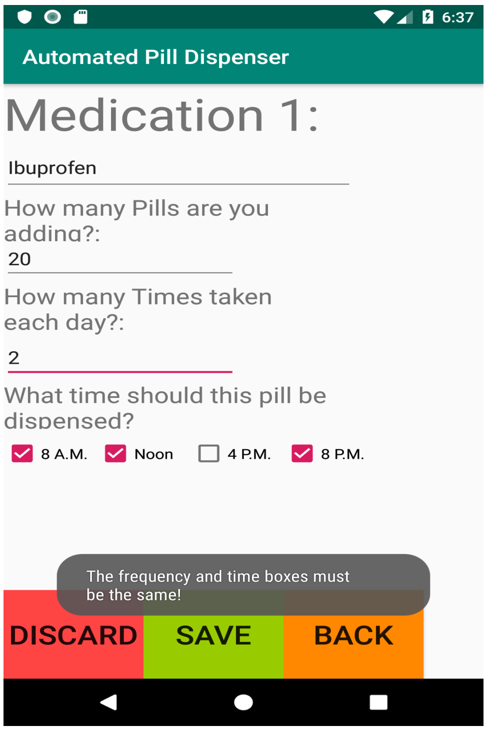


Figure 112: Error Message: Times do not match Frequency

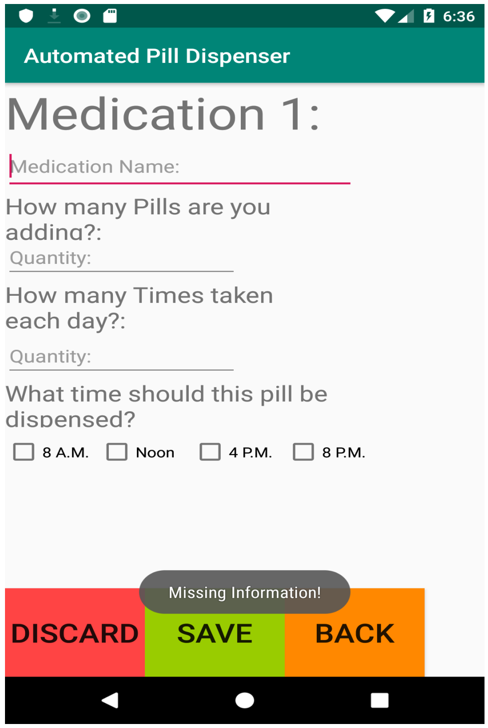


Figure 113: Error Message: Information is missing

When a user saves this information, it will bring them back to the home screen. Here the user can choose what time they want their dispensed medications to be ready by. When the user clicks on the "Dispensing Time" button on the home screen, a dialog shown in Figure 114. If the user chooses 6:55 for their dispensing time, the Automatic Pill Dispenser will begin ten minutes before to make sure the pills are dispensed by the chosen time. When the user has the dispensing time and medication information filled out, they can click the "Update" button on the home screen. If the user entered information for only the first medication, a dialog shown in Figure 115 is shown to the user. They can bypass this error because they might not be adding four medications to the machine at the time. If the user selects "No", they are redirected to the medication page, where they can add more medications. If they choose "Yes", the app will simply update the machine.

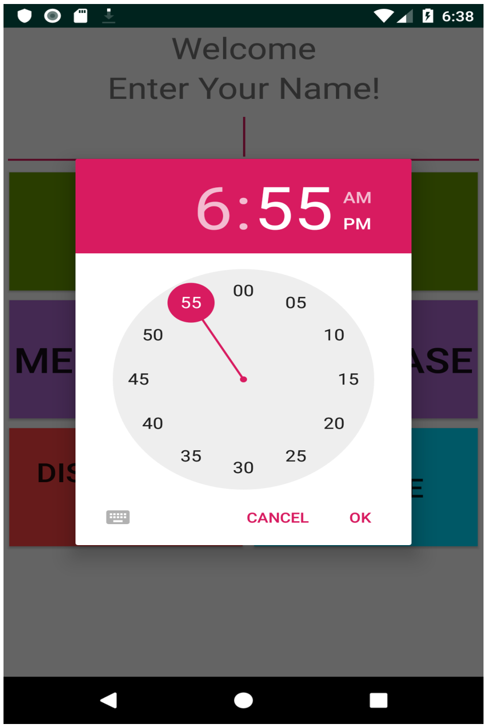


Figure 114: Prompting the user for a dispensing time

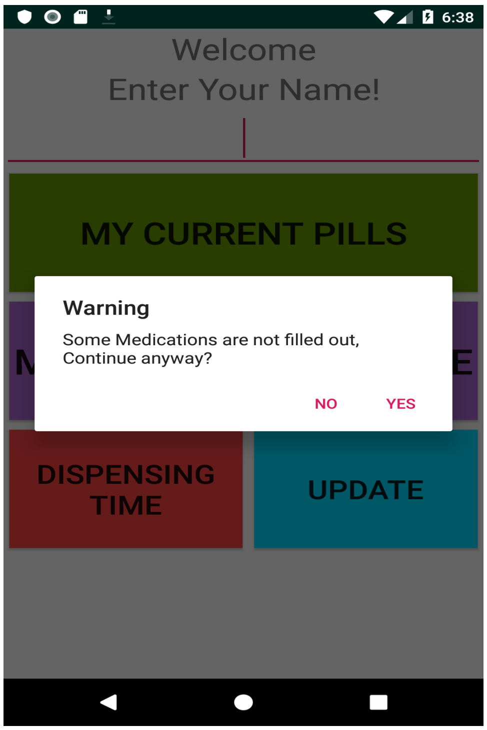


Figure 115: Error Message: Not all medications have information filled out

When the user has input all information and has updated the Automatic Pill Dispenser, and it comes time for the user to take a medication, the app will present the dialog box found in Figure 116. After the user has taken the specific medications, the user can dismiss the message.

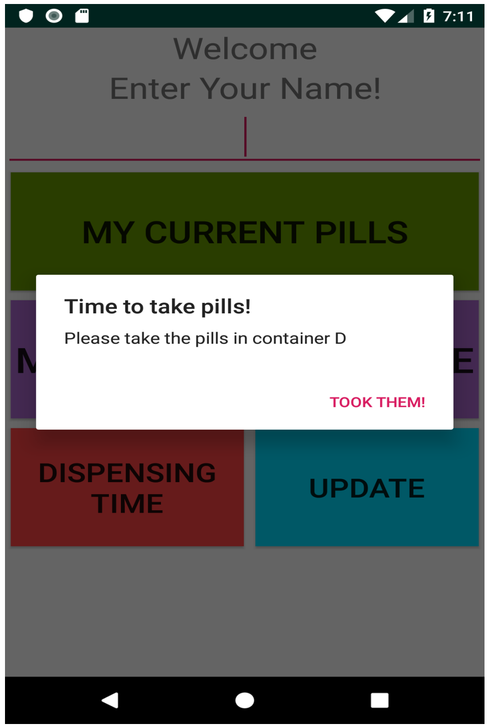


Figure 116: Reminder to take medications

The medication one, two, three, and four screens all have the same function. Each screen will allow the user to input various information about each medication. These screens allow the user to input the name of each medication, specify the number of pills that are initially put into the dispenser, how many times each pill is taken daily, and any other special instructions. This information is there for the user to refer back to at any point. The code used to create this app can be found in the Appendices.

Another function that was desired within the android application was a comprehensive database that the user can input different information and refer back to. This will essentially serve as the users medication, vaccine, and procedures record. This function within the android app allows the user to enter the name, the quantity per dose, and the date entered for either a medication, vaccine, or procedure. This feature is accessible through the home screen of the app. It can be accessed from the large ”Medication Database” button.

Figure 117: Database Upon Opening

The figure above is the screen that opens upon clicking the ”Medication Database” button. As shown, there are three editable text fields and two buttons on this screen.

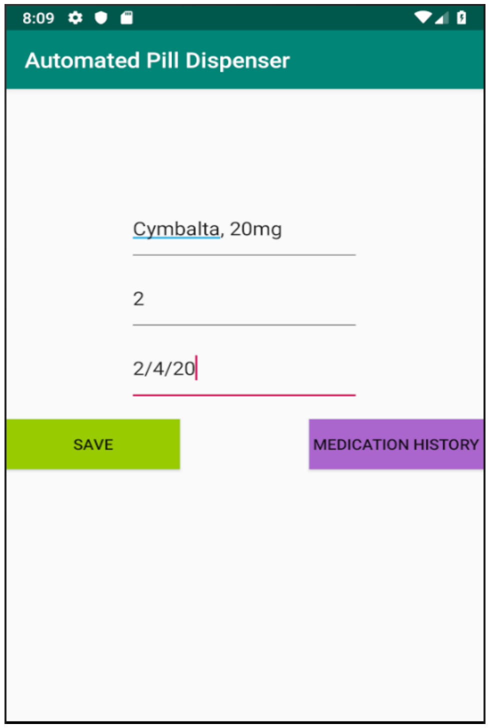


Figure 118: Database with text fields filled out

In figure 118, it can be seen that the text fields are filled out with a name, a quantity per dose, and a date. All of the text has large enough font that will be easily visible for all users.

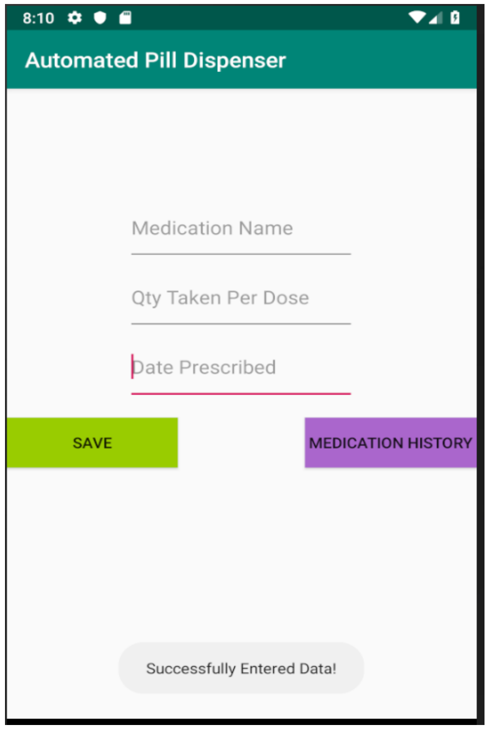


Figure 119: Message: Successfully Entered Data!

The figure above shows that the information entered was successfully entered into the database. A message will appear in the lower portion of the screen that verifies that the information was successfully entered. This will occur when the user hits the green save button and all of the text fields are filled out accordingly.

Figure 120: View of Database before entering data

Figure 120 shows the view of the database upon hitting the ”Medication History” button. This view is before entering the new medication.

8:10

Automated Pill Dispenser

Name	Qty/Dose	Date
Ibuprofen, 200mg	3	3/4/19
Melatonin, 5mg	2	3/4/19
Zithromax, 500mg	1	3/6/19
Fish Oil, 1200mg	1	3/20/19
Advil, 200mg	3	3/20/19
Measles Vaccine	1	5/18/19
Prednisone, 10mg	1	7/26/19
Albuterol, 2.5mg	2	7/26/19
Flu Shot	1	11/14/19
Methadone, 20mg	1	1/13/20
Cymbalta, 20mg	2	2/4/20

Figure 121: View of Database after entering data

In figure 121, it can be seen that the new medication, Cymbalta, was entered into the database. This can be crucial for a doctor to see if a patient is taking medications simultaneously that they should not be. For example, it can be seen that Methadone was entered on 1/13/20 and Cymbalta was entered on 2/4/20. This medications can not be taken together, like they are shown, since Methadone is a painkiller and Cymbalta is a depressant. These medications can cause a lethal reaction.

9.2 Portable Device

The dimension and appearance of the device were changed when compared to the portable device from the team last year. The dimensions and compartments which reside within the base were increased in size, and changes were made to the top of the portable device. A defect in the previous portable device is the entire top needed to be taken off in order to retrieve a single pill. The user having to take off the entire top of the device could allow for medication to fall out of the portable device since the whole base where all of the pills reside are exposed to the environment. One could fall and all their pills could be wasted, spending additional money to replace the pills, and in some cases may require a new prescription from their doctor. To avoid this, the cap of the portable device was redesigned to have individual compartments for each of the four compartments in the base. Lastly, the target market is older adults so the design of closure needed to be adjusted to their needs, making it as simplistic as possible.

The new design of the top can be seen in figure 122. As seen in the drawings from Solid Works there are individual compartments drawn on the original top of the portable device.

Each compartment was drawn to the dimensions of the compartments in the base of the original portable device. By making the dimensions exact there will be no room for the pills in the other compartments to fall into another compartment, keeping the medication separated. There is also a top and bottom layer in each compartment opening. The design behind this was so the connection between the flap and the top of the portable device when assembled will be more secure. The flap when closed will sit within the opening compartment making it harder for the flap to hook onto something and opening the compartment. Additionally, the dimensions of the opening near the center on the top piece was made larger than the dimension of the flap, so the user could open and close the device. Also, as seen on the top of the portable device there is a knuckle at the outer end. The knuckle length on the top of the portable device is made to the dimensions of the length between the two knuckles on the flap. The flap is the piece that will be connected to the compartment opening and will be used to open and close each compartment. Also the diameter of the knuckle is made the same for the knuckle on the top of the portable device, as well as the two knuckles on the flap. The hinge connection was placed on the outside of the top of the portable device, for the hinges did not fit in the center. If the hinges were placed in the center, the hinges would be too small, and would not be sturdy. Therefore, the hinges are around the outside of the top piece.

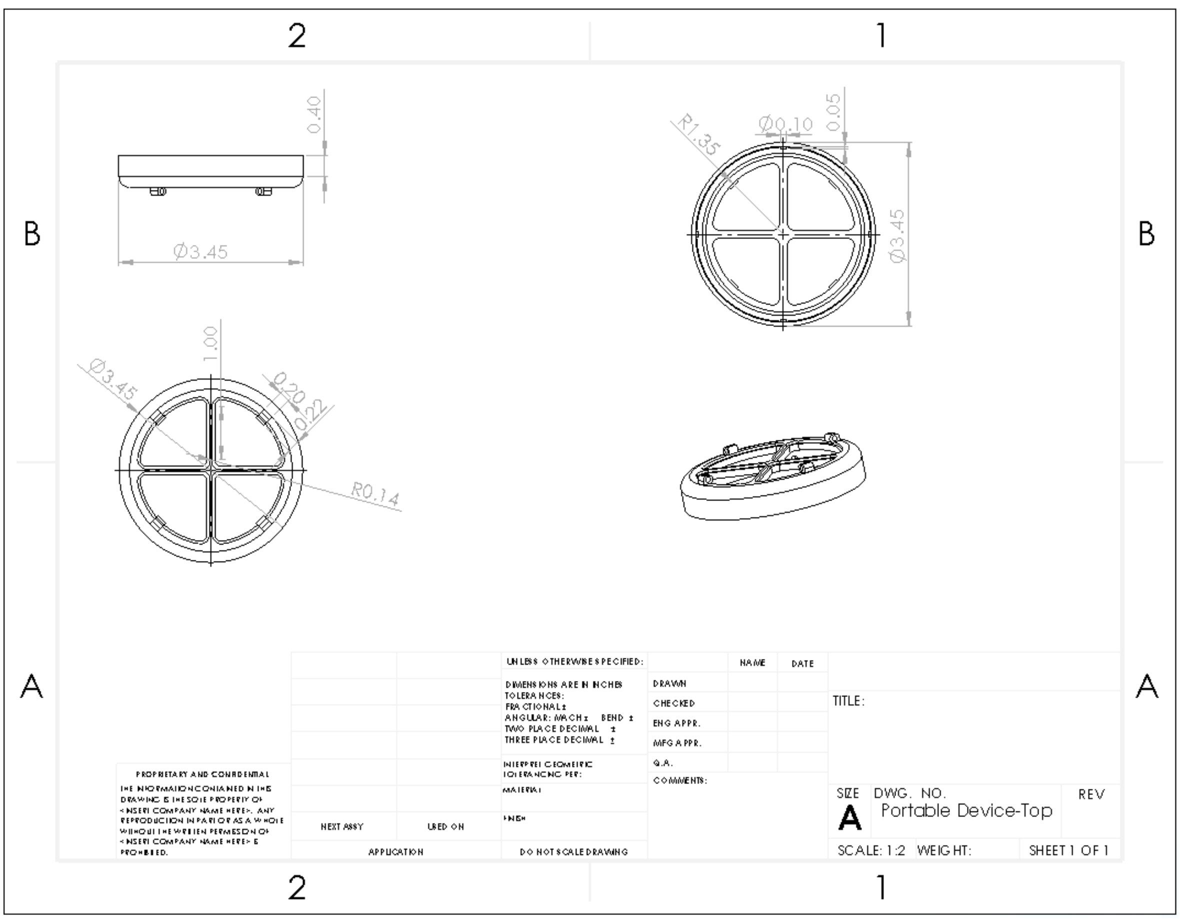


Figure 122: Portable Device Top

The flap, which is also known as an opening door will be the way the compartment will be opened and closed. The flap was made similar to the dimensions of the opening within the top piece of the portable device. The inner edge was made smaller, so the user can open the device when the flap is assembled to the compartment. On the flap there are two knuckles which are separated by the length of the knuckle on the top piece of the portable device. The diameter of the two knuckles is kept consistent with the diameter of the knuckle on the top piece. Also as seen in figure 123, the flap has an indent on the bottom of the smaller edge. Since the flap lines up with the top piece, the indent will help avoid jamming. This was designed to help people open the flap with a muscle deficiency in their hands. To also avoid difficulty in opening and closing the flaps, a pull tab was created on the smaller edge of the flap to help create a grasp, as well as make it easier to open/close. The flap was placed closer to the edge where the flap is opened/closed to increase the distance from the hinges which causes for a greater torque around the hinges which allows for less force to be applied. Therefore, making it easier for users who suffer from a weakened muscle disorder to open and close, since less force is required. The goal in mind for the portable device was to make it as secure as possible and more user-friendly, to prove the improvements made to the previous design are worth the money to reproduce. If the design is not secure and are not made more user-friendly it would not be worth the money to redesign the top piece.

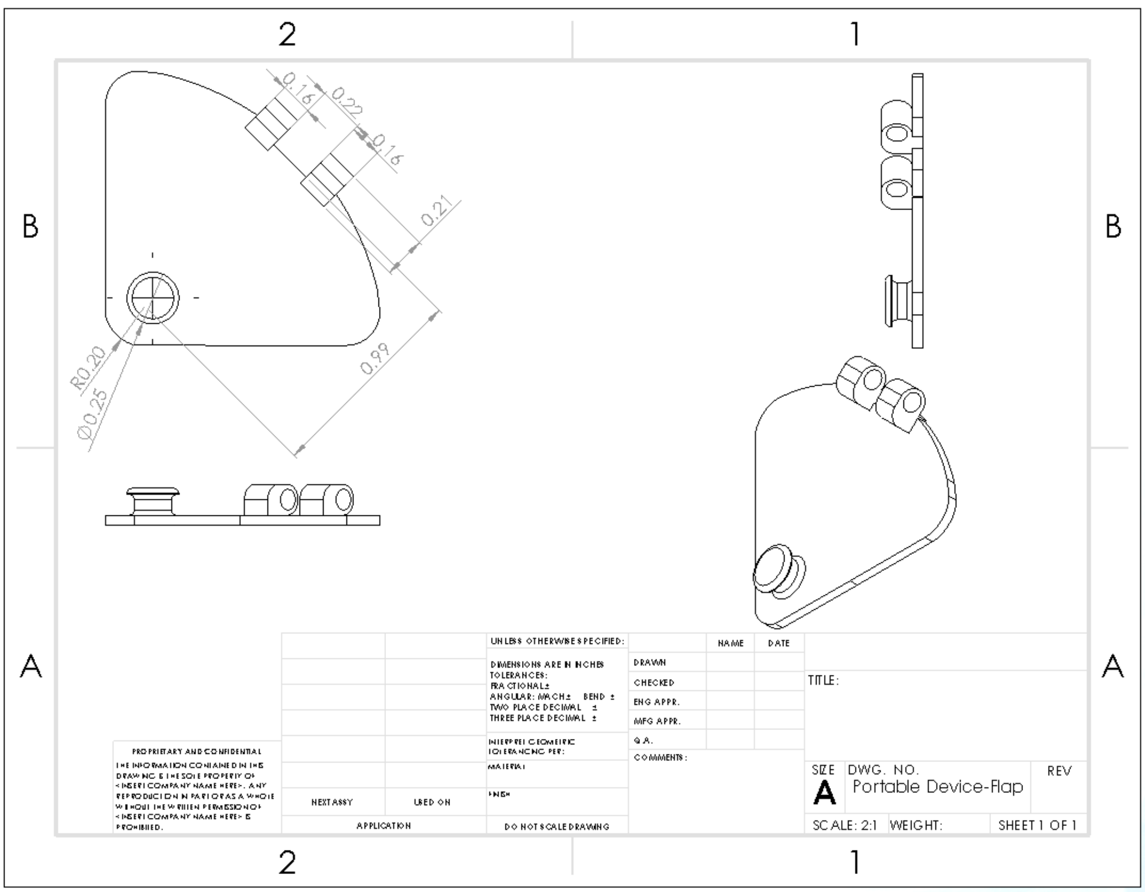


Figure 123: Portable Device Flap

As seen in figure 124, the top piece of the portable device and the flap are assembled. The portable device, and the flap are connected by a hinge and pin assembly. With the diameter of the two knuckles on the flap and the knuckle on the portable device being the same, the pin is able to be inserted and have an exact fit. Also the pin was made to the dimensions of the diameter of the knuckle, to avoid it being lose. Also when the flap is assembled into the top piece, there is space at the inner edge to avoid jamming, making it easier to open and close. With the pull tab on the front face of the flap it gives the user additional help to open the device. The device is opened from the inside for as mentioned before the hinges for all four compartments did not fit in the center of the top piece. Also as seen in figure 124, the assembly of the flap to the top piece is assembled to the bottom of portable device. The height of the device is 1.32in and the diameter of the device is 3.45in which is the average size of a daily pill case.

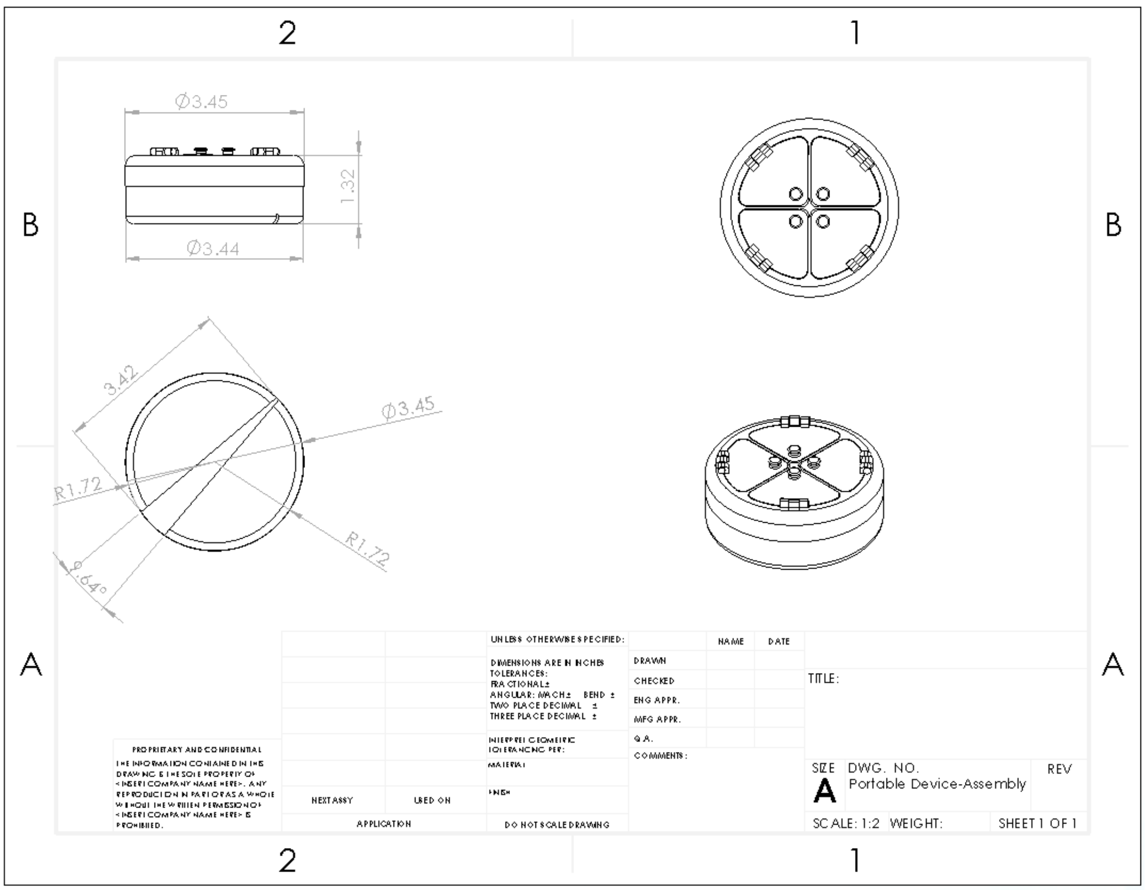


Figure 124: Portable Device Design of Closure

The design of closure for the top and bottom piece was also redesigned to meet the needs of the target market and the design specifications. The previous design for the portable device was a threaded design, however this design does not meet the design specifications for it is not user-friendly. The new design of closure is a twist and lock design, where the top and bottom pieces line up and are pulled up or pushed down and twisted to lock into place. The design is illustrated in 125 and 122. The top has four extruded circles in the inside of the top that slides into the four L-shape extrude-cuts on the top of the bottom piece. The locks mechanism was designed in SolidWorks by using the dome feature on the inside top face of the L-Shape on the bottom piece. The dome feature allows the top piece to be secure into the bottom piece as the user twists the two pieces into place.

The bottom piece was altered in size to meet the pill size requirements of the design specifications. The average pill size range from 0.315in-0.984in, therefore the size of each compartment needed to be increased to allow for at least four pills of this size pill to fit into each compartment. Each compartment was increased to have a radius of of 1.52in and a length of 1.25in when compared to last year's portable device. The bottom face of the bottom piece was made similar to last year's design of inserting the portable device into the pill dispenser. On the bottom face a V-shape was extrude-cut in SolidWorks which will slide into place with a rotating disc in the pill dispenser that has an extruded V-shape, as seen in 125. This design allows for a secure fit while the portable device is rotating in the pill dispenser during the dispensing process, as well as is easy to take out and place into the pill dispenser.

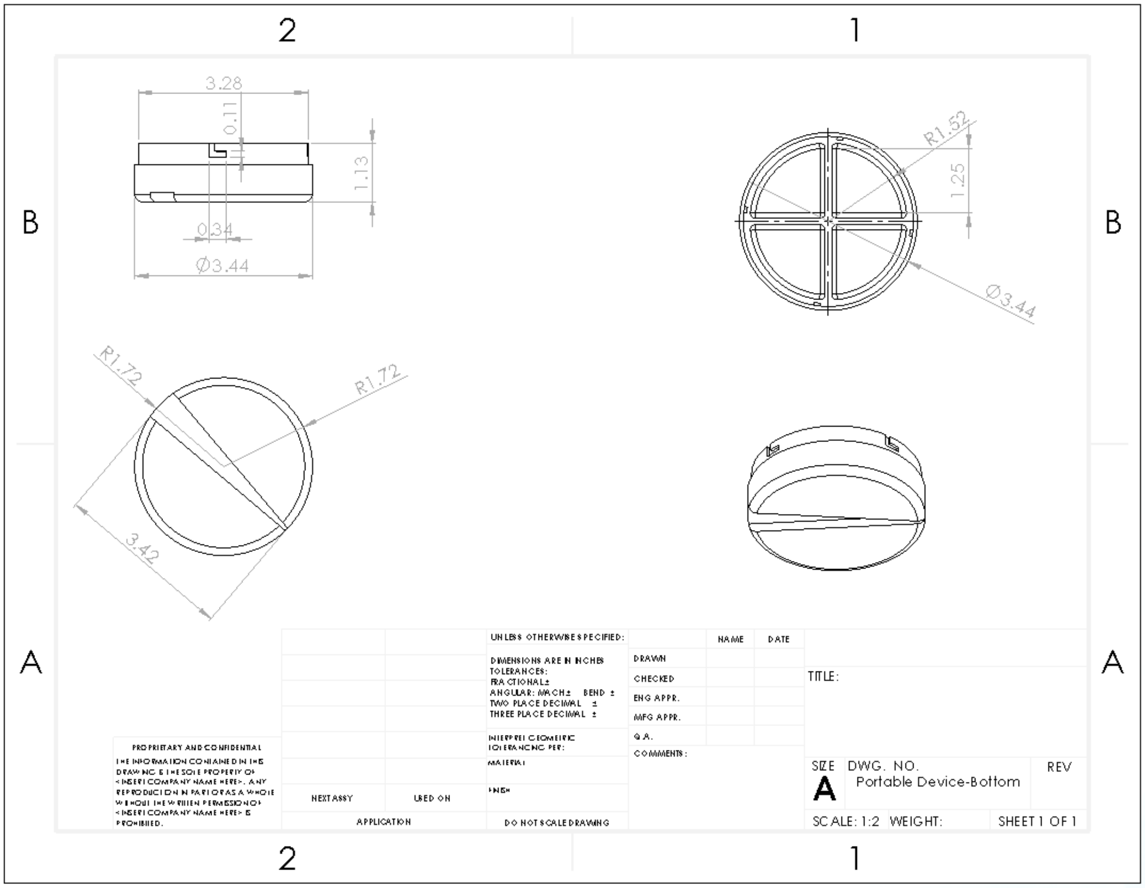


Figure 125: Portable Device Bottom

9.3 Bill of Materials for Portable Device

Table 4: Bill of Materials for Portable Device

Item Description	Unit Price
VeroClear 3D Printing Material- 2000g	\$300
Objet 30 3D Printer	\$300/hr
3M 400 Grit X-Fine Sanding Sheet	\$4.27

The items listed in the BOM for the Portable Device were all resources offered by the College of Engineering. The prices listed are all standard prices for each item if the portable device were to be manufactured elsewhere. The cost to the team was \$0 to produce the portable device due to all of the items being available in-house.

9.4 RaspberryPi Code

Last year's code indeed proved to be still somewhat functional but it was far from being optimized. Due to an error while rewiring the internal components the RPi was fried and all data was lost. Thankfully a lot of the code was rebuilt and became functional. Some functions, such as the UI in FIgure 126, were removed. Separate files were created to emulate any functions that the old code could have carried out. From there the main code file was built, of which snippets will be included as the main file will be provided on Sakai.

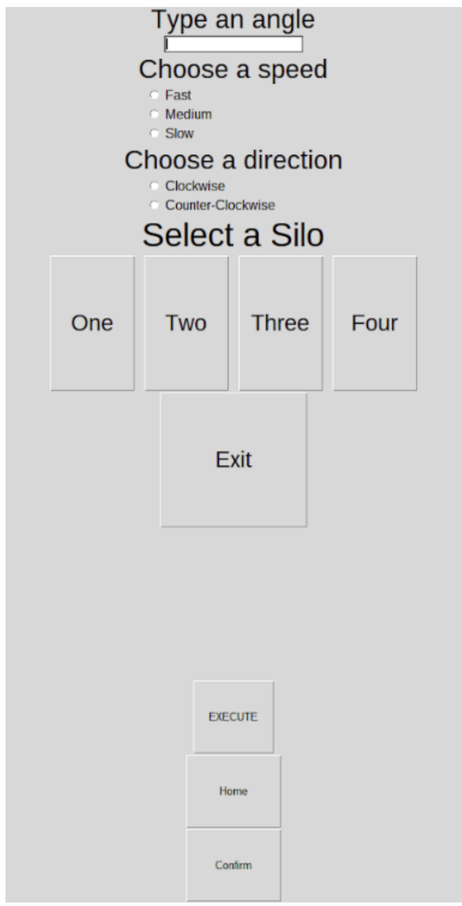


Figure 126: Old RaspberryPi Test User Interface.

```
GPIO.setup (coil_A1_pin, GPIO.OUT)
GPIO.setup (coil_A2_pin, GPIO.OUT)
GPIO.setup (coil_B1_pin, GPIO.OUT)
GPIO.setup (coil_B2_pin, GPIO.OUT)

GPIO.setup (22, GPIO.OUT)
GPIO.output (22, False)
def setStep(w1 ,w2 ,w3 ,w4):
    GPIO.output(coil_A1_pin, w1)
    GPIO.output(coil_A2_pin, w2)
    GPIO.output(coil_B1_pin, w3)
    GPIO.output(coil_B2_pin, w4)

for i in range (0 ,steps):
    setStep(1 ,0 ,1 ,0)
    time.sleep(delay)
    setStep(0 ,1 ,1 ,0)
    time.sleep(delay)
    setStep(0 ,1 ,0 ,1)
    time.sleep(delay)
    setStep(1 ,0 ,0 ,1)
    time.sleep(delay)

delay = 0.0055


GPIO.output(22, True)
time.sleep(1)
#delay = 0.00275



for i in range(0 , steps):
    setStep(1 ,0 ,0 ,1)
    time.sleep(delay)
    setStep(0 ,1 ,0 ,1)
    time.sleep(delay)
    setStep(0 ,1 ,1 ,0)
    time.sleep(delay)
    setStep(1 ,0 ,1 ,0)
    time.sleep(delay)
```

Figure 127: Calibration File Part 1.

This snippet of code in Figure 127 from the file is to test solely the linear actuator as well as the vacuum pump.

```
import RPi.GPIO as GPIO
import time

GPIO.setmode(GPIO.BOARD)

ControlPin = [7,11,13,15]
ControlPin2 = [8, 10, 12, 16]

for pin in ControlPin:
   GPIO.setup (pin, GPIO.OUT)
   GPIO.output (pin, 0)

for pin in ControlPin2:
   GPIO.setup (pin, GPIO.OUT)
   GPIO.output (pin, 0)

seq = [ [1 ,0 ,0 ,0] ,
        [1 ,1 ,0 ,0] ,
        [0 ,1 ,0 ,0] ,
        [0 ,1 ,1 ,0] ,
        [0 ,0 ,1 ,0] ,
        [0 ,0 ,1 ,1] ,
        [0 ,0 ,0 ,1] ,
        [1 ,0 ,0 ,1] ] #Clockwise
seq2 = [ [1 ,0 ,0 ,0] ,
        [1 ,0 ,0 ,1] ,
        [0 ,0 ,0 ,1] ,
        [0 ,0 ,1 ,1] ,
        [0 ,0 ,1 ,0] ,
        [0 ,1 ,1 ,0] ,
        [0 ,1 ,0 ,0] ,
        [1 ,1 ,0 ,0] ] #Counter Clockwise
seq3 = [ [1 ,0 ,1 ,0] ,
        [0 ,1 ,1 ,0 ] ,
        [0 ,1 ,0 ,1 ] ,
        [1 ,0 ,0 ,1 ] , ]
seq4 = [ [1 ,0 ,0 ,1] ,
        [0 ,1 ,0 ,1] ,
        [0 ,1 ,1 ,0] ,
        [1 ,0 ,1 ,0] , ]


for i in range (6):
   for halfstep in range (8):
         for pin in range (4):
            GPIO.output(ControlPin[pin], seq[halfstep][pin])
         time.sleep (0.001)

GPIO.cleanup()

print('home')
```

Figure 128: Calibration File Part 2.

This snippet of code in Figure 128 from the file to test and re-calibrate the stepper motors.

```
import imaplib
msrvr = imaplib.IMAP4_SSL \
        ('imap.gmail.com',993)

unm = 'smartypillrasppi'
pwd = 'Capstone1819'
msrvr.login(unm,pwd)

stat , cnt = msrvr.select('Inbox')
stat , dta = msrvr.fetch(cnt[0],'(UID BODY[1])')

print (dta[0][1])

msrvr.close()
msrvr.logout()

a=dta[0][1]
a = a.decode("utf-8")
import re
a = re.sub('\r\n', '', a)

import numpy as np
b = np.matrix(a)
```

Figure 129: Main Code Part 1.

This snippet of code in Figure 129 sets up communication with the Smart phone App and the Raspberry Pi. It also acquires information sent from the App and saves it to the Raspberry Pi.

```
############################Morning Compartment############################

if b[0,0]+b[1,1]+b[2,1]+b[3,1] > 0:

    for i in range (127):
        for halfstep in range (8):
            for pin in range (4):
                GPIO.output(ControlPin2[pin], seq2[halfstep][pin])
            time.sleep (0.001)
    if b[0,0] == 1:
        print ('Pill 1 Engaged, Morning')


        for i in range (102):
           for halfstep in range (8):
                 for pin in range (4):
                    GPIO.output(ControlPin[pin], seq2[halfstep][pin])
                 time.sleep (0.001)

        time.sleep(1)


        for i in range (0 ,steps9):
            setStep(1 ,0 ,1 ,0)
            time.sleep(delay)
            setStep(0 ,1 ,1 ,0)
            time.sleep(delay)
            setStep(0 ,1 ,0 ,1)
            time.sleep(delay)
            setStep(1 ,0 ,0 ,1)
            time.sleep(delay)

        delay = 0.0055
        for i in range (0 ,steps10th):
            setStep(1 ,0 ,1 ,0)
            time.sleep(delay)
            setStep(0 ,1 ,1 ,0)
            time.sleep(delay)
            setStep(0 ,1 ,0 ,1)
            time.sleep(delay)
            setStep(1 ,0 ,0 ,1)
            time.sleep(delay)

        time.sleep(1)
        GPIO.output(22, True)
        time.sleep(0.5)
        delay = 0.00275
```

Figure 130: Main Code Part 2.

The snippet of code in Figure 130 shows one part for the main dispersal process.

9.5 Dispenser Housing

The prototype that was left by the team from last year was deemed to be far too tall. The consensus was that the housing should be made shorter without compromising the function of the internal components. The prototype from last year was measured to be 14.5 inches. The new design measured in at 13.25 inches. This difference came solely from shrinking the middle and bottom tiers. The team was unable to make the top tier any shorter because we were unable to find a new functional linear actuator causing us to use the one from the original prototype. This caused the top tier to stay the same height. Although there were only a few changes made to each tier, each can be noticed when comparing the new to the old.

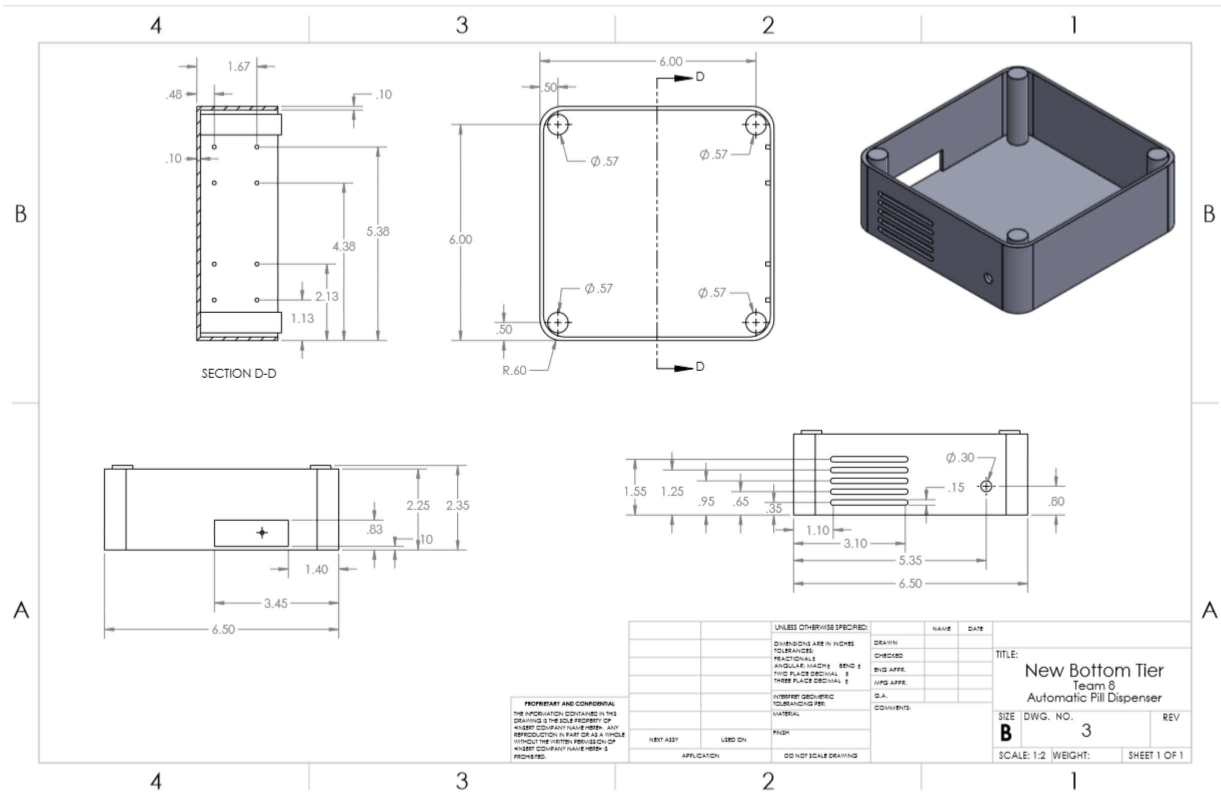


Figure 131: New Design of Bottom Tier

The changes made to the bottom tier were very minimal when comparing to the prototype. The only change that was made to this tier was that it is now 2.25 inches tall. This is approximately 0.75 inches shorter than the prototype. This was made possible by replacing the vacuum pump. The original vacuum pump required more clearance height in the bottom tier than the new one requires.

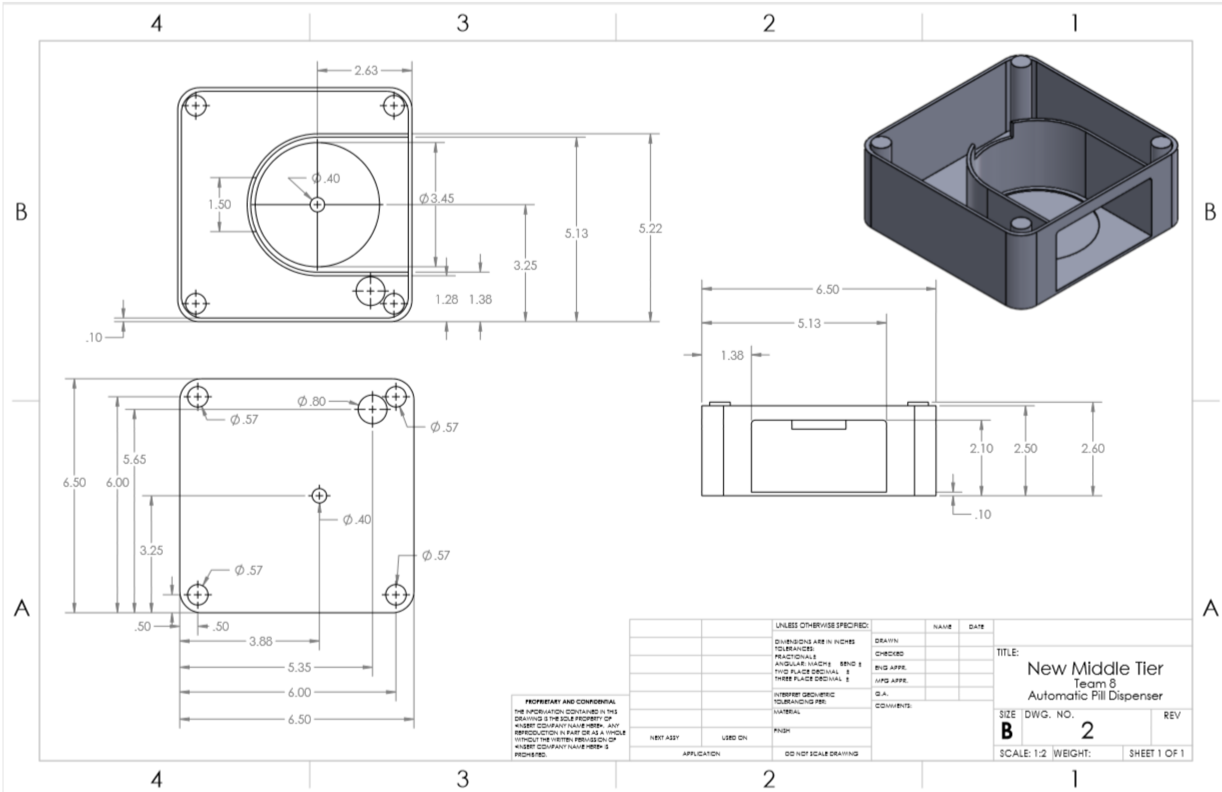


Figure 132: New Design of Middle Tier

There were more evident changes made to the middle tier. The first change made to this tier is that the door to the dispenser was taken out of the design completely. This allows for more clearance on the front of the dispenser for the portable device to fit through. This change also allows for the dispenser to be more easily manufactured. This is because the tier is now only one solid piece, instead of three. The previous middle tier consisted of the body itself, a door, and a pin. Another change in the design is that the opening on the dispenser was placed in the center of this tier. For whatever reason, the opening to the original dispenser was slightly off center. The last design change that was made was that the tier is now 2.5 inches tall as opposed to the original 3 inches from the prototype. This contributes to the new assembly being shorter than the original.

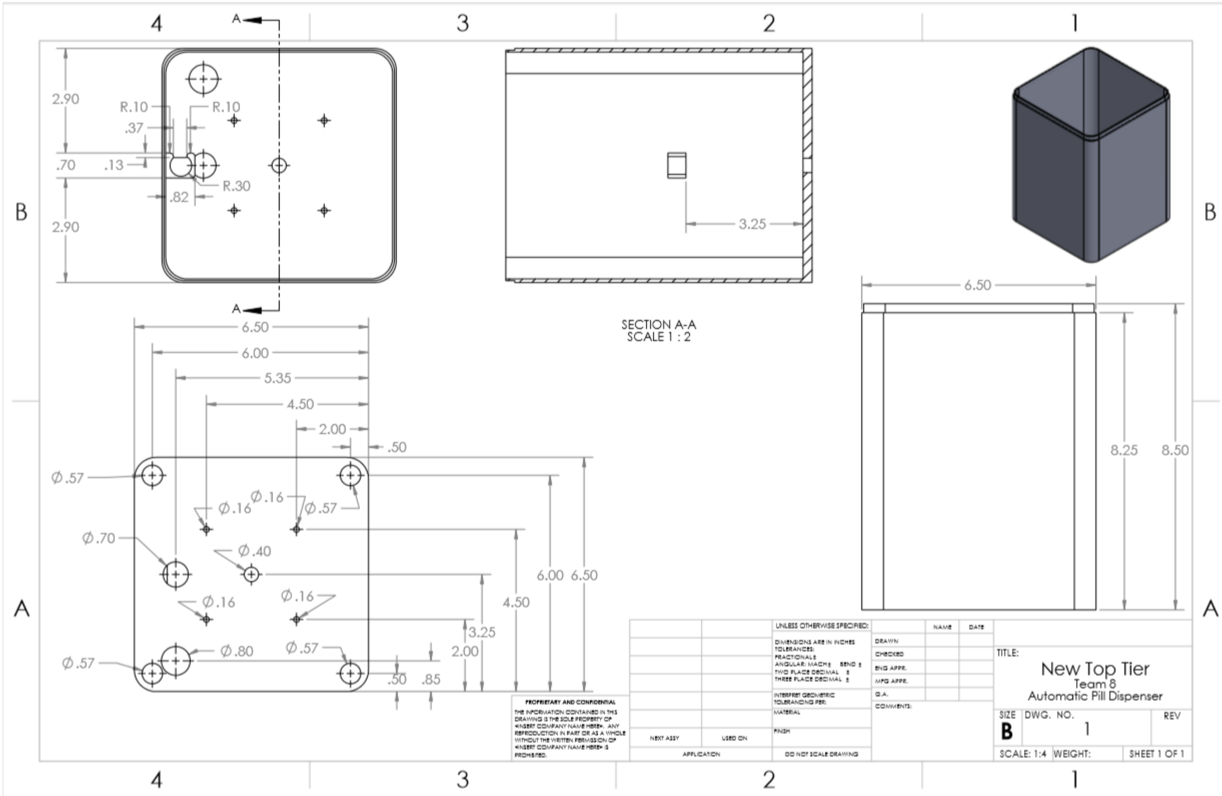


Figure 133: New Design of Top Tier

When referring to the re-design of the top tier, there was only one change made. In the new design, a holder for the linear actuator has been added. In the original prototype, the linear actuator was simply taped to the side of the housing. This caused the actuator to move slightly while running. The holder allows for the actuator to be extremely secure.

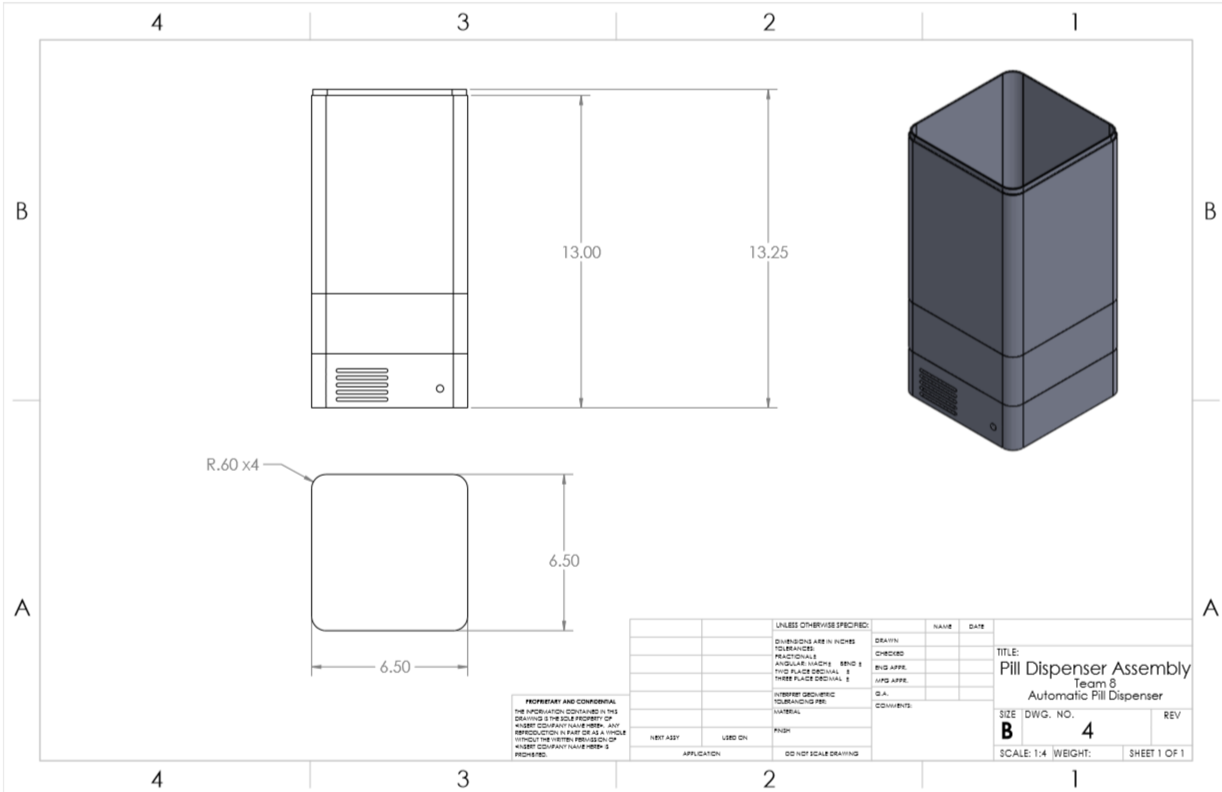


Figure 134: Full Assembly of Dispenser Housing

The entire assembly can be seen in figure 134. As shown, when all tiers are together, the dispenser has a very sleek and simplistic look.

9.6 Bill of Materials for Prototype

Table 5: Bill of Materials for Prototype

Item Description	Unit Price
4.5 - 6V Vacuum Pump	$8.99
Stepper Motor with Drivers	$13.99
12V Power Supply	$18.96
Vacuum Tubing	$5.39
2 GB SD Card	$3.54
Raspberry Pi 3 B+	$34.99
Vacuum Tip	$6.22
Turntable Bearing	$10.71
Stepper Motor Screw with Nut Slider	$22.99
3D Printer Parts	$56.97
Wiring	$15.99
Stepper Driver	$3.96
Buck Converter	$9.95
Proto Breadboard	$4.50
Total	$217.15

The cost to create our prototype was $217.15. The team was able to reuse a lot of what was left by the team from 2017-2018 which did not come out of our budget. This price does not include everything that was purchased, this was just the cost of each part in the prototype itself.

10 Engineering Analysis

Since the pill dispenser will be administering medication to consumers, there are FDA regulations that must be followed when creating a final product. Being a dispenser of solid medication, the pill dispenser will fall into the product class of NXB [21]. The NXB product code can be defined as any solid medication dispenser device intended for medical purposes that is used to issue solid (pills) medication. In order for this dispenser to be sold to consumers, the FDA must analyze all aspects of it and give it their stamp of approval.

As of right now the team believes that the dispenser will meet most of the requirements that the FDA has in place. The only issue that the FDA may have with the dispenser, is the material in which it is made from. According to the FDA food contact laws, PLA is not considered safe [22]. PLA is the main material that the prototype is made from. There has been studies conducted that PLA will secrete small amounts of lactic acid into food that it has been in contact with for an extended period of time [23]. These studies show that this is not necessarily harmful to the human body, but it is enough to not meet FDA standards. Upon finding this information about PLA, the team may look into finding an alternative material to make the housing and other components from. A very common 3D printing material is ABS. Luckily, ABS is considered to be food contact safe. This will allow the team to keep the same manufacturing process while meeting all FDA regulations. For the teams prototype, they can continue to build it using PLA, but if they are to ever want to sell it to consumers and get it FDA approved, ABS is the best option to use.

10.1 Vacuum Force Calculations

The new vacuum pump that the team has selected has a minimum vacuum of 533.29 mbar and has a maximum vacuum of 866.60 mbar [20]. With the vacuum tip already selected, and the known area of contact due to this vacuum tip, the mass of pill that can be lifted by this pump can be found.

The mass calculations will be found for both the minimum vacuum pressure and the maximum vacuum pressure.
For the minimum vacuum pressure:

$$533.29mbar = 53.329KPa$$

The diameter of the vacuum tip that the team is using 1.5 mm, making the radius 0.75 mm. With this radius the contact area can be found:

$$A = \pi r^2 = \pi(.00075m)^2 = 1.7662 * 10^{-6}m^2$$

By multiplying the pressure times the contact area, the forces provided can be found:

$$F = PA = 53,329kg/m * s^2 * 1.7662 * 10^{-6}m^2 = 0.09419kg * m/s^2$$

Lastly, the mass that this vacuum pressure can lift against gravity can be found:

$$F = ma$$

$$0.09419kg * m/s^2 = m(9.81m/s^2)$$

$$m = 0.009601kg = 9.601g$$

For the maximum vacuum pressure:

$$866.60mbar = 86.660KPa$$

The diameter of the vacuum tip that the team is using 1.5 mm, making the radius 0.75 mm. With this radius the contact area can be found:

$$A = \pi r^2 = \pi(.00075m)^2 = 1.7662 * 10^{-6}m^2$$

By multiplying the pressure times the contact area, the forces provided can be found:

$$F = PA = 86,660kg/m * s^2 * 1.7662 * 10^{-6}m^2 = 0.153058kg * m/s^2$$

Lastly, the mass that this vacuum pressure can lift against gravity can be found:

$$F = ma$$

$$0.153058kg * m/s^2 = m(9.81m/s^2)$$

$$m = 0.01560kg = 15.602g$$

After these calculations, it can be seen that the new vacuum pump will be able to lift at minimum of 9.601 grams and lift a maximum 15.602 grams. This range is even larger than the previous pump, which could lift a minimum of 9.002 grams and lift a maximum 14.403 grams. Even while cutting down on the noise produced, the new pump is still stronger than the previous pump. Both pumps provide a sufficient enough range however, it is a plus that the new one can lift more.

10.2 Vacuum Force vs. Tensile Strength of Pills

A potential issue that could be faced when using a vacuum tip on pill is that the vacuum force could be strong enough to break the pills. To ensure this is not the case, calculations can be made. The tensile strength of different shapes were researched by two engineers by the names of Kendal G. Pitt and Matthew G. Heasley [24]. They studied the yield tensile strength of different pill shapes and sizes. They studied two shapes of pills, these being round and caplet shaped pills. For caplet shaped pills, they found the maximum tensile strength to be about 1.5 MPa. For round shaped pills, they found the tensile strength to be about 1.05 MPa. These tensile strengths can then be compared to the vacuum pressures exerted by the vacuum pump picking up each pill. The pressure exerted by the vacuum ranges from 50 KPa to 80 KPa. This confirms that most pill shapes and sizes will be able to withstand the vacuum pressure exerted.

$$53,329Pa < 1,500,000Pa$$

$$53,329Pa < 1,050,000Pa$$

This shows that for both shapes, pills will be able to withstand the minimum vacuum pressure.

$$86,660 Pa < 1,500,000 Pa$$

$$86,660 Pa < 1,050,000 Pa$$

This shows that for both shapes, pills will be able to withstand the maximum vacuum pressure.

11 Build/Manufacture

Each section of the Automatic Pill Dispenser, including the Portable Device, Android App, Code and Internal Hardware, and Dispenser Housing is discussed. In each of these sections the build of each aspect is explained, and includes the steps for mass production, and a proposed manufacturing system design.

11.1 Portable Device

The manufacturing steps for the portable device included four main steps. The designs were originally sketched in an engineering notebook. These drawings were then converted to a SolidWorks drawing. Drawing the design in SolidWorks was an important step because now 3D printing can begin, as well as, the design in SolidWorks is in 3D, allowing to see all tolerances, and how the design works. Each part of the portable device was drawn separately and then using the assembly tool in SolidWorks, the parts were brought together to see how they act in motion. The drawings were broken up into the top piece, bottom piece, flap, and pin. One flap, and one pin needed to be created for in the SolidWorks assembly mode, each part can be duplicated. This feature saved time for there are four pins, and four flaps and with the copy feature all the pieces are identical.

The next step was 3D printing, the Soldiworks file was converted to an STL file to allow for it to be set up in the 3D printing software. The portable device was originally printed with the Raise3D printer. However, after a few failed attempts the portable device was then printed on the Objet 30 printer. 3D printing is its own process, however it is important to check on the piece halfway through its print, to avoid having to reprint and waste material if a malfunction were to occur. The last step in the manufacturing procedure of the portable device is cleaning off the support material from the Objet 30 by using a waterjet. When the device was printed on the Raise3D the support material was taken off with a scraper tool. The pins were sanded down using x-fine 400 grit sandpaper, for it was difficult to clean the pins with the waterjet due to the size of the pins. Once all of the parts are free of support material, the assembly process can begin. The pins and the flaps are assembled to the top of the portable device by inserting the flaps into its section on the top piece and securing the part with a pin through the hinge for each flap.

The most direct course for producing the portable device is drawing it in Solidworks, converting the file to an STL, setting up print on Objet Studio Software, then printing the device in the Objet 30, cleaning and assembling. The prototype was 3D printed for it was the least expensive method while still being within our set budget. The printers are offered by the URI College of Engineering, and are allowed by capstone students to use. Using the in-house 3D printer is less expensive then outsourcing and allowed the team to use the budget in other areas of the automatic pill dispenser. An overview of the manufacturing process can be seen in figure 135.

Steps for Mass Production

If the device were to be mass produced, the most efficient way of producing the portable device is injection molding. There is one portable device for every automatic pill dispenser. Depending on the market and the amount of automatic pill dispensers being sold, the amount of portable device being produced will be increased or decreased. The process for injection molding includes three major steps. The first step is creating a design in a CAD software, which this step is complete for the drawing has been created in SolidWorks and proves to work. The SolidWorks design has to be exact to the dimension needed, or money will be wasted in having to reproduce. Additionally, testing has been performed on the portable device which is additional money saved in the injection molding process. The design will now need to be turned into a mold, made out of material of prehardened steel. Prehardened steel is the material of choice for it is less expensive to create, and at most 100 automatic pill dispenser will be produced when the product is brought to the market. Prehardened steel does not last for as many cycles as steel, however steel is used to produce hundreds of thousands. The prehardened steel should last for the number of cycles needed to produce the portable device. The mold will then be sent to the injection molding process, at a predetermined temperature plastic will melt into the mold, and pressure will be applied during the cooling process. The part is then ejected from the mold, and the process is then repeated depending on the number of products needed to be produced.

Proposed Manufacturing System Design

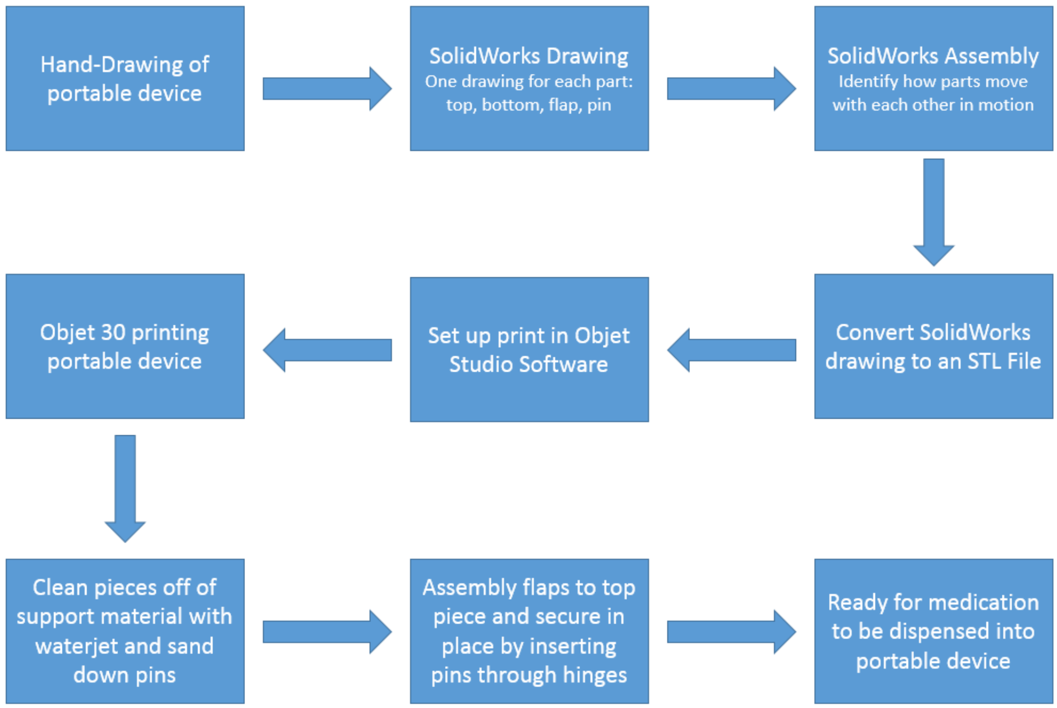


Figure 135: Portable Device Manufacturing System Design

11.2 Android App

When creating the android app, there was not much physical building or manufacturing involved. The building of the app came solely within the emulator on Android Studio or on an android smart phone. This however did not make the process to create the app much different from physical manufacturing. The first step that was taken in building this app was to do research on the desired functions. Once the team got an idea on what was needed to be done, the code could begin to be written. Each function in the app proved to be challenging in it's own way given that coding as a whole was a new topic to the team. Each "screen" in the app can be referred to as an activity. Each activity is comprised of both Java code and XML code. When writing the code, the Java portion of each activity must be written first. This is what makes the app perform each function. After that is done, the XML portion of each activity will be written. The XML code is what gives the app it's appearance (colors, button size, location, etc.). When this has been done for each activity in the app, the writer of the code can try and run the app. If the app fails to build, it should first be debugged. There is a debug function within android studio that is fairly easy to use. If it does not build due to an error message, the source of the error must be found and fixed. When the app builds with no errors and does not crash upon opening, it can be considered functional. This process is repeated over and over again until the entire app can perform and includes all necessary functions.

11.3 Code and Internal Hardware

Almost no physical manufacturing needed to be done with the components already in place. The only thing that needed to be changed was removing the old 12V vacuum pump and soldering the smaller pump in its place, as well as transferring components to the newly 3D printed housing pieces. Building the internal code was a bit more complicated as all the old data from last years project was lost due to a current-overload frying the old Raspberry Pi. Python was used as the main programming language. The first step was rewriting the code to run the actuator, stepper motors, and the vacuum pump. After that, various test codes were created to test loops and other options to figure how to have the code receive data from the app, process it, then run the machine. The code retrieves information from an online server via specific credentials and reads data from the most recent entry. A 5x5 matrix was decided on to be the main conveyor of data from the app to the machine. Each column corresponds to the time the pill is taken at, and the rows correspond to the pill type. Each coordinate value is either a 0 or 1 which tells the machine whether or not to dispense the type of pill at this time. The (5,4) and (5,5) coordinates contain the time variable. This data is taken and used to tell the machine when to activate the dispersal process. After this the code contains various if/then statements to figure out which pills need to be dispensed for which time slot.

11.4 Dispenser Housing

Manufacturing the dispenser housing was relatively straight forward. The initial step in creating this prototype was analyzing the original prototype. This is possibly the most important step in creating this because this is how the team was able to determine what needed to be changed from the previous model. Next, a sketch of the housing was drawn in an engineering notebook, where all changes to the original prototype were noted. This was a rough sketch just to ensure the concepts were viable. After the sketch was created, the parts were sketched and created in SolidWorks. The Top, Bottom, and Middle Tiers were all created with specified dimensions. These dimensions ended up making the housing approximately 1.25” shorter than the original prototype. Once the parts were created, they were each put into a SolidWorks assembly to ensure that all parts fit together properly and there are no clearance issues. Once it is confirmed that there are no fitment issues, convert each part file to an STL file. These STL files will then be uploaded into the slicer IdeaMaker. In the slicer set all 3D printing settings as desired, and slice the model into a gcode file. The gcode file is what tells the 3D printer what movements to execute. The gcode files are then to be uploaded to the Raise3D printer and the printing can begin. When the print finishes, remove the part from the heat bed to ensure accuracy. In this time, remove any and all support material produced by the printer. After this is done, test the fitment of the parts together. In this case the tiers had to snap into one another easily. If not, perform any post-processing that is necessary. Some of these post-processes include sanding, drilling, or filing. One the parts are finished being post-processed, install all motors, actuators, pumps, and other internal components into the housing of the dispenser. Upon completion, the dispenser can begin to dispense pills.

Steps for Mass Production

If this product was to ever be mass produced the steps in manufacturing would be very similar to what what the team performed. The steps would be virtually identical until reaching the point that the design is to be manufactured. When manufacturing this product, the plastic pieces will likely be injection moldings. Injection moldings are typically the easiest way to create a large number of a particular product. This is because once the mold has been created, it can be used over and over again. Plastic is heated up and poured into the mold. When the plastic cools, it can be removed from the mold and is ready for use. The largest down fall of injection molding is the cost to create the mold itself. Creating the mold is very expensive and does not allow the designer to make any changes upon creation. If the design will be mass-produced, and is as perfect as possible, injection molding is the best manufacturing process as it is far more accurate and reliable than 3D printing.

The quantity of the product that is being produced is largely dependant upon how many dispensers the team thinks they will initially sell. The creators of this product, think that it would be a good idea to only produce a small number at first, maybe only make 100 or 200 units. Only manufacturing this quantity will allow the team to get an idea of how consumers like the product and if there is anything that they think needs to be improved. This will allow the team to make any changes necessary to maximize the number of units purchased by consumers. If we were to produce a large quantity and there were many complaints or errors, we would be stuck with many useless products. Once we get an idea of how consumers react to the product, we will mass produce accordingly.

Proposed Manufacturing System Design

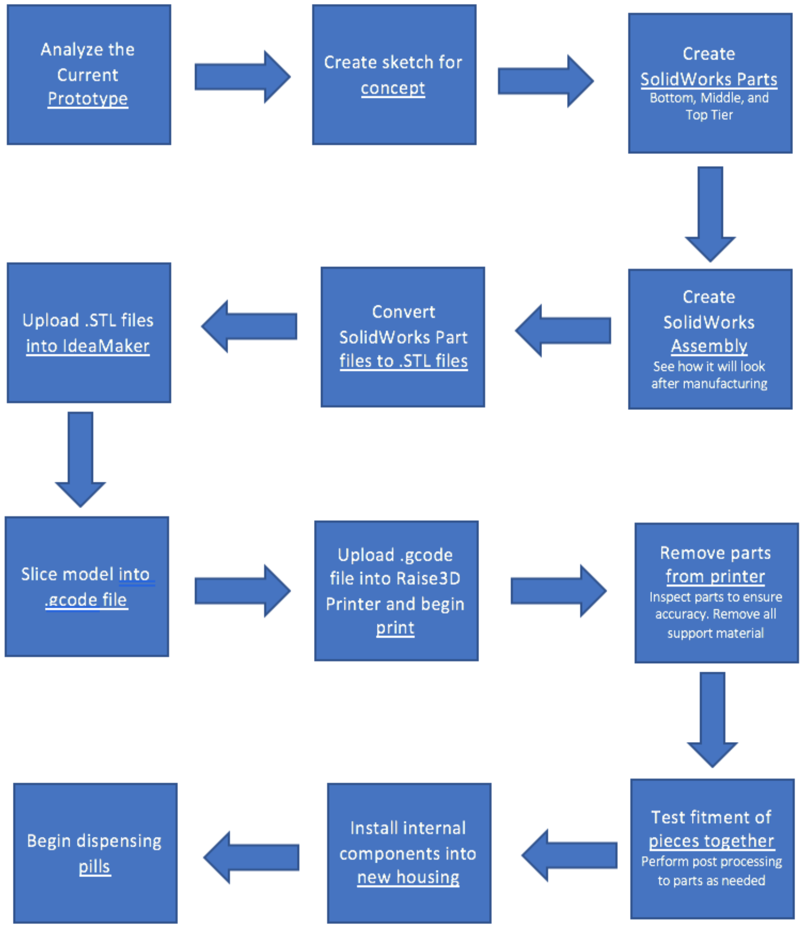


Figure 136: Dispenser Housing Manufacturing System Design

12 Testing

Testing is a major part of the design process. The aspects of the the automatic pill dispenser that were tested include the portable device, Android app, and the Code and Internal Hardware. These section include how testing was completed, and the testing matrix for each aspect. Some section also go into greater detail of the design specification compliance, safety consideration, and the environmental consideration.

12.1 Portable device

Throughout the testing process, these three concepts were kept in mind with every design; user-friendly, durable, and appearance. User-friendliness is ideal for the target market is older adults, including those who may suffer from arthritis or a weakened muscle disorder in their hands. Durable is important for the device is for travel purposes, withstanding different service environments, and breaking. Lastly, appearance is important for if the user needs to take their medication on the go, the device will be with the user for a large portion of the day and seen by potential customers. The look of the portable device needs to be appealing to the eye and the size of the device needs to meet the average standards of a travel pill dispenser. Also as a product used for drugs, the portable device needs to comply with the codes set by the FDA. A major consideration to be approved by the FDA is the material. For the portable device the final prototype was made out of PMMA which is approved by the FDA. The testing procedures are outlined in separate testing matrices, each entailing one of the following categories; design specification compliance, safety, and environmental considerations.

Design Specification Compliance

For the testing matrix of design specification compliance, figure 137 each test was evaluated for each area of the portable device. Quality is a main focus point for each user for it has to be appealing to the eye, while being durable. The portable device was printed three times with three major alterations to the overall design of the portable device. The testing matrix helped keep track of the areas that succeed, and failed and the proposed resolution to each failed area. If a planned resolution was not stated in the testing matrix, figure 137 then that area of the portable device did not need to be reprinted/revised. All four areas of the portable device succeed on the final test print. The pins, and the V-shaped cutout on the bottom of the portable device were sanded down with X-fine 3M sandpaper, which allowed them to become use able in the design. The final print ended up being the final prototype for the automatic pill dispenser and reminder.

Safety Consideration

The safety consideration testing matrix was used to keep track of the materials that comply with FDA regulations, for the device will be storing medications, figure 138. The PLA material used in the Raise3D 3D printer is not compliant with the FDA regulations. PLA is not approved food safe by the FDA in the US [23]. That drugs will be stored in the portable device, and these drug will be consumed by entering into the users' mouth, drug is considered to be in the same category as food safe. PLA being not food safe, the material needed to be changed if the device were to be sold on the market, and passed by the FDA. The material used in the Objet 30 is made out of PMMA, which is also known as acrylic. PMMA is approved by the FDA, and considered food safe [27]. The final prototype was made out of PMMA, therefore the device would be able to be sold on the market and used safely by consumers.

Environmental Consideration

Another consideration when testing the portable device is the environmental consideration, figure 139. Environmental consideration is important for the material at some point needs to be able to be disposed of. PLA which was used in the first three prints in the Raise3D 3D printer is biodegradable. PLA decays as a result of exposure to the ultra violet rays of sunlight and oxygen. It decomposes forming carbon dioxide and water, which present no danger to the environment. PLA is also environmentally friendly and sustainable for it is processed from the starch of plants such as corn, sugar cane and sugar beet [26]. PMMA is also not considered a risk to the environment, for it is recyclable, and sustainable. PMMA can also be reground, melted and extruded into new products. The recycled material can be used again, not only saving on raw materials, but also reducing waste [25].

29-Mar	**Area**	**What to test?**	**Test Parameters**	**Results**	**Planned Resolution**
OBJET 30	Flap	quality	dimensioned area between knuckles	Flaps are able to move up and down with no rubbing	N/A
	Pin	quality	needs to fit into hinge	pins do not fit into open width on hinge	pins were sanded down and fit in open width of hinge
	Top	quality	needs to be durable and fit in bottom piece	snap and lock design works	N/A
	Bottom	quality	needs to be durable and fit in top piece, also cutout on bottom needs to fit on rotator platform	snap and lock design works. Cutout on bottom was made smaller than rotating disc	With sanding, the cutout now fits onto rotating disc in pill dispenser.
1-Mar	**Area**	**What to test?**	**Test Parameters**	**Results**	**Planned Resolution**
OBJET 30	Flap	quality	needs to fit into opening on top piece	rubbing on top piece	need to sand down or decrease the area between hinges
	Pin	quality	needs to fit in open width of hinge	does not fit in open width of hinge	needs to find a pin that is small enough and durable for hinge
	Top	quality	needs to be durable and fit in bottom piece	snap and lock design works	top does not need to be fixed
	Bottom	quality	needs to be durable and fit in top piece	snap and lock design works	need design for bottom to slide into pill dispenser
25-Feb	**Area**	**What to test?**	**Test Parameters**	**Results**	**Planned Resolution**
Raise3D 3D printer	Flap	quality	needs to fit in slot on top	pins did not print with the best quality	need to reprint flaps for not presentable
	Pin	quality	needs to fit in open width of hinge	does not fit in open width of hinge	needs to find a pin that is small enough and durable for hinge
	Top	quality	needs to be durable and fit in bottom piece	top and bottom are stuck together	need to improve the one thread design
	Bottom	quality	needs to be durable and fit in top piece	top and bottom are stuck together	need to improve the one thread design
16-Feb	**Area**	**What to test?**	**Test Parameters**	**Results**	**Planned Resolution**
Raise3D 3D printer	Flap	quality	needs to fit in slot on top	3/4 flaps printed correctly; filament leaked	need to reprint more flaps
	Pin	quality	needs to fit in open width of hinge	2/4 pins printed	need to reprint pins
	Top	quality	needs to be durable and fit in bottom piece	need less threading for the threads did not print	redesign threading
	Bottom	quality	needs to be durable and fit in top piece	need less threading for the threads did not print	redesign threading
9-Feb	**Area**	**What to test?**	**Test Parameters**	**Results**	**Planned Resolution**
Raise3D 3D printer	Flap	quality	needs to fit in slot on top	filament leaked into hinge	need to reprint for hinges are not useable
	Pin	quality	needs to fit in open width of hinge	does not fit in open width of hinge	reprint pin
	Top	quality	needs to be durable and fit in bottom piece	support material destroyed threading	need to reprint with less support material
	Bottom	quality	needs to be durable and fit in top piece	support material destroyed threading	need to reprint with less support material
8-Feb	**Area**	**What to test?**	**Test Parameters**	**Results**	**Planned Resolution**
Raise3D 3D printer	Flap	quality	needs to fit in slot on top	flaps did not print correctly	need to reprint
	Pin	quality	needs to fit in open width of hinge	only one pin printed	need to reprint
	Top	quality	needs to be durable and fit in bottom piece	threading did not print correctly	need to reprint
	Bottom	quality	needs to be durable and fit in top piece	threading did not print correctly	need to reprint

Figure 137: Design Specifications Compliance

29-Mar	Area	Material	Safety
OBJET 30	Flap	VeroClear-Acrylic	FDA Approved
	Pin	VeroClear-Acrylic	FDA Approved
	Top	VeroClear-Acrylic	FDA Approved
	Bottom	VeroClear-Acrylic	FDA Approved
1-Mar	**Area**	**Material**	**Safety**
OBJET 30	Flap	VeroClear-Acrylic	FDA Approved
	Pin	VeroClear-Acrylic	FDA Approved
	Top	VeroClear-Acrylic	FDA Approved
	Bottom	VeroClear-Acrylic	FDA Approved
25-Feb	**Area**	**Material**	**Safety**
Raise3D 3D printer	Flap	Hatchbox 1.75mm PLA	The FDA has not approved PLA as a food safe material in the US
	Pin	Hatchbox 1.75mm PLA	The FDA has not approved PLA as a food safe material in the US
	Top	Hatchbox 1.75mm PLA	The FDA has not approved PLA as a food safe material in the US
	Bottom	Hatchbox 1.75mm PLA	The FDA has not approved PLA as a food safe material in the US
16-Feb	**Area**	**Material**	**Safety**
Raise3D 3D printer	Flap	Hatchbox 1.75mm PLA	The FDA has not approved PLA as a food safe material in the US
	Pin	Hatchbox 1.75mm PLA	The FDA has not approved PLA as a food safe material in the US
	Top	Hatchbox 1.75mm PLA	The FDA has not approved PLA as a food safe material in the US
	Bottom	Hatchbox 1.75mm PLA	The FDA has not approved PLA as a food safe material in the US
9-Feb	**Area**	**Material**	**Safety**
Raise3D 3D printer	Flap	Hatchbox 1.75mm PLA	The FDA has not approved PLA as a food safe material in the US
	Pin	Hatchbox 1.75mm PLA	The FDA has not approved PLA as a food safe material in the US
	Top	Hatchbox 1.75mm PLA	The FDA has not approved PLA as a food safe material in the US
	Bottom	Hatchbox 1.75mm PLA	The FDA has not approved PLA as a food safe material in the US
8-Feb	**Area**	**Material**	**Safety**
Raise3D 3D printer	Flap	Hatchbox 1.75mm PLA	The FDA has not approved PLA as a food safe material in the US
	Pin	Hatchbox 1.75mm PLA	The FDA has not approved PLA as a food safe material in the US
	Top	Hatchbox 1.75mm PLA	The FDA has not approved PLA as a food safe material in the US
	Bottom	Hatchbox 1.75mm PLA	The FDA has not approved PLA as a food safe material in the US

Figure 138: Safety Considerations

29-Mar	Area	Material	Environmental Consideration
OBJET 30	Flap	VeroClear-Acrylic	recyclable and sustainable material
	Pin	VeroClear-Acrylic	recyclable and sustainable material
	Top	VeroClear-Acrylic	recyclable and sustainable material
	Bottom	VeroClear-Acrylic	recyclable and sustainable material
1-Mar	**Area**	**Material**	**Environmental Consideration**
OBJET 30	Flap	VeroClear-Acrylic	recyclable and sustainable material
	Pin	VeroClear-Acrylic	recyclable and sustainable material
	Top	VeroClear-Acrylic	recyclable and sustainable material
	Bottom	VeroClear-Acrylic	recyclable and sustainable material
25-Feb	**Area**	**Material**	**Environmental Consideration**
Raise3D 3D printer	Flap	Hatchbox 1.75mm PLA	biodegradable, environmental-friendly, sustainable material
	Pin	Hatchbox 1.75mm PLA	biodegradable, environmental-friendly, sustainable material
	Top	Hatchbox 1.75mm PLA	biodegradable, environmental-friendly, sustainable material
	Bottom	Hatchbox 1.75mm PLA	biodegradable, environmental-friendly, sustainable material
16-Feb	**Area**	**Material**	**Environmental Consideration**
Raise3D 3D printer	Flap	Hatchbox 1.75mm PLA	biodegradable, environmental-friendly, sustainable material
	Pin	Hatchbox 1.75mm PLA	biodegradable, environmental-friendly, sustainable material
	Top	Hatchbox 1.75mm PLA	biodegradable, environmental-friendly, sustainable material
	Bottom	Hatchbox 1.75mm PLA	biodegradable, environmental-friendly, sustainable material
9-Feb	**Area**	**Material**	**Environmental Consideration**
Raise3D 3D printer	Flap	Hatchbox 1.75mm PLA	biodegradable, environmental-friendly, sustainable material
	Pin	Hatchbox 1.75mm PLA	biodegradable, environmental-friendly, sustainable material
	Top	Hatchbox 1.75mm PLA	biodegradable, environmental-friendly, sustainable material
	Bottom	Hatchbox 1.75mm PLA	biodegradable, environmental-friendly, sustainable material
8-Feb	**Area**	**Material**	**Environmental Consideration**
Raise3D 3D printer	Flap	Hatchbox 1.75mm PLA	biodegradable, environmental-friendly, sustainable material
	Pin	Hatchbox 1.75mm PLA	biodegradable, environmental-friendly, sustainable material
	Top	Hatchbox 1.75mm PLA	biodegradable, environmental-friendly, sustainable material
	Bottom	Hatchbox 1.75mm PLA	biodegradable, environmental-friendly, sustainable material

Figure 139: Environmental Considerations

12.2 Android App

While developing the android application there was one underlying goal at mind; functionality. Functionality is crucial because if the app does not function properly, it is essentially useless. The largest portion of the android app that was designed was the communication between the app and the raspberry pi board. The other functions of the app including the database, the reminder to the user, the input of each medication, and the appearance of the app were much more straight forward. Each portion of the app was tested simply by running the code that was written and see if the app was able to run without any error messages. Once one section of the app was written successfully, the team moved on to the next function. The app underwent several iterations until it was at the point it is today. Once the app was able to run a successful build on either an emulator or android phone the team would test the app itself to ensure that it performed the desired functions. If it did not perform the desired functions, the code would be inspected to see what is needed to be added or changed.

	What to Test?	Test Parameters	Results	Planned Resolutions
User input	All input is filled	Feedback to user: Missing Info	Success	
User input	Frequency is between one and four	Feedback to user: Must be between 1 and 4	Success	
User input	Frequency matches checked boxes	Feedback to user: Freq and Boxes must be the same	Success	
User input	Update checks medications and time are filled	Feedback to user: Do you want to update with missing info?	Success	
User input	Information is not overwritten			Only update new information
User input	Save button saves information	Saves information to a matrix and file	Success	
User input	Discard button wipes information	Discarding information. "Resets" medication info	Success	
User input	Back button sends user back one screen	Does not interact with user input, only moves screens	Success	
Coding	AlertDialogs: Running low	Informs user when medications are have less than 5 pills		Build Notification Manager
Coding	Time updates	Subtracts Frequency from amount daily		Build Counter
Coding	AlertDialogs: Time to take pills	Tells user when and what pills to take at certain times	Success	
Coding	Matrix building	Creates a 5*5 Matrix of information	Success	

Figure 140: Android Application Testing Matrix

3 Column Database				
March 6th	**What to Test?**	**Test Parameters**	**Results**	**Planned Resoltion**
Database Entry	Function	Will it show inputted results?	Shows input. No error messages	None needed.
March 4th	**What to Test?**	**Test Parameters**	**Results**	**Planned Resoltion**
Text field hint	Visibility/ User Friendliness	Does this help user enter data?	Yes. Successfully helps user.	None needed.
Text size of buttons/ fields	Visibility/ User Friendliness	Are textfields and buttons large enough?	No. Must make bigger.	Increase size of text filed. Make buttons larger.
March 3rd	**What to Test?**	**Test Parameters**	**Results**	**Planned Resoltion**
Database Entry	Function	Can you enter 3 different fields?	Successfully able to enter.	None needed.
Database Entry	Function	Can you enter 3 different fields?	Error message. Unknown variable.	Find the unknown variable and make sure all match.
Database Entry	Function	Can you enter 3 different fields?	Error message. Unused Variable btnAdd	Make sure btnAdd is used in all commands.
March 1st	**What to Test?**	**Test Parameters**	**Results**	**Planned Resoltion**
Database Entry	Function	Can you enter 3 different fields?	Public class not found.	In one command the class name was spelt wrong.
Database Entry	Function	Can you enter 3 different fields?	Database name does not match.	Change database name in MedicationDB.java to myDB.
February 28th	**What to Test?**	**Test Parameters**	**Results**	**Planned Resoltion**
Database Entry	Function	Can you enter 3 different fields?	Edittext, etDate does not match res file.	Make sure etDate is spelt correctly in both res and java files.
Database Entry	Function	Does new code work?	No, many error messages came up.	Address each error message.
Single Entry Database				
Area	**What to Test?**	**Test Parameters**	**Results**	**Planned Resoltion**
Database Entry	Function	Can you enter multiple fields?	No. Just EditText does not fix.	Must recode and add two more columns to Database.
Database Entry	Function	Can you enter multiple fields?	No. Only one is allowed.	Add an extra EditText field in res file.
February 20th	**What to Test?**	**Test Parameters**	**Results**	**Planned Resoltion**
Database Entry	Function	Can you save inputted data to database?	Yes successfully saved data.	None needed at the time.
Database Entry	Function	Can you save inputted data to database?	No. error message.	Find error in code.
Database Edit/Removal	Function	Can you edit the inputted data?	Yes. Successfully edit/remove data.	None needed.
Database Edit/Removal	Function	Can you edit the inputted data?	No. Error message.	Check logcat to see error messages.
February 18th	**What to Test?**	**Test Parameters**	**Results**	**Planned Resoltion**
Text size of buttons/ fields	Visibility/ User Friendliness	Are textfields and buttons large enough?	Yes. Successfully helps user.	None needed.

Figure 141: Medication Database Testing Matrix

12.3 Code and Internal Hardware

For the Code and Internal Hardware, functionality was also the main focus of testing. If this part of the project did not function then the machine would be useless. The first thing was testing the old components: the actuator, stepper motor, and vacuum pump. Once this was done, a new code would be written to run the machine. Unfortunately during one of the tests some wiring came undone and the circuit was rewired incorrectly and caused an overload. A new Raspberry Pi was acquired and rewired so that testing could continue. Once this was done, code had to be tested so that the data transferred between App and machine, which proved successful. After that, the rest of the code was tailored to function with the received data from the App. The most important aspects of this testing procedure was 1) whether the machine functions, 2) whether it picked up and dispersed the pills accurately, and 3) the overall dispensing time.

Item	Date	What to test?	Test Parameters	Results	Planned Resolutions
Old Program/UI Tests	2/6-2/20	Functionality		Cumbersome code, no function	
New Program	3/3	Machine function	""	Unknown, circuit board blowout	New Circuit Board to retest
Linear Actuator	3/3	Functionality with new program	Speed and reliability of Actuator	Unknown, circuit board blowout	New Circuit Board to retest
Stepper Motors	3/3	Functionality with new program	Speed and reliability of Motors	Unknown, circuit board blowout	New Circuit Board to retest
RPi B+	3/10	Reintegration and Functionality	Needs to run software and hardware properly	Success	
RPi B+ Heat Syncs	3/10	Heat dissapation	RPi board cooled properly	Success	
New Program, retest	3/24	General functionality	""	Success	
Linear Actuator, retest	3/27	General functionality	""	Success	
Stepper Motors, retest	3/27	General functionality	""	Success	
Piston Vacuum Pump	3/27	Noise		Too loud, excessive vibrations	
x2 30x30x7mm Fans	4/3	Functionality	Fan must operate	Success	
5v Vacuum Pump	4/3	Functionality and Noise	""	Success	
App-Rpi Data Transfer	4/3	App must send data to Rpi, Rpi must then interpret	Data must be received and procesed	SUCESS	
Fans (need to mount)	TBD	Fans must be added to base, and provide airflow	Compartment temperature	/	
Vacuum Pump	4/12	Suction power of new pump and tubing	Pick up the pill	SUCESS	
Full Product Testing	4/12	Full functionality of machine	Parts function together	Sucess	

Figure 142: Raspberry Pi Python Code Testing Matrix

13 Redesign

Many aspects of the automatic pill dispenser were redesigned throughout the semester. The portable device was completely redesigned making it more user-friendly for its user. The Android app, and code and internal hardware were redesigned to meet the needs of the design specifications. The housing for the automatic pill dispenser was altered to meet the dimensional changes of the portable device. Additionally, recommendations for future groups is included in each aspect of the automatic pill dispenser described in this section.

13.1 Portable Device

Over the course of the semester, the portable device went through three major alterations in the design of the device. At the end of the fall semester, the top of the portable device was alerted significantly from the previous portable device. The bottom of the device was kept the same, with a threaded design of closure with minor dimension changes at the end of the fall semester, as seen in figure 143. This design was printed using the Raise 3D printer. This design did not succeed in the 3D printer, for the thread profile was made to small of dimensions. When removing the support material it destroyed the threading on the top and bottom piece, therefore not making it use-able. The portable device was then reprinted with a greater thread profile, to avoid ruining the threading while removing the support material. In this print, the top design was also kept the same. The print did not succeed in the Raise 3D printer, for the flaps of the top device printed incorrectly, as well as filament sunk into the hinges. For the thread, a greater thread profile did succeed in the Raise 3D printer, however when attaching the top to the bottom piece, the piece became jammed. Therefore, this print was also not use-able, for the top could not be taken off. The target market for the portable device is older adults, specifically who take medication and might suffer from arthritis and a weakened muscle disorder. If the top were to get jammed into the bottom piece for the user, the device would lose a substantial amount of customers. Therefore, the original redesign was altered into a second design. The threaded design was no longer an option as a design of closure, due to numerous failures. The design of closure was redesigned into a twist and lock design. Overall, the twist and lock design is a better fit for the target market. The user will only have to turn and pull up the top piece when opening, and then turn and push down the top piece when closing. This alleviates the need to make numerous turns, which users who suffer from arthritis or weakened muscles may have trouble with. The flaps were also alerted in the second design. After testing the original design, the flaps were difficult top open. A cylindrical pull tab was designed on each flap as a way to create a grasp, decreasing the difficulty to open/close, as illustrated in figure 144. The device was also not printed on the Raise 3D printer, but instead on the Objet 30 3D printer. The Objet 30 is known for accurately printing a smaller range of engineering tolerances, especially with the hinges and pins. This print was successful, in that the top and bottom piece connected and disconnected with minimal issues, and the flaps attached to the top with the pin and hinge design. This device was tested among potential consumers ranging in the ages of 45-75 years. However, the diameter of the cylindrical pull tabs needed to be increased in size, for there was not enough material to secure a firm grasp. This lead to the final design, as well as the final prototype of the portable device. For the final design, the diameter of the cylindrical pull tabs were increased in size from 0.13in to 0.25in, allowing for a stronger grasp. Also, changes were made to the bottom of the bottom piece. Since the portable device, is used in the pill dispenser, a V-shape was extruded cut in SolidWorks on the bottom of the piece as a way to slide in and slide out of the pill dispenser. The V-shape cutout slides onto a rotating disc with an extruded V-shape within the pill dispenser, creating a secure fit as the pills are dispensed into the portable device. The final design is seen in figure 145.

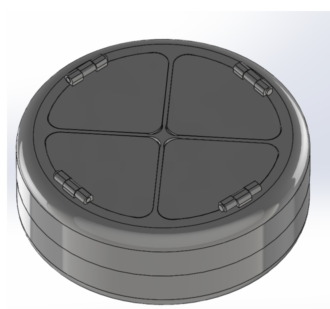


Figure 143: SolidWorks Assembly of Design 1

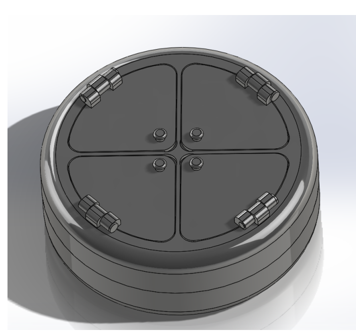


Figure 144: SolidWorks Assembly of Design 2

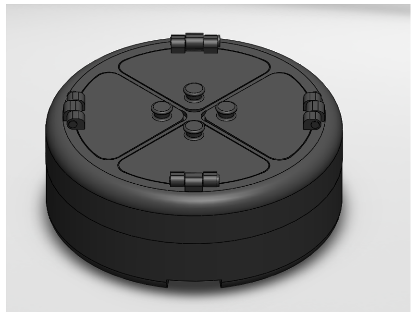


Figure 145: SolidWorks Assembly of Design 3

Recommendations

The final design could be taken a step further by alleviating the hinge and pin design. For production, inserting all four pins into the four hinges on the top piece causes for additional man hours which costs more money to produce. The design could be alleviated by making it similar to a ice breaker mint container by having a seal over the flap that would serve the same purpose but omit the need for a hinge and pin. Additionally, the portable device could have its own alarm system. When it is time to take the medication, the compartment in which the pills reside in will light up/flash alerting the user to take those pills in that compartment. The system for the portable device would need to be in sync with the smartphone application, for that is how the user inserts the time to take each medication. Lastly, to be approved by the FDA, each flap of the portable device needs a labeling system. The labeling system could include putting average medication times on each flap, by editing the SolidWorks file, and extrude-cut the average times into each flap. For example, the flap could be labeled by including a 9AM, 12PM, 3PM, 6PM on one of each of the four flaps. The most important consideration with labeling the flaps, is each compartment needs to be in sync with the smartphone application, to avoid the user taking the wrong medication at a certain time. The smartphone application tells the user the exact compartment that the pills for each specific time reside in. Therefore the labels for each compartment needs to be exact with the smartphone application on every dispense, or possible lawsuits may be faced.

13.2 Android App

The Smartphone app was a large part of the project this year, as Team 8 wanted to control the machine directly from a users phone. The teams priority for the app was functionality over all else, with relatively little regards to layout or design friendliness.

Recommendations

There were a few functions that did not make it to the final app, those being a counter, persisting information, and background notifications. The counter would keep track of the number of pills in the machine, and would subtract the frequency from the total amount. When the amount became less than a certain threshold, the app would warn the user they are almost out of a medication. The next feature that did not make it was persisting information.

This means information that would be visible in between app sessions. For example, if a user entered a medication name and closed the app after saving, the medication name would not be visible. All information is saved and stored in the app, but is not visible in between sessions. There is an Android class called "Shared Preferences", which can save information between sessions, but the team did not have the time nor the prior experience to utilize this feature to its full potential. The last feature that did not make were background notifications. Currently, the app will show a dialog box, as seen in Figure 116. This fulfills the purpose of notifying the user, but it will not remind the user if their phone is idle. A true notification will wake the phone from an idle state, accompanied by either a vibration or noise, or a combination of the two, in ways similar to an alarm. The team was not able to accomplish this due to time constraints.

13.3 Dispenser Housing

After designing, printing, and testing the dispenser housing, it was found that the housing worked as expected and does not require any design changes at this time. However, If any internal components are changed on the dispenser the housing will likely need to be re-designed.

Recommendations

The device could become more technologically advanced by adding an LCD/touch screen to the front of the dispenser. This would allow for a user that does not have an android phone or a user that is not very savvy with their android phone, to still have the ability to use this product. With the addition of an LCD/touch screen, the front of the top tier would need to be redesigned in order to accommodate the screen. Another aspect that the team considered changing was the height of the pill silos within the top tier. The team was considering to make the silos slightly shorter, allowing for the overall height of the dispenser to be shorter. If further work is done on this product and this is decided to be done, the top tier of the housing could be made shorter. Lastly, the team contemplated using a smaller, faster linear actuator. If further work is done on this product and is decided to make this change, the top tier can be redesigned. The holder for the linear actuator will need to be changed in order to hold the new one. Also, if the linear actuator is shorter, the top tier can be made shorter.

13.4 Code and Internal Hardware

The code was optimized by reducing the overall dispensing time. This was done by increasing the speed of the linear actuator, therefore picking up and dispensing pills in shorter amount of time. Additionally, the rotation of the silos was altered in the code, also reducing the overall dispensing time.

Recommendations

An addition that could improve accuracy for the dispersal is perhaps a pressure sensor on the vacuum to detect when the actuator has made contact with the pill and is holding it.

If this was tied into the code a fail-safe system could be put in place to tell the device to redo the procedure of lowering, making contact with the pill, raising, and so on. Another issue that would need to be overcome is how the machine receives data from the App. Bluetooth functionality proved too complicated to figure out, perhaps delegating this part of the project to the Electrical Engineering department will prove more fruitful. Or maybe even a cross-department cooperation for this project. The final step would be creating a total, dedicated circuit board to run all the internal components instead of a Raspberry Pi, but that may lay outside the abilities of engineering students.

14 Project Planning

The purpose of the Project Plan is to monitor the progress of each member of the team, and to make sure everyone is on track with all assignments at hand. The project plan involves creating a set of tasks to help guide the team through the implementation and closure phases of the project. The plans created during each phase of the device will overall help manage time, cost, quality, and changes. Using Microsoft Project, the project plan was created for each week, where new assignments, as well as changes made during each week were added. Additionally, the progress of new and old assignments, as well as changes made were noted as a percentage, and used to know how much work needed to be completed till all tasks at hand were one-hundred percent complete. The project plan is outlined as a Gantt Chart and helped all team members see the progress and delays of the project. A managerial strategy is for team assignments, the assignments were broken up evenly per team member. By doing this each team member can focus on the sections they are assigned to complete. This system worked for there were no issues or delays when completing the team assignments for the fall semester. Additionally, we had a main team member for the Weekly Project Report, where each week the individual kept track of each team member's progress throughout the week. For the Project Plan, we rotated each week to complete the project plan on Microsoft Project, that way each team member can familiarize themselves with Microsoft Project. The tasks for the fall and spring semester helped improve the outcome of the project, and can also be seen in the Gantt Charts, figure 146 and figure 147.

Table 6: Project Plan Resource Name Abbreviation

Name	Title	Initials
Lyndsay Castle	Design Engineer	L.C
Joesph Jacobs	Software Engineer	J.J
Brian McDonough	Software Engineer	B.M
Kyle McKenna	Computer Engineer	K.M

14.1 Fall Semester 2018

- First meeting with the Sponsor, Professor Nassersharif, the team met and discussed the goals for the Fall Semester.
- Patent Search Assignment; each individual completed on their own and researched patents that related to the keywords of the device.
- The Product Design Specification Assignment; completed as a team where it contained information about the features, dimensions and specifics of the device.
- Literature Search Assignment; individual assignment where each team member searched literary papers about the automatic pill dispenser and reminder.
- Conception Generation and Analysis Assignment; individual assignment where each team member came up with 30 design and explained each design for the automatic pill

dispenser and reminder. The conceptual drawings were designed on the expectations, and the guidelines of the product that the team's sponsor has set for the team.

- QFD Assignment; team assignment where each team member compared their 30 designs. After picking the best design out of the 120 designs, that designs was compared against the product from last year, as well as a few pill dispenser on the market.

- Meeting with Professor Marcoux and Professor Orr to gain insight on the device that the team last year developed, and the improvements that need to be made. Professor Marcoux, and Professor Orr were the sponsors of last year's team.

- CDR Presentation presented our ideas for the device, and received feedback to implement in the device for the Proof of Concept Presentation. The team presented five concepts in the device from last year's team that needed to be improved upon.

- Meeting with Sponsor, Professor Nassersharif, to learn about Professor Nassersharif's expectations for the POC Presentation. Also, to find out any other expectations or task that needed to be completed for the fall Semester.

- For the POC presentation one team member worked on the design for the Portable Device. Two other team member worked on the App Development for the POC. The last team member worked on the Raspberry Pi code and making the device pick up the medication and dispense under 30 seconds.

- POC Presentation, gained additional feedback on the team's work that was completed on the device for the semester, and the parts of the device that can be improved on going into the Spring semester. The team presented three out of the five concepts that were successful for the Fall Semester.

14.2 Project Plan Fall Semester 2018 - Gantt Chart

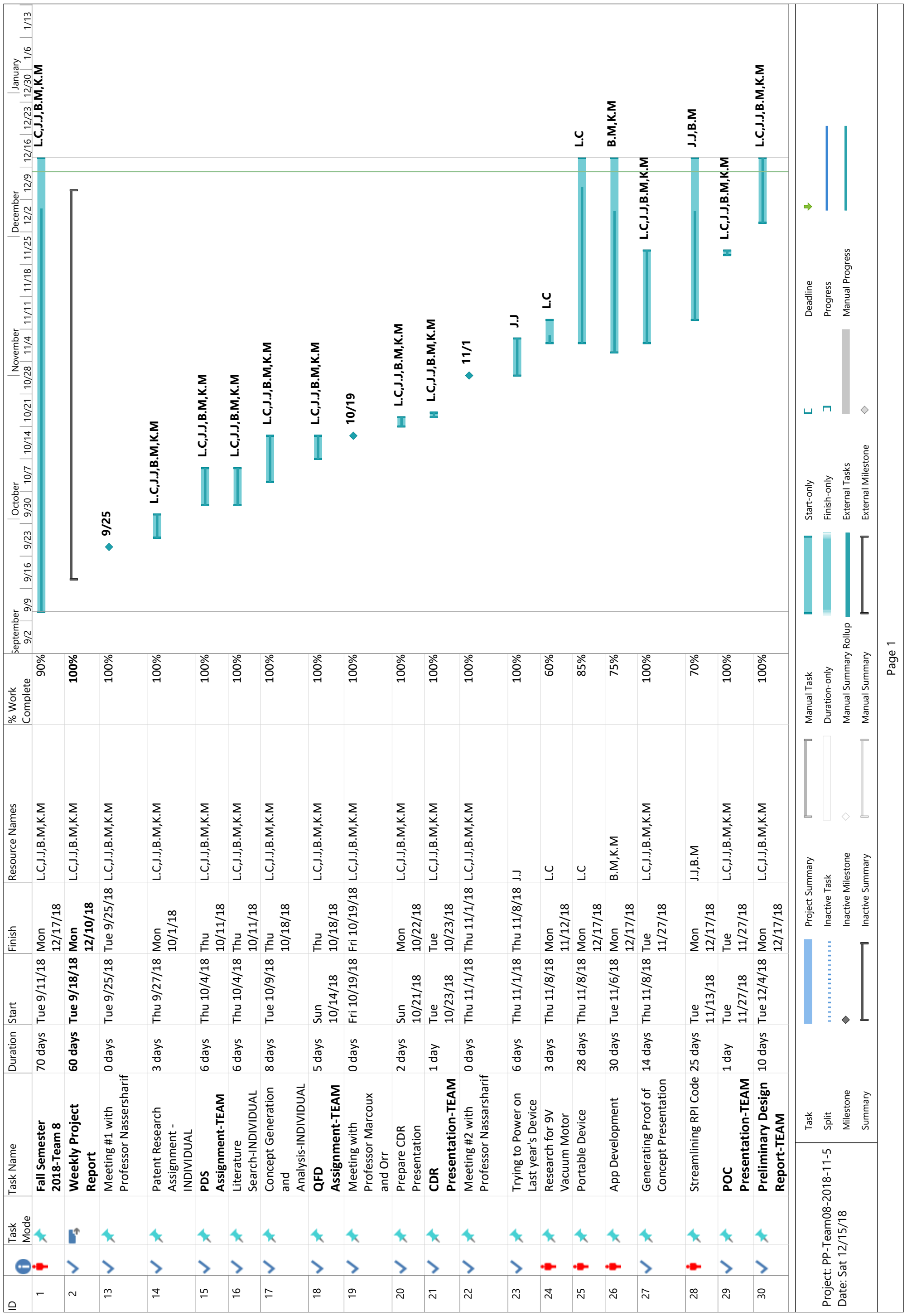


Figure 146: Team 8 Project Plan Fall Semester

14.3 Spring Semester 2019

- A main focus for the spring semester is the build, test and redesign. The semester began with a testing schedule, which laid out each aspect of the device, who was testing and the progress of each aspect. The progress was represented as a percentage out of 100.The testing schedule was broken up in the team's main parts to be redesigned including, the portable device, code for device, smartphone application, vacuum pump, and redesign of the pill dispenser.
- Build and Test Review; graded on overall progress of the device throughout the semester, including the testing matrix for each part of the device, design specifications, engineering analysis, and completeness of the device.
- Replaced vacuum pump and increased speed of linear actuator; great improvement for it reduced the noise volume, and the dispensing time for a single pill reduced from 45 seconds to 26 seconds per pill. The overall dispensing time is now less than 10 minutes for all 16 pills.
- Build, Test and Redesign Presentation; graded on design quality, design specifications, test matrix, engineering analysis and redesign rationale and completeness.
- Reprinted the all three tiers of the automatic pill dispenser. The middle tier was redesigned by omitting the door, and centering the opening for the portable device. The bottom tier was redesigned to have built in compartments to organize the breadboards and wiring of the system. The top tier was reduced in size, as well as a built-in for the linear actuator was created. The top tier shifted in the middle of the print, making it not use-able.
- For the Design Showcase, the team presented our project in a professional manner and demonstrated how the device works, the purpose of the device, and how we redesigned the device from the previous capstone group. The team also presented visitors with a poster and brochures, as well as the design binder and all team members' engineering notebooks.
- One of the last task for the Spring Semester is the final design report. The report is an overview of all the work that team 8 spent on the automatic pill dispenser. The report will be broken up evenly, overlapping on larger portions of the report.
- Complete peer evaluations and capstone wrap up and check sheet. These are for Professor Nassersharif's reference to see how the team worked together, as well as the teams' overall thoughts on capstone design course.
- Completed a total of 12 Weekly Project Reports that helped the team set goals, and stay on time with all tasks and assignments for the spring semester.

14.4 Project Plan Spring Semester 2019 - Gantt Chart

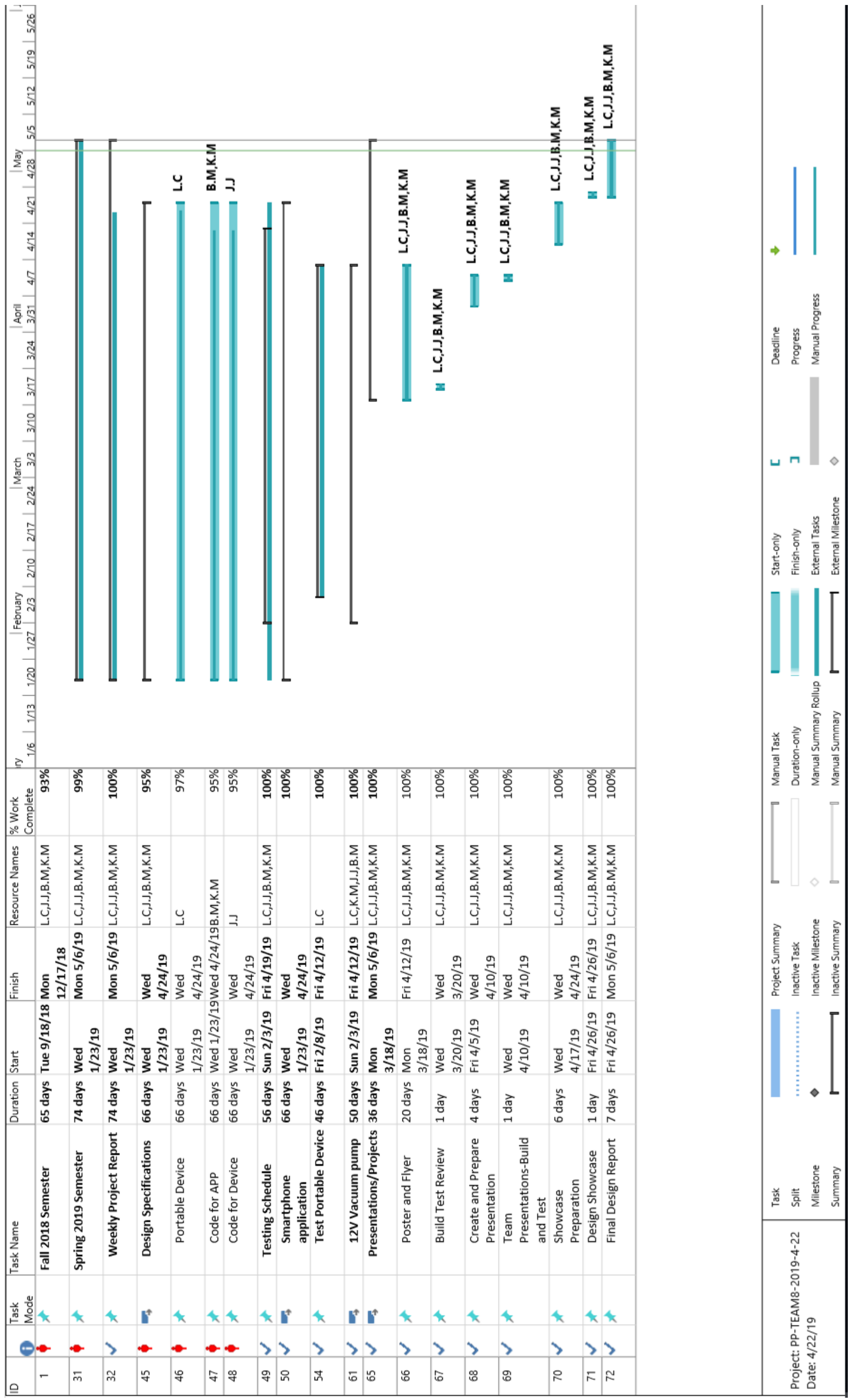


Figure 147: Team 8 Project Plan Spring Semester

15 Financial Analysis

In this section, the financial analysis throughout the year is discussed. This includes the expenses for the fall and spring semester, as well as the expenses for the previous capstone group. The person hours and dollar equivalent spent on the project by team members, faculty and sponsors are described in detail. Additionally an analysis of the cost for mass production of the automatic pill dispenser is discussed. As well as a break even analysis of the start up cost for the automatic pill dispenser.

15.1 2017-2018 Team Expenses

Throughout the first semester, the team did not spend any of their allocated $300 budget. The Proof of Concept that the team has presented for the Fall Semester was able to be completed without spending any money. The redesign of the android app was done on a free software. The redesign of the portable device was modeled and designed on SolidWorks. The Python Raspberry Pi code was able to be changed all on the board itself. The finances being presented are for both what the 2017-2018 team purchased and left, and the expected expenses during the second semester.

Table 7: 2017-2018 Teams Expenses

Item Description	Unit Price
12V Vacuum Pump	$21.95
Stepper Motors with Drivers	$13.99
12V Power Supply	$18.96
1/4” Vacuum Tubing	$6.05
4mm Vacuum Tubing	$8.99
16 GB SD Card	$14.98
Raspberry Pi 3 Model B	$34.81
Raspberry Pi 3 Power Supply	$9.99
Vacuum Tip	$6.22
Turntable Bearing	$10.71
Tubing Converters	$8.50
Stepper Motor Screw with Nut Slider	$22.99
Acrylic	$30.00
Epoxy	$5.00
Screws	$0.80
Brackets	$4.00
AWG 22 Gauge Wire	$15.99
AC/DC Power Supply	$13.99
Pressure Sensors	$10.50
Stepper Motor Driver	$4.95
Buck Converter	$9.95
Proto Breadboard	$4.50
Wire Housing	$1.95
Total	$279.97

In table 7, it can be seen that the team from last year came in under their $300 budget, spending only $279.97. The parts that they purchased were used to created the prototype that they left. This years team will be using as much of what is currently on the prototype as possible. Particularly, the Raspberry Pi board, the vacuum tip, and all of the motors when a new prototype is created. This is a large help for this years team because it will allow us to allocate our budget to other components.

15.2 2018-2019 Expenses

After finishing the semester, the team was successfully able to build a prototype with the following parts purchased:

Table 8: 2018-2019 Expenses

Item Description	Unit Price
Raspberry Pi 3B+	$34.99
Baomain 4mm ID x 6mm OD Peristaltic Pump Flexible Hose	$5.39
5V-6VDC Miniature Vacuum Pump Mini Air Pump	$8.99
Yosoo DC12V DC Micro Piston Vacuum Pump Mini Pump	$20.99
Micro Vacuum Pump Mini Negative Pressure Medical Air Pump 3V	$15.69
Total	$86.05

Based upon the teams expenses, all of the $300.00 was not completely used. The team only spent $86.05. This means that the team has $213.95 that was not spent. The 3D printers were offered as a resource by the College of Engineering costing a total of $0 to produce both the automatic pill dispenser and the portable device. If we had more time to develop the product further there would be more money spent since it is not ready to be to be sold on the market.

Table 9: Savings from reuse of 2017-2018 Supplies

Item Description	**Unit Price**
Stepper Motors with Drivers	$13.99
12V Power Supply	$18.96
Raspberry Pi 3 Power Supply	$9.99
Vacuum Tip	$6.22
Turntable Bearing	$10.71
Tubing Converters	$8.50
Buck Converter	$9.95
Proto Breadboard	$4.50
Wire Housing	$1.95
Total	$84.77

From reusing parts off of the prototype already created, the team was able to save $84.77 of the $300.00 budget. This was a significant amount and allowed for extra features to be added to the new prototype that was created.

15.3 Equipment and Facilities Cost

Table 10: Equipment and Facility Cost

Item Description	Unit Price	Number of Hours	Total Cost
Raise3D printers	$4.00 per hour	127 hrs	$428.00
Object 360 printer	$300 per hour	2.5 hrs	$750.00
Schneider Electric Computers and Software	$5 per hour	50 hrs	$250.00

The items listed in table 10 were all resources offered by the College of Engineering. There was a total of $0 cost to the team to use these resources. The hours stated are for the Spring Semester for all of the items were used to create the parts used in the testing process. These items also ended up being used to create the final prototype for the automatic pill dispenser, and portable device. In the Fall Semester, only SolidWorks was used to design the portable device and redraw the SolidWorks files for the automatic pill dispenser which was relatively the same amount of hours spent as in the Spring Semester.

15.4 Mass Production Cost

Table 11: Mass Production Cost Per Unit

Item Description	Unit Price
4.5 - 6V Vacuum Pump	$1.29
Stepper Motor with Drivers	$1.30 (qty. 2)
12V Power Supply	$6.00
Vacuum Tubing	$2.50, $1.25 per unit
2 GB SD Card	$3.54
Raspberry Pi	$10.00
Vacuum Tip	$5.00
Turntable Bearing	$1.11
Stepper Motor Screw with Nut Slider	$11.21
3D Printer Parts	$40.00
Wiring	$0.50
Stepper Driver	$3.96
Buck Converter	$7.96
Proto Breadboard	$0.50
Total	$94.87

After determining the price per unit when mass producing the product, the price per unit of the entire dispenser can be found to be $94.87. This cost per unit is down $0.29 from our teams previous estimated price per unit cost of $95.16. This slight decrease comes from the smaller vacuum pump and an anticipated pressure sensor that was $2.43 was removed. Although the price is down from the previous cost, the team was unable to cut the height of the dispenser down as much as initially anticipated. The expected cost of the 3D printed parts was increased by $5.00 from the original expected mass production cost.

The target selling price point was set to be $99.99 by our sponsor Bahram Nassersharif. Our mass production cost comes in just under this selling point. However, the profit per unit will only come out to $5.12 with this selling point. If the selling point is raised to $110.00 or $120.00, the profit margin will be much greater. Also, this mass production cost was calculated assuming that the housing and other plastic parts are 3D printed. If this product was ever brought into mass production, the housing will more than likely be injection molded. Injection molding is quite expensive up front to create the molding, but will decrease the price per unit significatly once manufacturing. This change will make the $99.99 selling price point much more realistic while maximizing the profit margin.

15.5 Human Resource Allocation

Throughout the year, the team worked on several tasks to get to the point we are at today. The task hours were broken up into scheduled class time, class assignments, and individual project related tasks outside of class. Scheduled class time includes group meetings, lectures given by Dr. Nassarsharif, presentations given to the class, and any other applicable activities in the scheduled lecture time. Class assignments are any assignments that the group must hand in to be graded both individually and as a team. These assignments include the Literature search, the Patent search, the 30 concept generation, the Critical Design Review Presentation, the Proof of Concept Presentation, the Build Test Review, the Build and Test presentation, Design Showcase and all weekly project plans and progress reports. Individual project related tasks include research, the android app development, the redesign of the portable device, the refinement of the Raspberry Pi Python code and the redesign of the dispenser housing. Each member on the team spent the approximate number of hours on this project over the semester as follows:

Table 12: Kyle McKenna Fall 2018 Hours

Task	**Number of Hours**
Scheduled Class Time	88
Class Assignment	24
Individual Project Related Tasks Outside of Class	49.5
Total	161.5

Table 13: Lyndsay Castle Fall 2018 Hours

Task	**Number of Hours**
Scheduled Class Time	88
Class Assignment	24
Individual Project Related Tasks Outside of Class	66
Total	178

Table 14: Brian McDonough Fall 2018 Hours

Task	Number of Hours
Scheduled Class Time	88
Class Assignment	24
Individual Project Related Tasks Outside of Class	55
Total	167

Table 15: Joe Jacobs Fall 2018 Hours

Task	Number of Hours
Scheduled Class Time	88
Class Assignment	24
Individual Project Related Tasks Outside of Class	33
Total	145

Table 16: Kyle McKenna Spring 2019 Hours

Task	Number of Hours
Scheduled Class Time	71.5
Class Assignment	12
Individual Project Related Tasks Outside of Class	117
Total	200.5

Table 17: Lyndsay Castle Spring 2019 Hours

Task	Number of Hours
Scheduled Class Time	71.5
Class Assignment	12
Individual Project Related Tasks Outside of Class	156
Total	239.5

Table 18: Brian McDonough Spring 2019 Hours

Task	Number of Hours
Scheduled Class Time	71.5
Class Assignment	12
Individual Project Related Tasks Outside of Class	130
Total	213.5

Table 19: Joe Jacobs Spring 2019 Hours

Task	Number of Hours
Scheduled Class Time	71.5
Class Assignment	12
Individual Project Related Tasks Outside of Class	130
Total	213.5

Based upon the titles that each member of the team has been assigned, the estimated cost of work over the entire school year can be calculated. Brian Mcdonough and Joe Jacobs were assigned to be Software Engineers. Kyle McKenna was assigned to be a Computer Engineer. Lyndsay Castle was assigned to be a Product Engineer. Each of their hourly wages were used according to the financial analysis presentation given by Professor Nassersharif.

Table 20: Total Cost for Fall 2018

Title	Quantity	Number of Hours	Price per Hour	Cost
Computer Engineer	1	161.5	$20,00	$3,220.00
Software Engineer	2	312	$20.00	$6,240.00
Product Engineer	1	178	$20.00	$3,560.00
Dr. Orr	1	2	$100.00	$200.00
Professor Marcoux	1	2	$100.0	$200.00
Dr. Nassersharif	1	4	$100.00	$400.00
Total				$13,820.00

After calculating the the cost per person based upon hours worked and hourly wage, the total cost of $13,820.00 was found. This cost is for the time spent on this project over the fall semester if everyone involved was actually employed as their hypothetical title.

Table 21: Total Cost for Spring 2019

Title	Quantity	Number of Hours	Price per Hour	Cost
Computer Engineer	1	200.5	$20.00	$4,010.00
Software Engineer	2	427	$20.00	$8,540.00
Product Engineer	1	239.5	$20.00	$4,790.00
Dr. Orr	1	1	$100.00	$100.00
Professor Marcoux	1	1	$100.00	$100.00
Dr. Nassersharif	1	8	$100.00	$800.00
Total				$18,340.00

The total cost per person for the spring semester came to $18, 340.00. The total cost is $4, 520.00 more than the total cost per person in the fall semester. The increase in price is from the spring semester being mainly focused on building, testing and reviewing the final prototype. More hours were spent per person completing the final prototype of the automatic pill dispenser and reminder.

15.6 Break Even Analysis

In order to start up the company and begin selling the dispenser, there is an initial cost associated. There are four engineers on the project that need yearly salaries to be paid. These engineers have been assigned the average base salary for each position according to Glassdoor.com. Also, there will be at least 2 warehouse employees needed to run the 3D printers and assemble the dispensers. These employees will get paid the Rhode Island minimum wage of $10.10. Initially, the engineers will have to help with assembly of the dispenser so the company does not have to pay any more factory employees. Since the housing of the dispenser is made from 3D printed material there will need to be quite a few 3D printers purchased to keep up with demand of the product. The team has selected the Lulzbot TAZ 6 to produce the housing. The team has requested at least 10 3D printers.

Table 22: Total Start Up Cost Approximation

Title	Quantity	Cost
Design Engineer	2	$66,227.00
Software Engineer	1	$108,541.00
Product Engineer	1	$84,739.00
Warehouse Employees	2	$21,008.00
3D Printers	10	$2,499.99
Price Per Unit	1	$94.87
Total		$392,844.81

After accounting for all of the engineers salaries, the warehouse salaries, the 3D printers, and the price per unit, the estimated start up cost has been approximated to $392,845.06. With this start up cost and the selling point of $99.99 is kept, the team must sell at least 81,335 units to break even. If the team increases the selling point to $110.00, the team will only have to sell 26,490 in order to break even. If the team increases the selling point even higher to $120.00, the team must sell 15,822 units to break even. Increasing the selling point to $120.00 seems to be the most realistic option as of right now. In one year, selling over 15,000 units seems like a bit of a strech, but is far more attainable than the amount of units needed to be sold at the $99.99 price point and the $110.00 price point.

16 Operation

Since one of the goals for the team this year was to make the app the single control point of the Automatic Pill Dispenser, the app can send commands to the machine without the use of a third party app. The app is designed in a way to make navigation easy and intuitive, although some explanation in a manual would make the user experience more straightforward. The product designed by Team 8 is not ready for the market, instead was created to troubleshoot and prototype, so there are still features to iron out. If someone were to buy an Automatic Pill Dispenser, they would need to set up the Raspberry Pi to connect with their WiFi, which can be a daunting task for those who are not tech savvy. Additionally, if the product were to be sold in the market, a safety manual would need to be produced, notifying the user of all possible safety factors if a malfunction were to occur. Also this would reduce the liability of the product for the customer was notified. Also a operator's manual would be produced, and would entail the set up of the device, as well as the smart phone application. A video of the set up may also be produced since the target market is older adults, and will be easier for the user to follow, and set up the device.

17 Maintenance

The Automatic Pill Dispenser is designed to have as little maintenance as possible throughout the device's lifespan. Along with other household and kitchen appliances, it is recommended that a user keeps the Automatic Pill Dispenser clean and clear of any debris. The Automatic Pill Dispenser was also not designed to allow the user to dissemble and perform maintenance by themselves, which could disrupt the accuracy or integrity of the machine, so the company or the machines' distributor would have a warranty to dissuade the user from doing so. After the lifespan of the device, the automatic pill dispenser will be discarded by being brought to a composting facility for it is biodegradable. The portable device will need to be chemically recycled for PMMA will be reduced to its original monomer unit of methyl methacrylate, from which new PMMA is created [28].

18 Additional Considerations

18.1 Economic impact

The purpose of this product is to help the consumer with medication adherence. If the consumer uses this product correctly, it could save them money on unused medications that they forgot to take, or medication that expires quickly. With the new design of the portable device, not all of the pills are exposed to the environment at the same time. Due to having individual compartments, the chances of losing all medication if the device were to be dropped is low. In the end this saves the user a majority of there money for they will only have to replace the pills dropped from that compartment when compared to the price of the medication in all of the compartments. This product will also be sold at a lower market price when compared to similar products. The lower price tag will allow the Automatic Pill Dispenser to compete against well established products that are on the market. The automatic pill dispenser will give potential customers the features they need to help with medication adherence but at a lower price.

18.2 Societal and Political impact

One of the effects this product could have is an increase in the independence and individuality of users of this product. Since some users may have trouble keeping track of medications, they often need help to organize their medications. With the introduction of the Automatic Pill Dispenser, they would no longer need the outside help and could regain some of their independence. For those who may not have trouble with the organization of medications, this would help with their adherence since this acts as a personal reminder. This would decrease the incidents caused by the lack of medication adherence. Since this product would have a relatively small scale production rate (Only those who take medications need this product, especially those who have to take multiple per day), there would not be much of a political impact.

18.3 Ethical considerations

Since this product will be dealing with the distribution of medication major ethical considerations must be taken into account. Accuracy and reliability are the most important factors of this product. If this product is released to the public and does not have near perfect accuracy and reliability, the developers of the product will be shown to have tainted morals. This will be deemed unethical, knowing that their product does not work properly since it could potentially be dealing with a users livelihood.

18.4 Health, ergonomics, safety considerations

Major health, ergonomic and safety considerations were huge factors considered in the development of the automatic pill dispenser and the portable device.

Health Considerations

Health is obviously at the forefront of these considerations since this product is directly dealing with the distribution of medication. If the medication is distributed in incorrect dosages or the dispenser simply distributes the incorrect medication to the user, there will be major health and safety issues. In some instances the incorrect dosage of particular medication can have fatal consequences. Elderly adults will typically put complete faith in this product and not second guess the dosage that is distributed, putting their health in the hands of the developers of this product.

Ergonomics Considerations

The ergonomics of this product was taken into consideration, for the device needs to be user-friendly, and overall improve the user's medication adherence experience. The egronomcis is more focused on the user's home environment rather than their workplace. The ergonomics of the portable device provided the largest challenge. The team was looking to make the device as ergonomic as possible while not taking away from the device's ability to store pills properly. The team wanted the user to comfortably be able to put the device in either their pocket or bag. Also, the team wanted the flaps on the top of the device to be opened as easily as possible. Since the target market of the product is elderly adults, commonly having dexterity issues, the flaps were designed to ensure there is limited trouble with opening them. Additionally, the design of closure for the portable device needed to be as simple as possible. The twist and lock design will allow users with arthritis, or weakened muscles to have little to no stress. Another ergonomic consideration that was taken into account was how easy the device will slide into the dispenser. The team wanted the user to be able to have no issue when placing the device in the dispenser.

Safety Considerations

Additionally, having a product dealing with drugs, the product needs to be regulated by the FDA. For safety considerations, the materials used need to be food safe, for the medication will be consumed through the user's mouth. If the product were to go into production, this would be an important consideration because the medication stored within the pill dispenser and portable device will be in direct contact with the material. For the final prototype the material used to make the portable device is PMMA and is considered food safe by the FDA. However, the automatic pill dispenser is made out of PLA, which at this time has not been recognized by the FDA as food safe. The material of the automatic pill dispenser will need to be made out of food safe material to avoid facing safety liability lawsuits.

18.5 Environmental impact and Sustainability considerations

Environmental and sustainability were considered while designing this product, for after its lifespan, the automatic pill dispenser will need to be discarded. One issue that the team had to consider is if the dispenser or portable device had any chance of allowing medications into the environment. This was more so considered for the portable device because if the device was ever to be dropped and medication was to fall out, the medication would be free in the environment. This could potentially cause harm to the environment in either the long term or short term, for most pills are not biodegradable. Another issue that should be considered is the material that the dispenser is made from. Assuming that at the end of the products lifetime it will be discarded, the material of the dispenser should be as environmentally friendly as possible. The material used in the final prototype for the automatic pill dispenser is a biodegradable, environmental-friendly, and a sustainable material. The automatic pill dispenser can be brought to a composting facility at the end of its lifespan. Additionally, the material used for the portable device is recyclable and a sustainable material. The portable device will be chemically recycled, using the existing PMMA to produce more. Therefore, our goals of achieving an environmental, and a sustainable product was achieved.

19 Conclusions

Team 8 was tasked with working with the product designed by last year's team and picking up where they left off by further optimizing and improving their design. The team has made great progress over the course of the fall and spring semester and has improved many aspects of the device. When improving the device, the design specifications set for the device were kept in mind. These specifications are addressed in more detail below.

19.1 Target Market

The target market for the device is older adults or anyone who takes many types of medications. Older adults usually do not take their medication correctly for there are many types of medication taken, with all having different sets of directions. Most of these adults need assistance when it comes to taking medication correctly. As the device was created the target market for the device played a huge role, and this requirement was met. The simplicity of the design was also kept in mind for older adults will be using this product.

19.2 Service Environment

The device is designed for home use, and therefore will be used in a home environment. The device will be used most likely in a kitchen, bathroom, or bedroom. The device will be exposed to average room temperature (60 to 80 degrees Fahrenheit) and must provide protection to the pills from humidity fluctuations.

19.3 Physical Description

Design changes have been made to the automatic pill dispenser. The size of the device was reduced by a smaller linear actuator motor was purchased. The middle tier was also redesigned by omitting the door, for this is an extra step that is not needed. Additionally, the cutout for the potable device is now centrally located in the middle tier. Also, the dimensions for the middle tier were altered to house the portable device which increased in size when compared to the previous device. Lastly, the third tier was revised by including built-ins that organized the breadboards and wires.

19.4 Key Features

Key features, such as the portable device, and the ability to dispense four different types of pills, each in under thirty seconds, have all been met. Other key features, such as the reminders and notifications through the smartphone application that will connect with the user's smartphone device is functional. The smartphone application has been created, and users are able to use to operate the device, as well as store additional medical information for their personal records. As for all the key features implemented into the device, great progress has been made on the portable device to be more user-friendly and the overall functionality of the automatic pill dispenser with the use of the smartphone application.

19.5 Training

Great progress, as already stated, has been made with the smart-phone app and Raspberry Pi integration. These two features were designed and optimized with user-friendliness in mind, so the design requirement for a simple training process and an overall easy-to-use device will be met. The user will only need to take 30 minutes to set up the device with their medications, as well as set up the phone application.

19.6 Manufacturing and Financial Requirements

The manufacturing and financial requirements have been met as minimal changes have been made in terms of the casing or hardware components, so the manufacturing process as well as the cost increased slightly. The team was able to reuse most of the materials bought from the previous team which helped save money in the team's budget. 3D printing was used for the prototyping process, but once the design is finalized injection molding could be used for mass production. This would be a high start-up cost but it would reduce the price per unit once it is underway.

19.7 Potential for Commercialization

The automatic pill dispenser does have potential to be sold on the market. However, at this point the automatic pill dispenser is not ready to be sold on the market. The automatic pill dispenser will first need to be approved by the FDA. The PLA filament used to produce the automatic pill dispenser is not considered food safe by the FDA due to unknown additives used to strength and enhance the color of the PLA filament. The filament would need to be changed to a food safe material approved by the FDA, or change the manufacturing process of the automatic pill dispenser. The portable device that is a feature apart of the automatic pill dispenser would be approved by the FDA for it is made out of PMMA. However, since the two devices are sold together the automatic pill dispenser would need to be revised to an FDA approved material. Comparing the automatic pill dispenser to its competitors it is stand outs out for it include similar features but sold at a lower price.

19.8 Next Steps

One of the bigger steps for this project would be to implement all planned features for the app, described in the Redesign section of this report. The team had neither the experience nor the time to implement the original features. This was due to the fact that the team spent most of their time learning how to use and implement the Android and Raspberry pi software. The next step for the portable device would to redesign the top to have not have a pin-hinge assembly. The pin-hinge assembly causes extra labor hours which is more money spent, therefore to omit the assembly money can be saved. Additionally, the next step for the automatic pill dispenser is to redesign the look of it. The automatic pill dispenser needs to be more appealing to the eye if it is going to sell on the market. Also an LCD screen could be built into the front of the automatic pill dispenser. This allows users who are not technological advanced in the smartphone area an opportunity to use the automatic pill dispenser. Lastly, to comply with the regulations set by the FDA, the material for the automatic pill dispenser will need to be changed to a food safe material approved by the FDA.

20 References

[1] Anon, 2014. Steiger Has Created the First Pill Case Specifically Designed For Travel. PR Newswire, pp.PR Newswire.

[2] Han-Yao H., Maureen M.G., Edgar M.R., Lawrence A.J., 15 October 2000, ”Impact of Pill Organizers and Blister Packs on Adherence to Pill Taking in Two Vitamin Supplementation Trials,” American Journal of Epidemiology, **152** (8), pp. 780–787.

[3] Zedler B.K., Kakad P., Colilla S., Murrelle L., Shah N.R., January 2011, ”Does Packaging with a Calendar Feature Improve Adherence to Self-Administered Medication for Long-Term Use? A Systematic Review,” Clinical Therapeutics, **33** (1), pp. 62-73.

[4] Mahtani, K.R. et al., 2011. Reminder packaging for improving adherence to self-administered long-term medications. Cochrane Database of Systematic Reviews, pp.Cochrane Database of Systematic Reviews.

[5] Cohen-Mansfield, J., Creedon, M. A., Malone, T. B., Kirkpatrick, M. J., Dutra, L. A., Herman, R. P., 2005. Electronic Memory Aids for Community-Dwelling Elderly Persons: Attitudes, Preferences, and Potential Utilization. Journal of Applied Gerontology, 24(1), 3–20. http://doi.org/10.1177/0733464804271277

[6] Vervloet, M., Dijk, L. V., Santen-Reestman, J., Vlijmen, B. V., Bouvy, M. L., Bakker, D. H. D.,2011. Improving medication adherence in diabetes type 2 patients through Real Time Medication Monitoring: a Randomised Controlled Trial to evaluate the effect of monitoring patients medication use combined with short message service (SMS) reminders. BMC Health Services Research, 11(1). http://doi.org/10.1186/1472-6963-11-5

[7] Fung, W.T., Chan, W.L., July 5, 2016, ”Pillbox, medication management system and medication dispensing system,” 9,381,139, USPTO Patent, Hong Kong.

[8] Priebe, R.N., Noble, T.O., June 17, 2008, ”Detachable pill container” 7,387,207, USPTO Patent, Apothecary Products, Inc., Burnsville, MN.

[9] Goldman, K.N., September 2, 2010, ”Daily Dose Personal Pill Dispenser” 20100219198, USPTO Patent Application, ALSTON BIRD LLP, NY,NY.

[10] Lim, J., January 28, 2003, ”Programmable automatic pill dispenser” 6,510,962, USPTO Patent, Oakland, CA.

[11] Bell-Greenstreet, D. L., Decemeber 18, 2001, ”Automatic medication dispenser”, 6,330,957, USPTO Patent, Green Valley, AZ.

[12] Lehmann, C., Brittelli, J., Chen, C.H., Kehoe, T., Barnikel, R., November 14, 2017, ”Home medication manager ”, 9,814,653, USPTO Patent, The Regents Foundation for The State University of New York, Albany, NY.

[13] Litton, L.J., May 29, 2018, ”Pill dispenser with compliance features”, 9,980,880, USPTO Patent, Scottsdale, AZ.

[14] Hutchinson,K., Self, A., Inabet,J., Milton,M., Bergeron,M., July 13, 2010, ”Vacuum pill dispensing cassette and counting machine,” 7,753,229, USPTO Patent, Pineville,IA.

[15] Gerold,W.O., Gerold, W.J., December 1, 2009, ”Automated pill-dispensing apparatus,” 7,624,894, USPTO Patent, Bridgman,MI.

[16] Metzger, C. E., Norton, P., February, 2014, The Building America Indoor Temperature and Humidity Measurement Protocol. https://www.nrel.gov/docs/fy14osti/61040.pdf

[17] Ruscin, J. M., Linnebur, S. A. Aging and Drugs - Older People’s Health Issues. https://www.merckmanuals.com/home/older-people’s-health-issues/aging-and-drugs/aging-and-drugs

[18] Medication management for older adults., May 4, 2017, http://www.bemedwise.org/medication-safety/medication-therapy-management-for-seniors

[19] Preidt, R., June 30, 2016. Why Some Seniors Don’t Take Their Meds., https://consumer.healthday.com/senior-citizen-information-31/misc-aging-news-10/why-some-seniors-don-t-take-their-meds-712253.html

[20] Eccenter diaphragm pumps (EC). https://www.schwarzer.com/pages-en/en-prod-start-gas-ec.php

[21] Product Classification. https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpcd/classification.cfm?id=2782

[22] Center for Food Safety and Applied Nutrition. Determining the Regulatory Status of Components of a Food Contact Material. https://www.fda.gov/food/ingredientspackaginglabeling/packagingfcs/regulatorystat usfoodcontactmaterial/default.htm

[23] Is 3D Printed PLA food safe?, https://reprage.com/post/36869678168/is-3d-printed-pla-food-safe

[24] Pitt, K. G., Heasley, M. G.,2011, December 29., Determination of the tensile strength of elongated tablets. Retrieved December 16, 2018, https://www.researchgate.net/publication/256832320-Determination-of-the-tensile-strength-of-elongated-tablets

[25] Product Categories Acrylic (PMMA) – Performance Plastics., http://www.performance-plastics.co.uk/product/classification/acrylic-pmma/

[26] Slijkoord, J. W., 2015. IS RECYCLING PLA REALLY BETTER THAN COMPOSTING? https://3dprintingindustry.com/news/is-recycling-pla-really-better-than-composting-49679/

[27] 2018. ”TITLE 21–FOOD AND DRUGS.CHAPTER I–FOOD AND DRUG ADMINISTRATION. DEPARTMENT OF HEALTH AND HUMAN SERVICES.SUBCHAPTER B–FOOD FOR HUMAN CONSUMPTION (CONTINUED)” **3** CFR - Code of Federal Regulations Title 21., https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm?fr=177.1010

[28] Sustainability.PMMA / Acrylic Sustainable Solutions., https://www.pmma-online.eu/sustainability/

21 Appendices

21.1 Android App Code

Android Application Source Code

Source Code for the Android Application can be found on the Capstone Design 2018-19 Sakai Site under 'AppSourceCode'.

RaspberryPi Source Code

Source Code for the Raspberry Pi can be found on the Capstone Design 2018-19 Sakai Site under the 'Raspberry Pi Code' folder.