Engineering 1182 SP21

Technical Design Review

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Executive Summary:

In an age of advanced medicine and high standards of medical safety, the vaccine administration process continues to struggle with several large threats to patient health and overall safety. In addition to this, the process has continued relatively unchanged since its adoption in the mid 1800's. The team saw this as an opportunity to innovate and create a product that aids in delivering vaccinations in a safer, faster, easier, and more effective way. The team sought to not only improve the vaccination experience for patients, but also for the administrator.

Through interviews, prototypes, and intense testing, the team considered many different design options. It was found that administrators desired a product that was simple and cheap, but also effective and robust. Users desired a product that was safe and trustworthy. The team settled on the design that is detailed in this report, as they believe it will most effectively serve both the patient and administrator. The product accepts most standard syringes, uses a simple screw-in mechanism to securely hold the syringe, aligns the syringe with the patient's arm and ensures that it is at a 90 degree angle, and safely holds the syringe and needle until they are disposed of. The initial reception of this design has been overwhelmingly positive, and the team sees it as the first major advancement in the vaccination process in almost two centuries. As has been previously detailed, this product will reduce the time and training required to administer a vaccine and make the process safer. However, the team also plans on implementing this product in undeveloped markets where vaccinations are much less common. They believe that this product will allow more people and a greater diversity of people to be vaccinated than ever before.

The product was given a specific set of requirements that it needed to fulfill before the team would be able to make a decision as to whether it was market-ready. The specific requirements are detailed in the report, but were formulated from what the team found to be its user's needs. These tests were conducted to ensure the product would be safe, robust, and convenient to use. After conducting testing, the team found the product to excel in every area tested. This not only proves that the product is safe and trustworthy, but also that it will be of serious genuine use for its intended customers. Following these successful tests and the positive feedback that this product received, the team can confidently recommend it for the medical market.

Problem Definition Review:

Introduction

Hundreds of millions of vaccines are administered in the United States annually. Regular and safe vaccinations are a cornerstone to quality healthcare. Because vaccines occupy such an essential role, it is crucial that the vaccination process be as simple, safe, and accessible as possible. Especially in regard to the Covid-19 pandemic, understanding and overcoming the faults in the current vaccination process is necessary to ensure public protection.

Through the team's research it was found that the current vaccination process is slow, requires high-level training, and can be unsafe, among other issues. This presents an opportunity to propose a solution that would not only cater to the commercial medical market, but also make vaccines available to individuals who cannot or prefer to not enter a doctor's office or pharmacy. A useful amendment to this process would be invaluable because it would not only increase accessibility, but decrease safety hazards and other major concerns.

Problem Definition

To fully understand the needs to which a solution would need to serve, one must understand the current strengths and weaknesses of administering a vaccine. An effective method for conveying this information is a user experience chart. This chart ranks actions in the vaccination process on a scale from entirely positive (++) to entirely negative (--). As can be seen on the chart, the areas in which current vaccines struggle most are: finding the correct spot, sanitizing the surface, inserting the needle, and time taken. A proposed solution should work to improve each of these areas. Strengths in the current process include: production cost of a syringe, disposing of the needle, effectiveness of drug delivery, and public reputation. A proposed solution should be careful to compromise these areas as little as possible while trying to improve the others. If possible, an ideal solution would continue to improve upon these strengths.

Table 1. User Experience Chart

Experience /Level	Finding the correct spot	Sanitizing the surface	Inserting the needle	Time taken	Production cost of a syringe	Disposing of the needle	Effectiveness of drug delivery	Public reputation
++					++		++	
+						+		+
0		0						
-				-				
--	--		--					

From the information gathered by creating the user experience chart, the team created a list of pains that they plan on eliminating with their solution. These pains fall under three categories: accessibility, resource management, and safety. Through research, it became clear to the team that those who need vaccines most often also have the most trouble leaving their homes to get one. Vaccines are also an inefficient use of resources. Although the drug in a syringe is the most expensive component, needles, safety mechanisms, and even the syringe itself significantly contribute to vaccine prices. By nature of being a disposable product, these plastic, metal, and rubber components are produced for one-time use before being discarded. Additionally, vaccinations require a nurse to administer them. If this task could be done without highly trained labor, it would allow for medical professionals to spend their time in other ways. Safety is another concern when considering the process. Sanitization, injection accuracy, and general needle safety are all pains associated with vaccinations.

A solution to this issue would also introduce users to a set of gains which were unavailable with the previous method. The solution could speed the vaccination process, increasing convenience and decreasing wait times. Convenience could also be increased by creating a solution that allows a user to get a vaccine without leaving their home. If reusable, it could be built to a higher safety standard than current disposable vaccines. The solution could also make immunizations available to a greater number of people than ever before.

Now having a more thorough definition of the issue and how this process can be improved, the task of this project can be stated with greater specificity. The team seeks to provide a solution that will administer vaccines in a manner that is able to reach the public quickly and reduce necessary manpower. This solution will address safety concerns, increase accessibility, and be more environmentally friendly than the current alternative. Through this solution, the opportunity of increased societal value becomes apparent, since keeping as many people safe as possible is a main goal of a society.

End Users

After understanding the specifics of the issue being addressed, it is also important to understand the end user. Generally, the end user of this product would be anyone administering or receiving a vaccine. However, it will most specifically impact someone like the user persona Susan. Susan is a 27-year-old nurse working for the Cleveland Clinic. The health of her patients and success of her department of the hospital are her utmost concerns. Because of this, she enjoys efficiency and order. She dislikes wasted time and unwise resource management. Susan wants a simple solution that will be easy to integrate into her tried and true patient routine.

Figure 1. Persona Graphics

Susan and other users have specific needs regarding a solution that need to be met to ensure they will be open to adopting it. These needs are discussed and ranked in the user need chart below.

Certain needs have specific contingencies that need to be met if the proposed solution is to be successful. For example, the new solution cannot be any less effective than the current vaccination process. Nurses and the general public have an understanding of the current effectiveness of vaccines and will be unwilling to adopt a product that has any evidence of being less effective. However, when considering price, it is understood that a reusable device will be more expensive than an individual disposable syringe. Different needs have differing levels of importance and urgency.

Table 2. User Needs

User Need	Description	Ranked Importance
Simple	Users need the solution to be simple. Nurses are not going to adopt a product that is more complicated than their current method, and users are not going to want to self-inject with a complicated machine.	3
Ease of Use	The solution needs to be easy for home users and professionals alike to administer. This will ensure that it is still widely accessible.	5
Effectiveness	The solution must be an effective method of introducing a vaccine into a patient. It cannot be any less effective than the current method.	4
Inexpensive	The solution should not be unaffordable for hospitals to buy in bulk or for home users to personally purchase.	2
Safe	The solution needs to prioritize safety for the patient and administer.	5
Speed of Use	The solution needs to work quickly.	5
Saving Materials	The solution cannot be wasteful and must save significantly more material than the alternative.	3
Environmentally Friendly	The solution must be reusable and minimize disposable parts.	1

Although a ranking can be arbitrarily assigned to these needs given previous research, it is more accurate to mathematically weigh them against each other. This can be done in a pairwise comparison chart. This chart pins one category against another until they have all been compared. As can be seen below, safety, effectiveness, and saving materials were ranked higher than expected. All other categories were ranked slightly lower than expected, excluding ease of use. This ranking technique helped demonstrate where actual priorities may differ from simply what was noticed in research.

Table 3. Pairwise Comparison Chart

	Simple	Ease of Use	Effectiveness	Inexpensive	Safe	Speed of Use	Saving Materials	Environmentally Friendly	Total	Normalized	Original
Simple		0	0	1	0	0	0	1	2	1.7	3
Ease of Use	1		0	1	0	0	1	1	4	3.0	5
Effectiveness	1	1		1	0	1	1	1	6	4.3	4
Inexpensive	0	0	0		0	0	0	1	1	1.0	2
Safe	1	1	1	1		1	1	1	7	5.0	5
Speed of Use	1	1	0	1	0		0	1	4	3.0	4
Saving Materials	1	0	0	1	0	1		1	4	3.0	3
Environmentally Fr	0	0	0	0	0	0	0		0	1.2	1

Market Character

Beyond end users, other individuals will be affected by this product. One category of those individuals are the stakeholders. The stakeholders for this project include vaccine administrators who could be replaced by a new solution. If users widely adopt home vaccinations, nurses will be administering them less frequently. Although some may view this negatively, it is mainly positive as it frees their time for other more urgent tasks. The elderly who are most affected by diseases are also stakeholders. If there was a solution that allowed them to receive a vaccine without leaving the safety of their own home, personal safety would improve. Vaccine distributors and producers who could expand their market by reaching more people also hold stake in this issue. The team intends to produce a solution that can be shipped, even to remote areas. This would increase market size and sales for distributors. The producers of syringes and other products involved with the current vaccination process are also stakeholders, as they would likely lose business from the proposed product.

Similar to having an understanding of the parties involved, the number of potential users must also be considered. About 94 million adults in 2018 got a flu shot. About 33 million elderly adults get pneumococcal vaccines every year. These two statistics are isolated examples of vaccine markets, but even still amount to over 100 million users. Information varies as to market size for other vaccines, or for children's vaccinations, but the entire market is easily in the hundred millions. However, realistically speaking, this product is not going to immediately capture the entire market. It is anticipated that it will be most popular among the elderly and in hospitals, with an immediate market size of 50 to 100 million.

There is little competition in this market space, which is not uncommon for medical products. There are no current competitors creating a product that attempts to innovate the vaccine as the team's does. Other competitors include the current method of administering a vaccine, opting out of vaccines, and essential oils/alternative medicine. Comparisons with the current method of vaccinations have already been heavily discussed. Users not getting a vaccine at all is a surprisingly large competitor. Many vaccines still have a public reputation as being optional. Although this product will not change public opinion about the drugs themselves, it will remove as many other motives as possible to keep this group from getting vaccinated. Alternative medicine has seen a recent rise in popularity and has successfully decreased some vaccination numbers. A large motivator for this is a distrust in the safety of the process, which this product looks to solve. As can be seen in the table below, there is not a current solution that is safe, effective, inexpensive, and easy/quick to use. Certain competitors achieve a mix of these factors, but all fall short on their totality. This provides solid evidence that there is a need for a product that can continue to perform well in the areas where the current process excels, but also improve upon the aforementioned categories.

Table 4. Competitive Matrix

User needs	The current way of getting a vaccine from a medical professional	Not getting a vaccine at all	Essential oils/Alternative medicine
Simple	☆	☆	X
Inexpensive	X	☆	X
Safe	☆	X	X
Effective	☆	X	X
Environmentally friendly	☆	☆	☆
Easy of use	X	☆	☆
Speed of Use	X	☆	X
Saving Materials	X	☆	X

Research Results

To further understand the need for the team's solution, primary research must be completed. A diverse user group can be found by recognizing the several different applications of our product. These applications include not only individuals in the medical field but also everyday users. Users in the medical field can be contacted by reaching out to the Wexner Medical Center or by taking advantage of group members' personal connections. Individual take-home users can be contacted by interviewing anyone who is unopposed to the idea of vaccines. Once a list of contacts is assembled, the team will reach out to them to begin the interview process. The group plans to gain consent before asking any questions, to let interviewees know that they can opt-out of questioning at any time, will not use their full names/pictures or videos of their face, try to talk to them in their most comfortable environment, and let them know what their feedback will be used for. Mr. Vukovic and Mr. Jablonski are questioners, while Mr. Little and Mr. Overbey are recording data.

Regarding specific questions, there will be two different sets for the medical field and the general population participants. The medical field participants will be asked the following questions: What are your biggest issues with giving vaccines? What are the most important practices when giving a vaccine? What training do you go through (how long, what do you learn, etc) What training could be eliminated with a product? What do you think the biggest reason is that people don't get shots? What part of the vaccination process takes the most time? The general population participants will be asked the following questions: Would you be comfortable administering a vaccine to yourself? What would make you more comfortable? What is your biggest concern when getting a vaccine? What's your biggest reason for not getting shots? Or if you do, what are the biggest pains of getting the shot? Would you be willing to pay more (insurance or out of pocket) to have the vaccine process be more convenient/easy? Would you rather have a vaccine administered by a professional or a well-researched device? It is important to note that these questions may be altered based on the nature of the interview. For example, if a participant is a member of the medical field who has knowledge about vaccines but has never actually given one, their questions will be changed. However, in the instances where this happened, a note will be made in the raw interview data.

In addition to first-hand interviews, secondary research must also be collected to fully understand this issue. Fortunately, the current vaccination process is well documented and secondary sources on the topic are plentiful. Much research has already been assembled on the topic, which simplifies the process of gathering information on the issue.

Deborah Wexler [1] explains people's reliance on vaccines being administered "safely, effectively, and correctly", and it explains the importance of these aspects. It also talks about how a prominent problem in this industry is the inadequate training of vaccine administrators.

This site gives the statistic that “VERP received 1,256 confidential reports of vaccine errors from September 2012 through June 2015.”

An article from Tableau Public [2] helps us as researchers get an idea at how expansive our product is and the number of people that we can reach. Knowing that we are going to be targeting a massive audience affects nearly every part of the design process because it adds another element that we need to meet for our product. For example, our product must be scalable and easy to distribute if we have any chance of reaching a large audience.

The article, “Parents With Doubts About Vaccines: Which Vaccines and Reasons Why“ [3], explains some of the reasons that parents don’t vaccinate their kids. The article dives into specific vaccines and some of the fears or concerns that parents have with that vaccine. This is important data to have because if we can try to make a product to alleviate specific concerns that parents hold, then we can not only tap into the existing vaccination market, but also tap into a part of the market that the current system is not in.

A news article on MedCityNews [4] explains that the majority of the issue with the current COVID-19 vaccine lies in administration of the vaccine rather than solely in distribution. It explains that means of administration is slowing down the process, preventing many people from receiving a much needed vaccine.

The article titled “What is ‘confidence’ and what could affect it?: A qualitative study of mothers who are hesitant about vaccines“ [5] collects qualitative data about why new mothers aren’t confident in getting their children vaccinated. These same people are the same type of people who do not get themselves vaccinated. Once again this is an important market to understand because if we could reach a market that is not currently being reached then that would show that our product has a place in a seemingly already well-defined system.

“Why the COVID 19 vaccine rollout is so slow” [6] speaks on the issue of vaccine distribution and administration regarding the current COVID-19 problem. The article states that according to the CDC, as of January 6 over 21.4 million doses of the vaccine have been distributed, but only about 5.9 million people have received at least 1 dose.

The article “A Drive-through Simulation Tool for Mass Vaccination during COVID-19 Pandemic” [7] discusses the drive-through system that is planned to be used/being used to administer the covid vaccine. Understanding the positives and negatives about this system of administration could greatly improve our product. Taking the good and attempting to eliminate some of the bad with our product is the key to reaching a large number of people. It is important to understand that for our product we cannot simply make it as good as the current system, but we need to make it better.

An article titled “Evaluation of a template for countering misinformation—Real-world Autism treatment myth debunking” [8] discusses not only the issue of misinformation about vaccines, but also how to combat this misinformation. Understanding the misconceptions out there is key for our product, being able to target and hopefully debunk these misconceptions with a new product is not easy, but can be very effective. The largest reason that people fear vaccines is their lack of knowledge of them, making a product that could help people feel safer about vaccines would help our product succeed greatly.

Following the collection of this data, conclusions can be drawn based on the results found. Regarding primary research, the medical field interviewee list included: three nurses and a pharmaceutical student. Members of the general public interviewed included: four college students. All interviewees were personal connections of group members, either professionals in the medical field or peers. From the questions presented earlier, the team was looking to obtain information on the most important aspects of vaccinations to look to improve them through the proposed product.

When talking to medical professionals, the team asked about points of friction in the process, general practices and training, fears of the general public, and the efficiency of the process. Through these questions, the team intended to gain a more full understanding of how vaccinations could be improved. When talking to peers, the team asked about their personal perception of vaccines, fears involved with the process, the economics of improving the process, and their overall openness toward our idea. Through these questions, the team was seeking to gauge public interest and understand how deeply rooted this issue truly was.

The first set of interview results found that medical professionals largely agreed that patient fear is one of the greatest challenges related to giving vaccines. They also agreed that when giving a vaccine, sterilization was an utmost priority, followed by patient safety and comfort. Training included learning about the process in medical/nursing school as well as getting hands-on experience. It was found that patients who avoid shots do so out of fear that professionals believe is often irrational. There was unanimous agreement that the preparation phase was more time-consuming than the actual shot-giving process.

Results from the general population were much more conflicted. These interviewees did agree that they would like thorough education before considering self-injection. They also agreed that their largest fear associated with vaccines was aftereffects. Their reasons to avoid shots included the physical pain associated with the process and the inconvenience of going to the doctor’s office. Results were mixed on whether they would pay more for the process to be improved, but most agreed that they were currently more satisfied with medical professionals administering their vaccines.

Value Proposition

Following data collection, it is important to weigh results with initial assumptions and research findings. Overall, no data results required the team to seriously reconsider the task or general solution. However, certain findings did adjust how the team approached specific design items. For example, user pain was discussed much more than anticipated and will have a definite influence on the final design. Following these new findings, the user experience chart from above was revised.

Table 5. Revised User Experience Chart

Experience /Level	Finding The Right Spot	Sanitization (in general)	Needle Insertion	Time It Takes	The Production Cost of a Syringe	Disposing of the Needle	Effectiveness of Drug Delivery	Public Reputation	Customer Accessibility
++					++		++		
+						+		+	
0									
-		-		-					-
--	--		--						

Millions of adults across the United States skip on their vaccinations out of fear, inconvenience or discomfort. The team seeks to produce a product that will help to make vaccinations more accessible, safer, faster, and easier. User convenience will see a large increase with this product, and users will be able to receive a vaccine without ever having to leave their house. The team plans to reach not only the current market of those who get vaccines but to also break into the market of those skeptical about the immunization process. As with all new medical products, the team does not expect their solution to have immediate widespread adoption, but does expect it to capture a sizable portion of the commercial market upon release. As its reputation among the general public grows, the team sees expansive growth of the product's home market share inevitable.

While discussing the issue with medical professionals, it was found that patient safety and sanitization were two of the greatest concerns when giving a vaccine. The solution will include a method for protecting the needle prior to and following an injection to ensure safety in these areas. The team will also work to streamline the distribution process of our product, as many nurses claimed that was their greatest annoyance with the current state of vaccines. The product will also be simpler to use and require less training than a traditional syringe, increasing its applications in the medical field.

When talking with the general population, there was an overall hesitancy associated with the idea of self-injection. To help speed the adoption process of this product, thorough education materials will be provided in video form. Most interviewees complained of the physical pain of receiving an injection, so the product will concentrate on providing a less painful user experience. The process of ordering and receiving the product will also be made as simple as possible, to maximize user convenience.

Conceptual Design Review:

Brainstorming Concept Design

The concept design process began with the team making sketches in notability. The team began by working independently on designs that they thought would best serve the needs of users. These designs were then compared and important features on each were discussed. After, the team each drafted a revised version of the initial design.

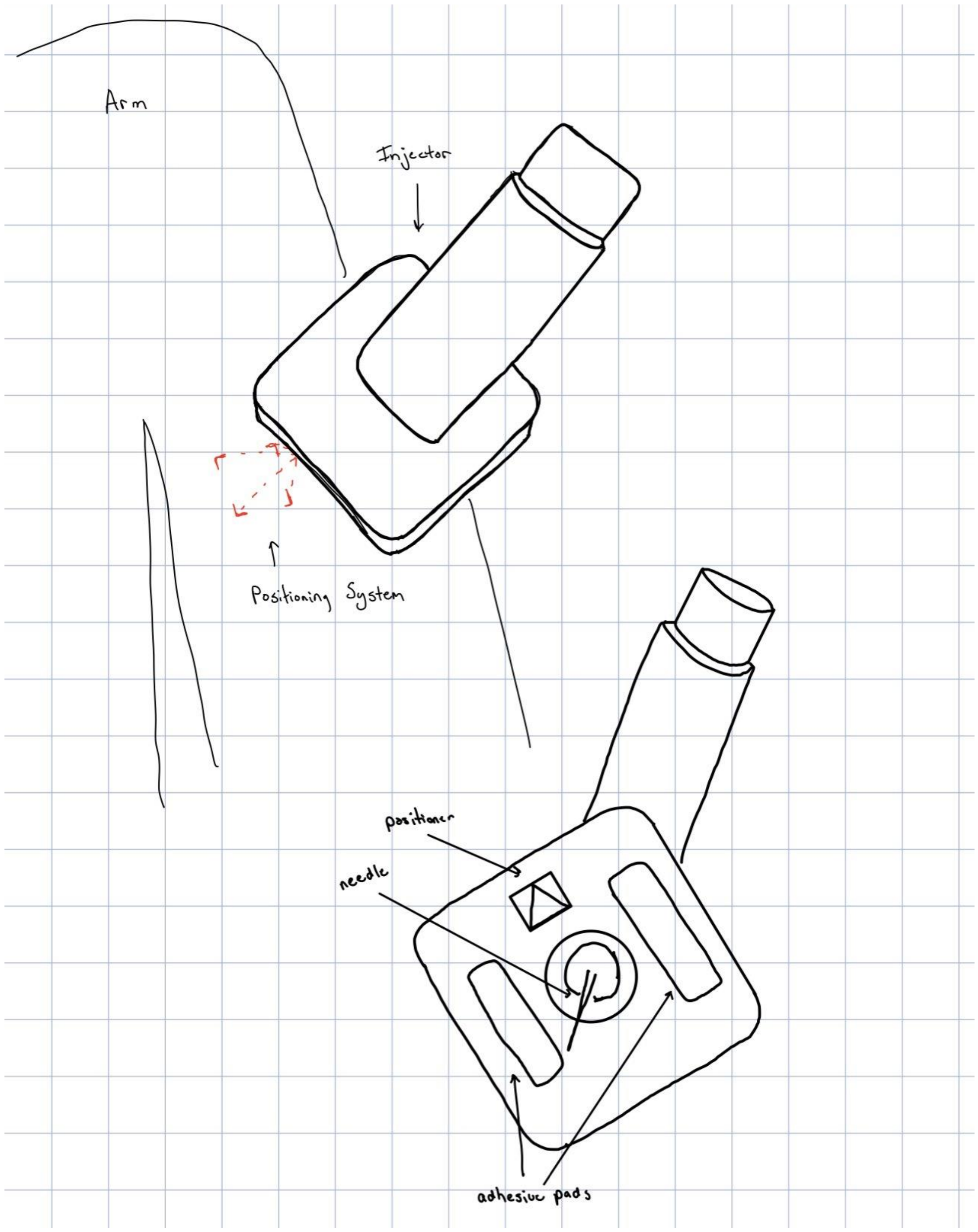
The team generated ideas, keeping in mind both in hospital and domestic use. After consulting potential users, certain designs like the cartridge system seemed to be more applicable to an at-home user since they value convenience whereas systems that use a standard syringe seemed to be more applicable for hospital use since they value compatibility more. The user needs have not changed because everything that was important to users is still just as important but, it is important to keep in mind that certain needs may be more relevant in different fields. Namely, users that would be using the device domestically and more commercial use. The lack of alteration to user needs is reflected in the table below.

Table 6. Updated User Needs

User Need	Description	Ranked Importance
Simple	Users need the solution to be simple. Nurses are not going to adopt a product that is more complicated than their current method, and users are not going to want to self-inject with a complicated machine.	3
Ease of Use	The solution needs to be easy for home users and professionals alike to administer. This will ensure that it is still widely accessible.	5
Effectiveness	The solution must be an effective method of introducing a vaccine into a patient. It cannot be any less effective than the current method.	4
Inexpensive	The solution should not be unaffordable for hospitals to buy in bulk or for home users to personally purchase.	2
Safe	The solution needs to prioritize safety for the patient and administer.	5
Speed of Use	The solution needs to work quickly.	5
Saving Materials	The solution cannot be wasteful and must save significantly more material than the alternative.	3
Environmentally Friendly	The solution must be reusable and minimize disposable parts.	1

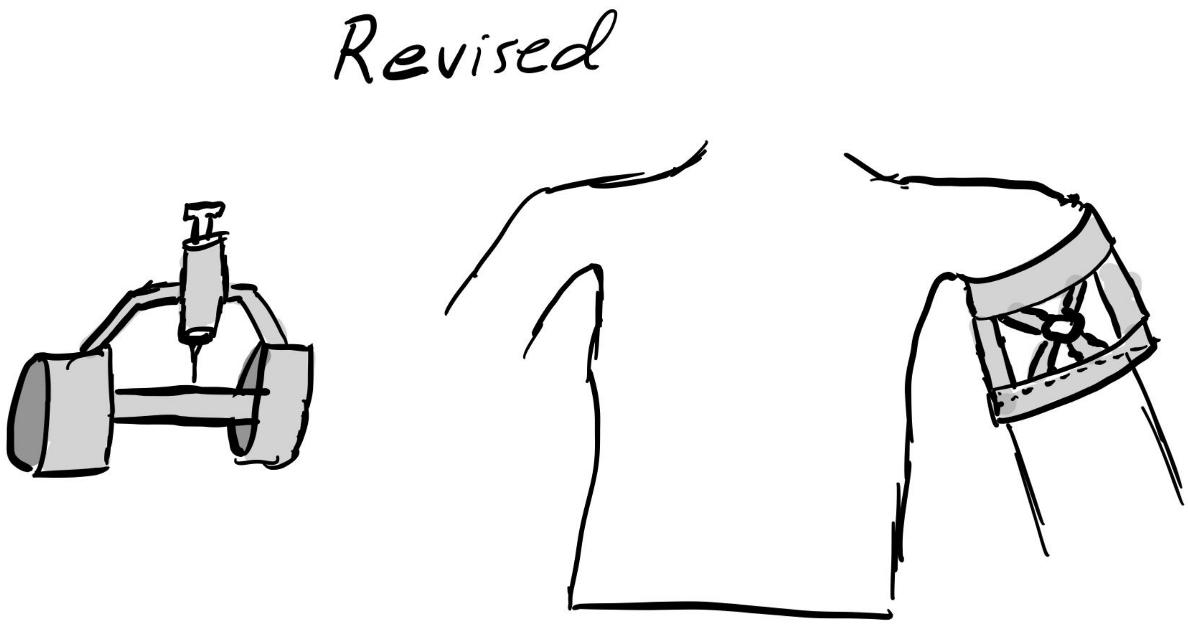
The team considered a variety of designs and features to be included in the final prototype. These designs varied in complexity, but all attempted to effectively address user needs. The team decided that it was most important to have a design that securely held the syringe against an arm and that simplified the motion of injecting. The designs were narrowed down to two concepts, depicted and described below.

Figure 2. Concept 1



In concept 1, the vaccine is inserted in the handle of the device. A scanner is used to determine the best area for the vaccine to be inserted, once lined up properly, the adhesive pads keep the device in place while the vaccine is being administered. Pressing down on the button pushes the needle into the arm and injects the user. This device would eliminate the human error aspect of finding the right spot to insert the needle. This device could not only potentially be safer but also faster and easier. A device of this sort would allow vaccinations to be done faster and/or without the need of a trained professional.

Figure 3. Concept 2



Concept two consists of an armband with an extension and a slot at a 90 degree angle to the arm for the syringe to be inserted into. The arm band will slide up the arm and be tightened into place at the shoulder, leaving only the vaccination region exposed to minimize any chance of inserting the needle into the wrong region. The slot will only allow the vaccine to be administered to the appropriate depth in the arm by having a narrow edge on the bottom to stop the syringe at the right spot. This device would eliminate the guessing when it comes to inserting the needle into the best area and the depth to insert the needle into. The device has potential to be safer then the standard way of administering vaccines but keeps around the same speed. This device also allows for patients to give themselves vaccines without the assistance of a medical professional.

Concept Selection

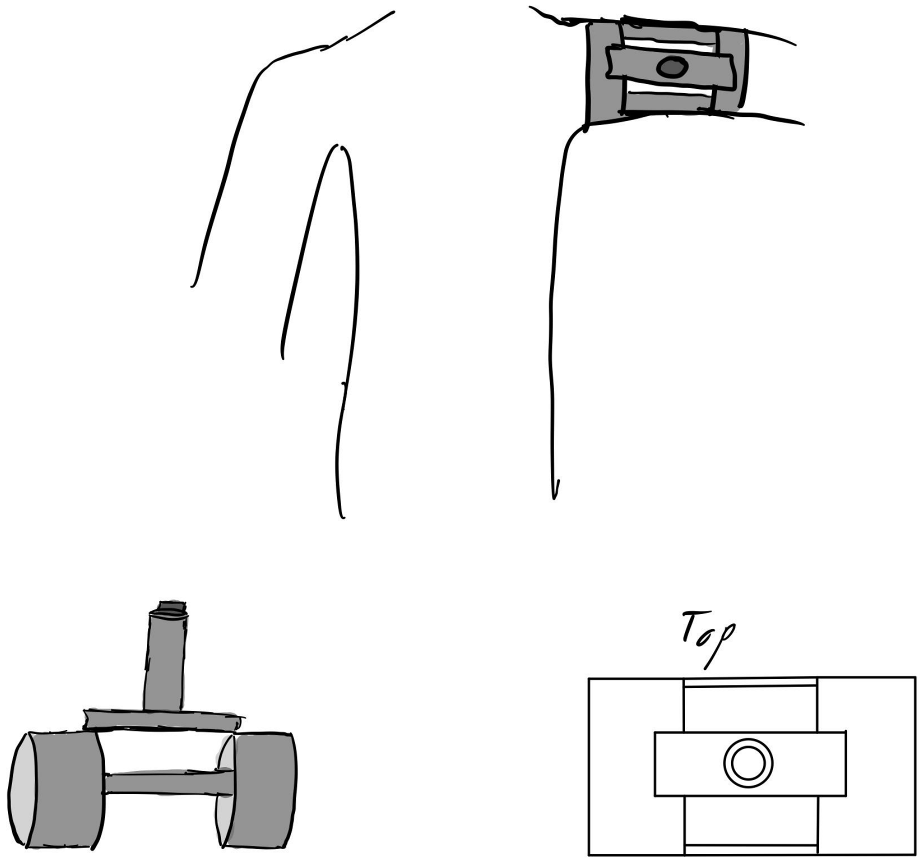
An excel pugh scoring matrix was used to evaluate how well the presented designs fit user needs. The reference used was the current system of vaccine delivery, a syringe and needle. The reference was compared to design concepts one and two. The reference weighted score was 74, mostly due to its difficulty of use and lack of reusability. The first concept scored the highest, with a 102. Although more complex and expensive than the traditional method of vaccine delivery, the concept had much improvement in reusability, speed of use, and ease of use. The second concept scored a 99. It had more concentrated improvement in simplicity and inexpensiveness, but also in the areas where the reference struggled most.

Table 7. Pugh Scoring Matrix

		Reference		Concept 1		Concept 2	
Need	Weight (1-5)	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Simple	3	3	9	2	6	5	15
inexpensive	1	3	3	2	2	4	4
safe	5	5	25	5	25	5	25
effective	4	5	20	5	20	5	20
environmentally friend	2	2	4	3	6	3	6
ease of use	5	1	5	5	25	4	20
speed of use	3	2	6	4	12	3	9
saving materials	2	1	2	3	6		0
			0		0		0
			0		0		0
TOTAL			74		102		99

The team's revised design combines features of the first two concepts including a strap at the base of the product to keep the apparatus secure to the user, and a long hand/tube that will hold the syringe. The button at the end of the tube will make injecting the vaccine not only easy, but also consistent. The flat base at the end of the handle will allow the product to stay flush against the arm, making it even more secure and thus, even safer. Not seen in this design is the fact that the cap will be able to unscrew, allowing for the vaccine to be placed inside.

Figure 4. Prototype Sketch



As before, this final prototype was compared to the current method of vaccine administration with a pugh-scoring matrix. As seen in the figure above, the team's final prototype makes large improvements in areas where the current alternative struggled, without compromising pre-existing strengths. Categories that saw the most improvement included ease of use and speed of use, with marginal improvements in environmentally friendliness and saving materials. This shows that the team stayed on task with their initial goal of creating a solution that would be simpler and faster than the current method of administration.

Table 8. Final Revised Pugh Scoring Matrix

		Reference		Final Concept	
Need	Weight (1-5)	Rating	Weighted Score	Rating	Weighted Score
Simple	3	3	9	3	9
Inexpensive	1	3	3	3	3
Safe	5	5	25	5	25
Effective	4	5	20	5	20
Evironmentally Friendl	2	2	4	3	6
Ease of use	5	1	5	5	25
Speed of use	3	2	6	4	12
Saving materials	2	1	2	2	4
			0		0
			0		0
TOTAL			74		104

Users were in search of a simpler design that was easier to operate. The team took this feedback into account while designing revised sketches. Combining the best parts of the first two concepts allowed us to keep the design fairly basic which not only helps with the production of the product but also the ease of use. Safety still appears to be the number one priority for users so that was still a heavy focus. The team made sure that the revised design would still be an effective and reliable way of administering a vaccine. To do this, the idea of using straps and a tube design to eliminate as much potential error as possible were combined. Steps were taken to mitigate home-user hesitancy with the self-injection process. Although the team does not expect the product to be immediately widely adopted in this market, it has been designed to make this transition as frictionless as possible.

Prototype Concepts

Team K will be prototyping the design in Solidworks and will be completing the necessary testing by using Solidworks simulations. Limitations of this project included that, given the current pandemic circumstances, it would be inconvenient and unsafe to have the team working together to create a physical product. The team also does not have the experience or tooling necessary to create a prototype with a high degree of accuracy. Delimitations for this project included that the team did not want to use aids like 3D printing or cardboard for this because the design is fairly complex and is meant to be used in a medical setting, meaning, the team wants the design to be precise. Accomplishing a successful design via 3D printing still does not necessarily tell us if the product is viable.

A correlation matrix can be used to determine the overlap between created requirements and user needs. By the nature of the project, all requirements should be closely tied to user needs, but certain requirements will still be of greater importance than others. The tables below mathematically compare requirements and user needs, giving them a weight and a point value.

From these point values, it can be seen that the most important requirements are that the housing is at a 90 degree angle to the arm, that the button injection system works at least 98% of the time, and that the device accommodates a standard vaccine syringe. These requirements are most closely tied to user needs because they directly impact effectiveness and safety of the product. The need for this product to work correctly and in a safe manner is extremely important, thus the top requirements are as well.

Table 9.1. Correlation Matrix 1

Design Requirements Correlation Matrix **User Needs**	The Entire Process Takes Less Than 5 Minutes	Body of the Product Can Survive Being Dropped	Housing is Made From Recyclable Plastic	Straps Adjust Between 7 and 24 Inches	The Button of the Device Can Withstand Pressure of Being Pressed	The Device Accomodates a Standard Vaccine Syringe	Materials Alone Cost Under $7	**weight**
Simple	3	1	3	1	1	9	1	3
Inexpensive			9	1		1	9	1
Safe		9		1	9	3		5
Effective	1			3	9	3		4
Enviromentally Friendly						1		2
Ease of Use	3	1		9	3	3		5
Speed of Use	9	1		1				3
Saving Materials			1	1		3	1	2
Need 9								
Need 10								
Importance ->	55	56	20	71	99	78	14	

Table 9.2. Correlation Matrix 2

	Unscaled	Scaled	Rounded	Points (100)
The Entire Process Takes Less Than 5 Minutes	10	14.0%	13.00%	13
Body of the Product Can Survive Being Dropped	10	14.2%	21.00%	21
Housing is Made From Recyclable Plastic	10	5.1%	6.00%	6
Straps Adjust Between 7 and 24 Inches	10	18.1%	16.00%	16
The Button of the Device Can Withstand Pressure of Being Pressed	10	25.2%	23.00%	23
The Device Accomodates a Standard Vaccine Syringe	10	19.8%	18.00%	18
Materials Alone Cost Under $7	10	3.6%	3.00%	3
		100.0%	100.0%	**100**

Table 10. Requirements

Requirement	Range	Ideal
Process Takes Minimal Time	1 min - 5 min	≤ 3 minutes
Body of the part can survive being dropped	4-6 feet	6+ feet
Housing Made from Recyclable Plastic	≥ 50% of plastic by volume is recyclable	≥65%
Straps Adjustable	Adjust between 7in - 24in	6in - 30in
The Device Rests Perpendicular to the Arm	Device angle between 85 - 95 degrees	Angle between 88 - 92 degrees
The Device Accommodates a Standard Vaccine Syringe	Accommodates at least 50% of syringe sizes	Accommodates at least 70% of syringe sizes
Minimal Device Materials Cost	Plastic used ≤ $20	≤$15

Above is listed the requirements that the team created to test this product. The specific tests run and their methodology is described below.

Test 1: approximate the time needed for each step of vaccination and combine to get the total time

Test 2: Test product being dropped from varying heights to see strength of product.

Test 3: Pick a material that is recyclable

Test 4: Test the minimum and maximum length of the straps around the arm

Test 5: Test the angle at which the device rest at

Test 6: Test different standard sized syringes to see if they fit and work properly

Test 7: Determine the cost of manufacturing a single product

Verification Plan

The team's three highest user needs are safety, effectiveness, and ease of use. It is important to create test methods that evaluate the requirements in light of these needs to ensure user needs are kept at the forefront of design. As described above, seven tests will be needed to test the developed design requirements. For test one, ten trials should be sufficient to gain a full understanding of the time required. This test will require someone operating the device on a patient or dummy and a timer. Test two states that it will need to be run one hundred times, and will need someone operating the device and recording results for each trial run. No set number of trial runs is necessary to verify test three, but will simply require choosing/evaluating a material that is known or supposed to be recyclable. This test could either involve more research or complex testing facilities depending on if the material chosen is known to be recyclable. Test four is a simple measurement which should be taken five times to ensure accuracy. This requires a person measuring and a ruler or measurement system. Test five is another measurement test, requiring an observer and an angle measurement device. All types of standard syringes will need to be collected and evaluated for fit in test six. This test requires a person measuring, a measurement device, as well as a general hand-feel fit report. Test seven must be completed later in the design process, as it requires knowing the production cost of all finalized parts. This test involves information about manufacturers, materials, shipping, and current market climate.
After speaking with three users, two patients and one administer, it became apparent that they also valued safety, effectiveness, and ease of use. These findings were not extremely surprising, as safety and effectiveness are usually a patient's two top concerns in regard to medical products. Administers are highly interested in saving time, and ease of use was consistently one of their top needs. To realistically test safety and effectiveness, the button injection system can be first thoroughly tested with ballistics gel to simulate the product entering into the human arm and injecting a vaccine into it. Through running this test a multitude of times the team can determine whether the product is operating as intended and is safe for the general population. Once safety has been proven through these tests, the team will transition to testing on actual patients. A realistic test for ease of use would be to have vaccine administrators try the product themselves and provide an improvement comparison rating to the traditional vaccination process given through a well conducted survey.
Attached below is the team's completed scorecard. This scorecard will be used to evaluate the success of the created requirements using a rubric generated with the top user needs in mind. Success is determined with a perfect score, anything less shows there is a need for improvement.

Table 11. Requirements Scorecard

Requirement	Range	Score Rubric	Score
Process Takes Less Than 5 Minutes	1 min - 5 min	Every minute over 5 minutes is 3 points off	13
Body of the part can survive being dropped	4-6 feet	Every foot off 10 points	21
Housing Made from Recyclable Plastic	≥ 50% of plastic by volume is recyclable	Every 5% off is 1 point	6
Straps Adjust Between 7 and 24 inches	7in - 24in	Every inch not in range is 3 points	16
The device rests perpendicular to the arm	Device angle between 85 - 95 degrees	Every degree off is 2 points	23
The Device Accommodates a Standard Vaccine Syringe	Accommodates at least 50% of syringe sizes	Every 5% off is 2 points	18
Device materials cost less than $20	Plastic used ≤ $20	Every 2 dollars off is 1 point	3

Prototype testing can become a confusing and lengthy process if not kept well organized. The team used the resources outlined in the tables below to ensure work was divided evenly and the project remained on schedule.

Table 12.1. Schedule

Date	Point Man	Class	Track Time
3/18/21	Charlie	R&D 1	45 min
3/20/21	Nolan	R&D 2	30 min
3/25/21	Sam	Detail Design 1	20 min
3/29/21	Nate	Detail Design 2	40 min
4/5/21	Nate	Social & Economic Value	30 min
4/8/21	Sam	Prototype Validation	40 min
4/12/21	Nolan	Prototype Validation	75 min
		Total	280 min

Table 12.2. Schedule

	3/18/21	3/20/21	3/25/21	3/29/21	4/5/21	4/8/21	4/12/21
Test R1	■						
Revise R1		■	■	■			
Retest R1		■		■	■	■	■
Test R2	■						
Revise R2		■		■			
Retest R2		■		■			
Test 3			■				
Revise R3			■	■			
Retest R3				■	■	■	■
Design R4	■						
Design R5		■					
Design R6			■				
Design R7						■	
Complete CDR				■			■

The team will be doing a structural analysis of the design in SolidWorks. More specifically, to test the points of the product that will undergo the most pressure. This analysis will tell whether the product will be able to withstand the forces that are meant to be applied to it. If the product can withstand the amount of force tested on it then the team can not guarantee from that alone that the product will be safe, but it will certainly be a step in the right direction. Once the SolidWorks model has demonstrated that it can withstand reasonable amounts of force, the team will use it to test several other product requirements. These force measurements will be used to determine whether the product can survive a 6 foot drop. Measurements will be taken to ensure the model can accommodate a strap that adjusts between 7 and 24 inches. The product will also be measured to ensure that it will rest perpendicular to an arm. To test that at least 50% of common syringe sizes fit in the product, measurements will be taken and the system that allows for syringes of different sizes to be held securely will be tested within SolidWorks. A cardboard mockup of the product will be made for testing the time required to use the device. This mockup will be able to simulate the actions required for using the device and will provide an accurate model for a time measurement. The material chosen for the device will be researched to determine recyclability and will be applied to the SolidWorks model for realism. The mass properties will be taken for the different materials used in the SolidWorks models to determine volume. This quantity will be used to calculate the cost of materials.

The team hopes to conclude from the analysis that the product created is effective and safe for the general public. Tests will be done to ensure that the product will be able to safely withstand more than the pressure it is expected to endure during general use. If the team is confident that the product can handle more than it will realistically experience in everyday use, then team K can be sure that if used properly, the product will be safe.

After discussing with other teams, an issue that frequently arose was ensuring that the solidworks design created was thorough enough to fully test the product. Many teams wanted to test very specific details of their product, which requires having those details fully modeled. Another point to consider from the team meetings is that solidworks files cannot always test for physical requirements like user feel and timing. This must be considered when testing requirements such as these.

Team K hopes to find the best design for the product after thoroughly running and analyzing the data from the tests on the prototype design. The team also hopes to get more recommendations from users on the product so team K can continue to maximize efficiency from the user’s end.

Final Design Review:

Create/Model Prototypes

After running all previously described tests, the product was found to fulfill all requirements. When using a model of the product to determine administration time, the length of the process was found to be 1 minute and 13 seconds. The simulated process with the model can be viewed in the video attached in the appendix. In order to simulate a drop test, the solid works model of the product was tested as being dropped from 6 feet. This distance is within the scorecard specified range. As can be seen in the attached images in the appendix, the model survived this fall with only a few moderately stressed areas. Research was conducted to find a medical grade plastic that was also recyclable. After some deliberation, high density polyethylene was chosen for the housing of the device. This plastic is medical grade and food safe. It is also recyclable according to Miller Recycling Corporation [9]. The entire housing is made from this plastic, so the product far exceeds the requirement of being at least 50% recyclable. For strapping, the team decided on velcro strapping from Amazon (linked below). The strapping will be able to adjust even tighter than 7 inches and looser than 25, exceeding this requirement. The team simulated button presses by running a force test on the model button in SolidWorks. The button passed this test, surviving 10 newtons of force, with a max stress of about 1.2 psi while the yield strength of our material is about 3700 psi. 10 newtons exceeds the forces that the button would normally be exposed to, meaning that even though our part does have minor displacement, it is minimal and should not be an issue for our product. The interior of the device chamber measures exactly one inch in diameter. According to IntelliSpense [10] , four out of five of the manufacturer's outer barrel diameters are within one inch, which means our product accommodates 80% of syringe barrel sizes. This hits far over the target of 50%. The material chosen for the housing is a high density polyethylene, which costs about $8.87 per pound according to Aqua-Calc [11]. At a mass of .62lbs, the material cost of the housing of one part comes out to be $5.50. According to Amazon [12] , 1 inch wide velcro can be bought at $14 for 25 yards. At the maximum 30 inch ideal adjustable range for the straps, this makes the velcro strap material cost come out to be only $0.47 per part. All together, the cost of material for a single part can be expected to be around $5.97 - well within the target cost. Although the product passed all of the test, a potential weak point could be in how long the adjustable straps should be made to try to optimize minimal cost of production, but maximize user satisfaction so that it fits the vast majority of users. This can be done with future research on customer feedback with the current 30-inch maximum length.

Final Prototype Design

The final prototype was created with all of this research and testing in mind. It was made to fulfill the aforementioned requirements, and surpass them in the ways described. The requirements were detailed to a point that the only final decisions to make were stylistic and ergonomic. The team made the product out of all custom parts, which can be viewed in the attached appendix. The parts are simple and mass producible, while also being robust and fulfilling the team's requirements. The team is custom-producing the device housing, the syringe retainer mechanism, and the button. These parts are all made from the medical grade plastic detailed above, are easily assemblable, and come apart easily for sanitation and safe disposal of the syringe.

Prototype Test Results

The score card below details specifically how the team's product ranked based on the set list of requirements. It quantitatively measures how well the product performed and, based on that information, how well it fits the needs of the team's users.

Table 13. Score Card

Requirement	Range	Score Rubric	Score
Process Takes Less Than 5 Minutes	1 min - 5 min	Every minute over 5 minutes is 3 points off	13
Body of the part can survive being dropped	4-6 feet	Every foot off 10 points	21
Housing Made from Recyclable Plastic	≥ 50% of plastic by volume is recyclable	Every 5% off is 1 point	6
Straps Adjust Between 7 and 24 inches	7in - 24in	Every inch not in range is 3 points	16
The button of the device can withstand pressure of being pressed	Button can withstand between 10 and 30 newtons of force	Every 5 newtons of force off is 2 points	23
The Device Accommodates a Standard Vaccine Syringe	Accommodates at least 50% of syringe sizes	Every 5% off is 2 points	18
Device materials cost less than $7	Plastic used ≤ $7	Every 2 dollars off is 1 point	3

Validation

After interpreting all the information collected from tests, the team's impression of the product is that the design is excellent. All designed tests run on our product design fell within their respective ranges of what the team considered passing. The team believes that there are very minimal tweaks to the design that will be needed to achieve maximum effectiveness like maybe changing the range that the straps cover or the range of acceptable syringe sizes. Considering, outside feedback we have received, it appears that the main concern is how will the device pin point the safest possible location on the arm to insert the syringe. In order to improve upon the issue of finding the correct spot for injection every time, a standard set of instructions could come with the product, or some sort of guiding device could be added to the model to let the user know when the device is at the right spot.

Specifically regarding user needs, these tests showed that this product will be easy to use, effective, and safe. The tests were designed to test individual aspects that all contribute to this being an easy to use, effective, and safe vaccine delivery device. The fact that this device passed all tests shows that it meets the needs of the product users, as the tests were designed with users in mind. One opinion that the team may need to keep in mind, however, is how universal application was assumed when designing the product. The tests were created in such a way as to only test a fairly general use case, which although beneficial, allows some users with more specific requirements to fall through the cracks. The team needs to keep this in mind when considering the success of this product.

Impact:

The product has a sizable startup cost, and it is primarily aimed to provide social benefit rather than maximizing profit for the company. The majority of expense comes in the form of developing the product, doing research and improvement, manufacturing, and distributing the product. Although the team believes this product could be profitable, its purpose is not financial gain. As it is more expensive than the current alternative, retail costs will be marked as low as reasonably possible to incentivize hospital implementation. The cost of maintaining and operating the product is relatively low since there isn't much involved in operating the system. The main cost of the product while operating and maintaining the product would come from buying the actual vaccines for the device and keeping the needle within the device sanitized. It is important to denote, however, that the team has intentionally excluded costs associated with vaccine drugs themselves from calculations. The product being created seeks to solve the administration issue but does not address issues related to medicine.

Below is a table detailing the cost and value created by costs associated with developing this product. As can be seen from the table, prototyping and market research was fairly inexpensive, but categories such as quality assurance and design were deemed much more costly. Also seen on the table is that the economic value created by the product is not extremely large, but the social value is sizable.

Table 14. Social and Economic Value:

<u>**COSTS**</u>	<u>**COSTS**</u>	<u>**VALUE**</u>
Research, Analytics & Wireframing	$$	
Creating Initial Prototype in Solidworks	$	
Analytics and user experience	$	
Market and current alternative research	$$	
Design, Style and Branding	$$$$	
Design	$$	
Back-end development (product production)	$$$	
Front-end development (product implementation)	$$$	
Quality Assurance	$$$	
Quality Assurance (safety testing)	$$$	
<u>**VALUES**</u>	<u>**COSTS**</u>	<u>**VALUES**</u>
Income		$$
Sales		$
Product Pitching		$$$
Social Value		*****
Vaccination is more available		****
More people vaccinated		***
Less preventable deaths		***
Time saved in health care jobs		**

The product has multiple aspects that contribute to its potential value to society. The speed and ease of use that has been a focus since the first steps of the design process mean that certain social values have always been prioritized. Vaccination becoming more widely available to the general public is the main contributing social value. The product is meant to not only make vaccination easier, but also simpler to the point that anyone can do it. Creating the ability for people to get vaccines who normally can't or won't would lead to more people vaccinated. More people vaccinated means less preventable deaths around the world which obviously has extreme social value. The product's ability to reach a mass market is most definitely its strong point in terms of social value, but in a more specialized scope, our product could be very beneficial in a health care environment. Reducing the time that is needed for vaccinations to be administered could save valuable time in a health care setting and would have an extremely positive social impact. The saving of time, materials, and overall outreach of our product is the key contributor in the large social impact that it could have.

Product Recommendations:

For further validation and improvement of the current product design, the team recommends having the product undergo independent certification testing. Although the team itself has proved this product to be safe, having the approval of a widely-recognized independent testing facility would increase the credibility of this product. The medical market can be difficult to win a share of, and being able to provide independent proof that this product is safe for the administrator and patient is extremely valuable.

The team also recommends conducting research in other areas of injection outside of vaccination. Specifically, IV injection is another area where technological advancement and increased safety would be welcome. Although this product is not directly applicable in that market, the team believes it could help lead them to a similar solution. After having experience in and innovating one area of medical injection, the team sees it as a natural progression to continue to work in other areas of the field that cause issues for patients and administrators.

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Appendix:

Table 15. Revised Version Chart

Assignment Title: Technical Design Review
Project Manager for Assignment: Sam Jablonski
Deputy Manager for Assignment: Charlie Vukovic
Drafted Assignment: Nolan Little
Reviewed Assignment: Nate Overbey
Revised Assignment: All Members
Proofread Assignment: All Members
Created Figures: N/A
Created Tables: N/A
Other Contributions: N/A
Problems Overcome: Compiling Documentation, TA Comment Based Revisions

List 1. A list of the team's full interview results

Interview 1

Participant Type (Medical or normal):

Medical - nurse

Data:

What are your biggest issues with giving vaccines?

Patient fear, moving suddenly, puts nurses in danger What are the most important practices when giving a vaccine?

Needle safety - for nurse and patient, recapping needle safety, cleanliness and sanitation, cleansing patient skin, disposal of the needle, keeping needles for personal use

What training do you go through (how long, what do you learn, etc.)

LOTS of practice, 4 or 5 injections in nursing school before giving for real, for

muscle injection

What do you think the biggest reason is that people don't get shots?

Pre-covid: needle fear, post-covid: fear of vaccine process in general What part of the vaccination process takes the most time

Ordering, and getting. Order - pharm - proof - delivering. Administering is very quick. Patient education as well

Interview 2

Participant Type (Medical or normal):

Medical - Pharm Student

Data:

What is the biggest reason to not get a vaccine?

Misconceptions about autism, putting a live virus in your body, religious beliefs, lack of education

Would you be comfortable administering a vaccine to yourself?

No, I would mess it up

What would make you more comfortable

Training, not the idea of getting a vaccine, capabilities to give it

What is your biggest concern when getting a vaccine

Watching the needle go into arm, not bothered by shots

What's your biggest reason for not getting shots?

No reason, vaxxer, believes in science

Or if you do, what's the biggest pains of getting the shot

Taking time out of day to go to doctors office

Would you be willing to pay more (insurance or out of pocket) to have the vaccine process be more convenient/easier

Yes

Would you rather have the vaccine administered by a professional or a well-researched device?

Apprehensive to let a machine do it at first, after it becomes more common would be interested

Interview 3

Participant Type (Medical or normal):

Normal - student

Data:

Would you be comfortable administering a vaccine to yourself? What would make you more comfortable?

No, knowing that I will put it in the right place

What is your biggest concern when getting a vaccine?

Aftereffects

What's your biggest reason for not getting shots or if you do, what's the biggest pains of getting the shot?

Don't know what is in them. Biggest inconvenience - soreness in the arm

Would you be willing to pay more (insurance or out of pocket) to have the vaccine

process be more convenient/easier

No

Would you rather have the vaccine administered by a professional or a well-researched device?

Professional

Interview 4

Participant Type (Medical or normal):

Normal - student

Data:

Would you be comfortable administering a vaccine to yourself? What would make you more comfortable?

If there was a video guide

What is your biggest concern when getting a vaccine

That it will make me sick

What's your biggest reason for not getting shots or if you do, what's the biggest pains of getting the shot/

They are scary,have to go to the doctors office and interact with sick people

Would you be willing to pay more (insurance or out of pocket) to have the vaccine process be more convenient/easier

No

Would you rather have the vaccine administered by a professional or a well- researched device?

Equally as likely to go to either

Interview 5

Participant Type (Medical or normal):

Medical - nurse

Data:

What is the biggest problem with giving vaccines now?

There's not enough vaccine to go around

What are the most important practices when giving a vaccine?

Making sure the surface is clean and sanitized and administering it with least amount of pain and soreness as possible.

What training do you go through?

Attending a nursing training program

What is the biggest reason why people don't get shot?

People, in their own mind, believe that there is more harm than good that would occur from the shot and that scares people away.

What part of the vaccination process takes the longest?

The documentation part of giving a shot by recording the dosage of shot and more.

Interview 6

Participant Type (Medical or normal):

Medical - nurse
Data:

What is the biggest problem with giving vaccines now?

People aren't willing to take it

What are the most important practices when giving a vaccine?

Keeping the patient calm and not stress while preparing and delivering the vaccine

What training do you go through?

Practicing how to give shots through medical school

What is the biggest reason why people don't get shot?

People don't trust medical professionals or advice. They'd rather believe in their own opinions

What part of the vaccination process takes the longest?

The preparation phase of administering a vaccine.

Interview 7

Participant Type (Medical or normal):

Normal - student

Data:

Would you be comfortable administering a vaccine to yourself? What would make you more comfortable?

No because the fear of messing up the administration process and potentially harming myself would always be lingering in my head. I don't think much could make me more comfortable.

What is your biggest concern when getting a vaccine

The harm it could do to me

What's your biggest reason for not getting shots Or if you do, what's the biggest pains of getting the shot

Something about seeing the needle scares me and the pain I feel during and after the injection

Would you be willing to pay more (insurance or out of pocket) to have the vaccine process be more convenient/easier

No

Would you rather have the vaccine administered by a professional or a well-researched device?

Professional

Interview 8

Participant Type (Medical or normal):

Normal - student

Data:

Would you be comfortable administering a vaccine to yourself? What would make you more comfortable?

Maybe, depending on the amount of training or how comfortable I feel.

What is your biggest concern when getting a vaccine?

I come out with some type of problem or disability.

What's your biggest reason for not getting shots or if you do, what's the biggest pains of getting the shot?

Biggest pain would be actually getting the shot

Would you be willing to pay more (insurance or out of pocket) to have the vaccine process be more convenient/easier

No

Would you rather have the vaccine administered by a professional or a well-researched device?

Probably a professional

Prototype Sketch Figures

Figure 5. Initial Prototype Sketch

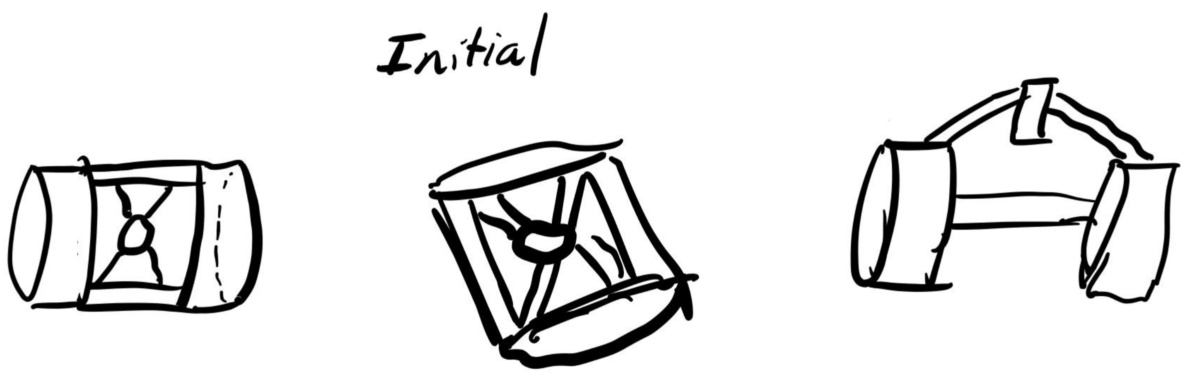


Figure 6. Initial Prototype Sketch

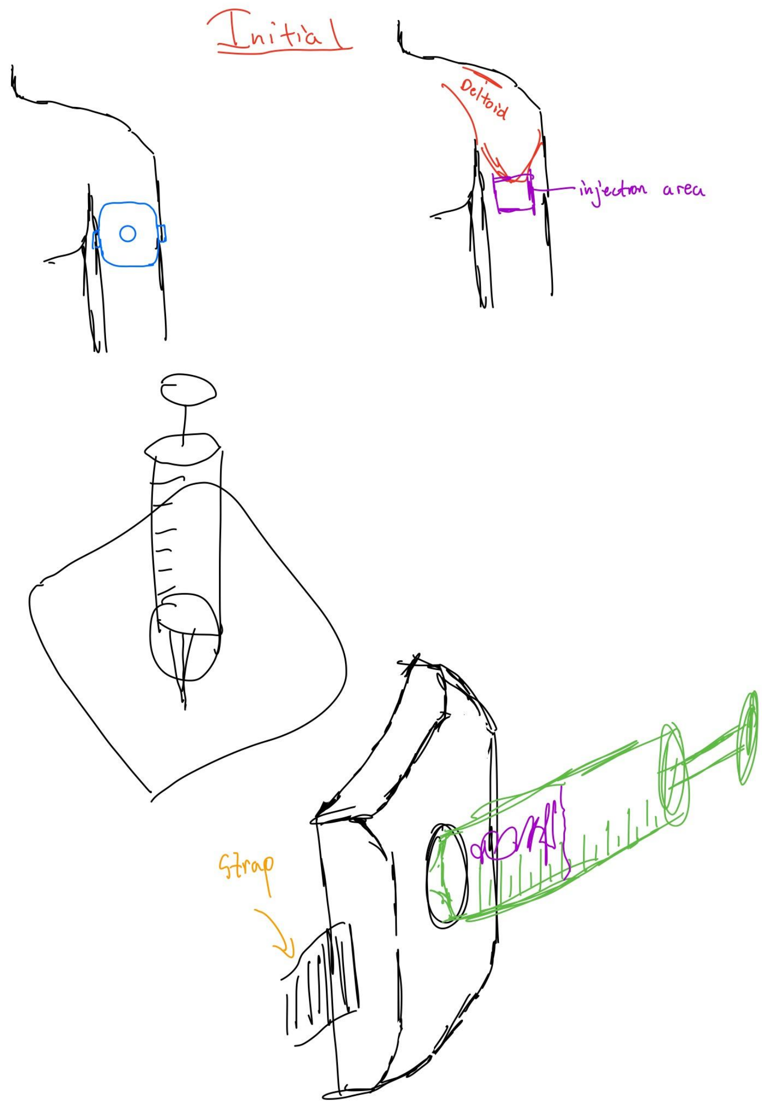


Figure 7. Initial Prototype Sketch

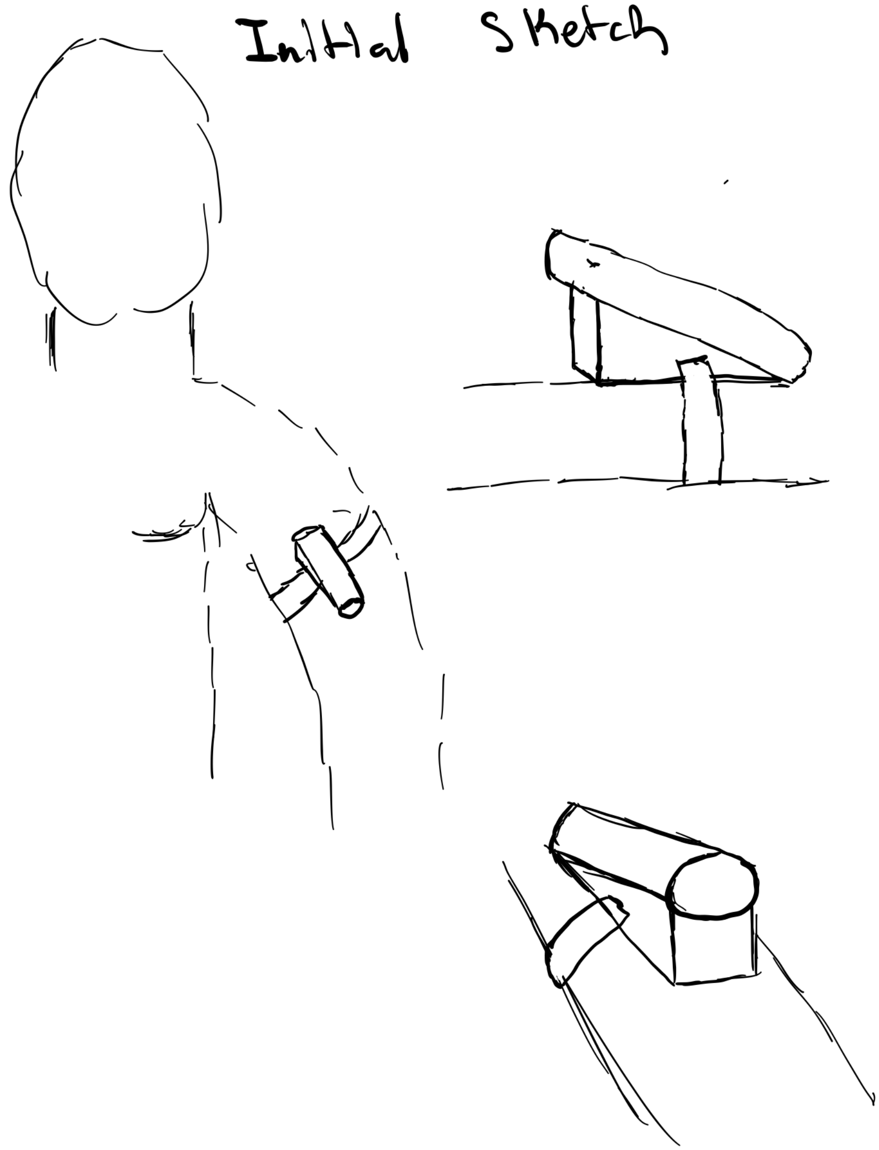


Figure 8. Initial Prototype Sketch

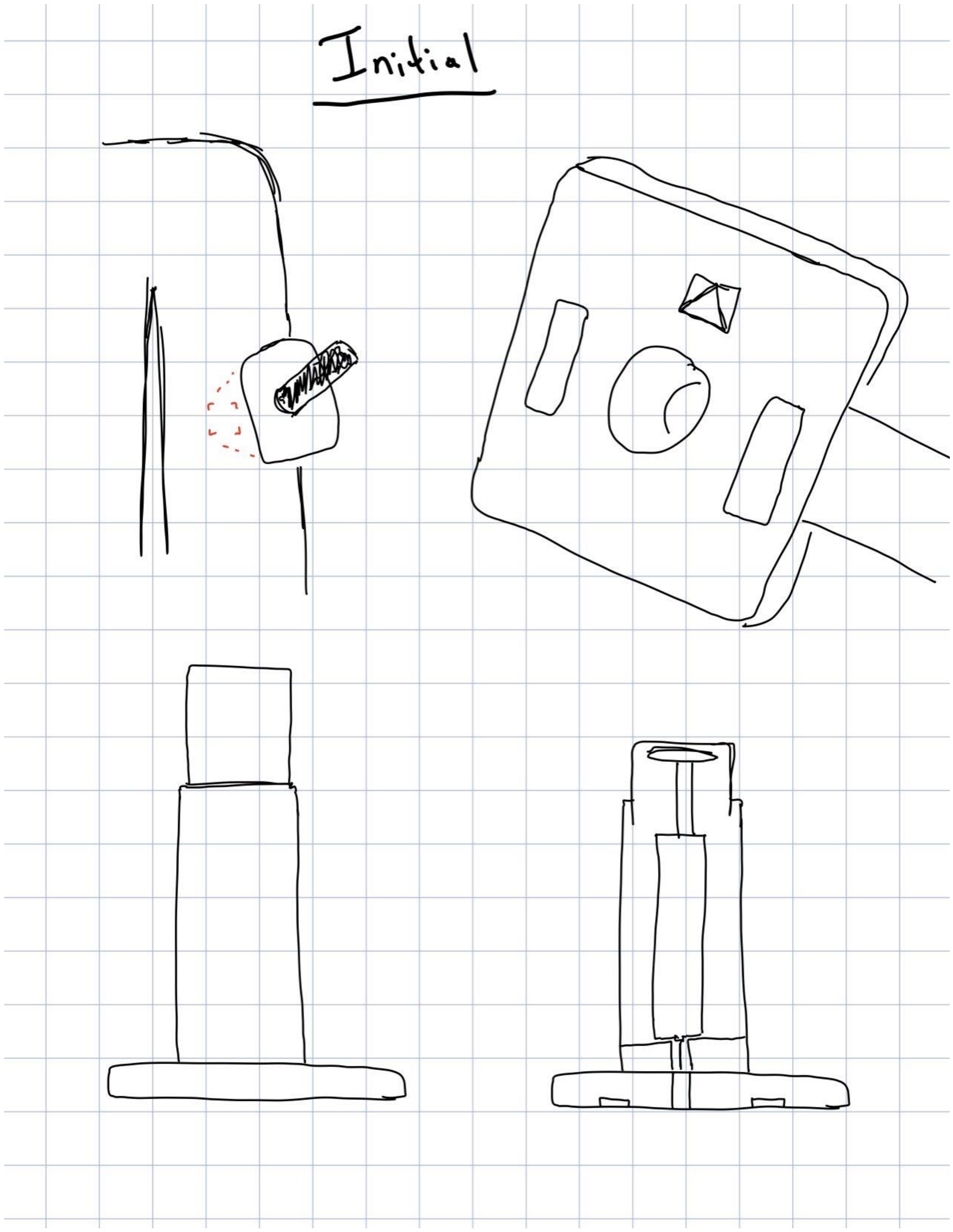


Figure 9. Revised Prototype Sketch

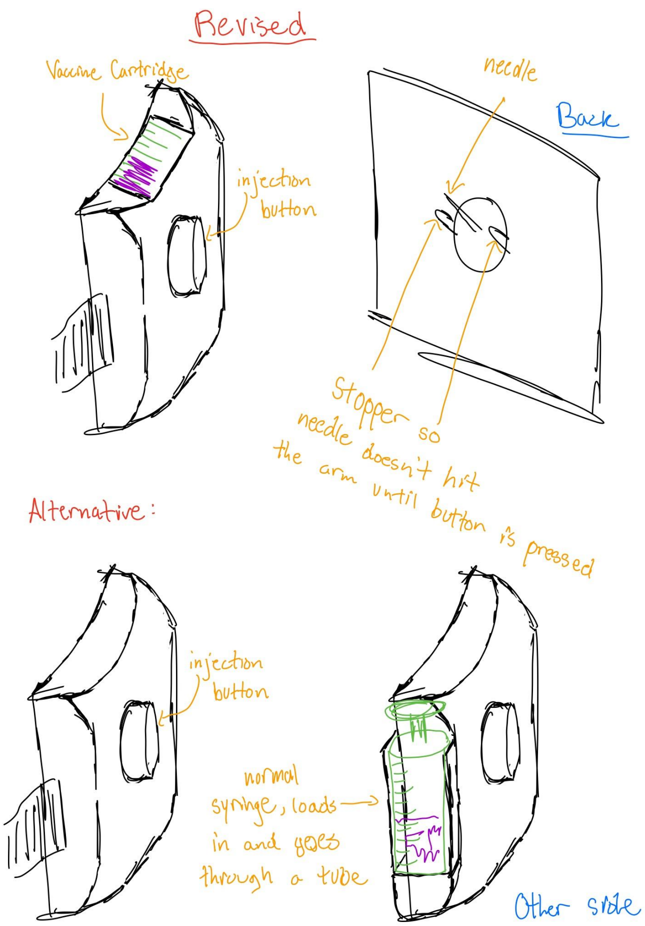


Figure 10. Revised Prototype Sketch

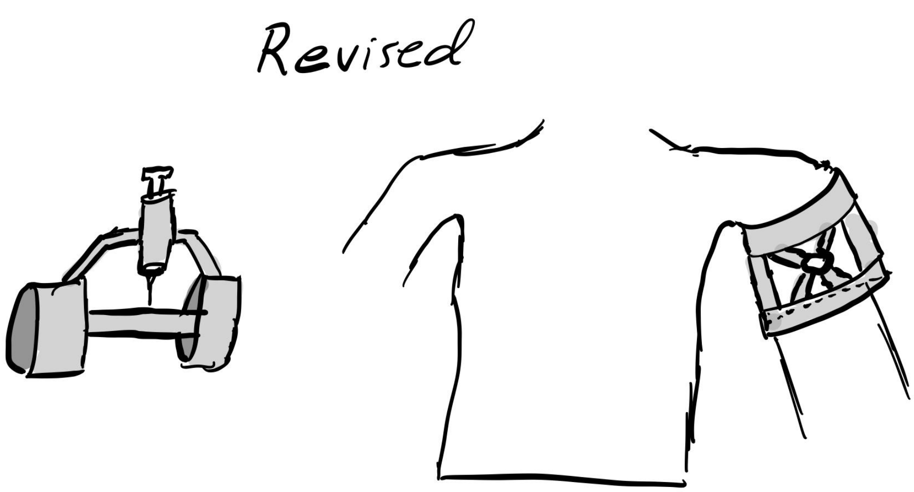


Figure 11. Revised Prototype Sketch

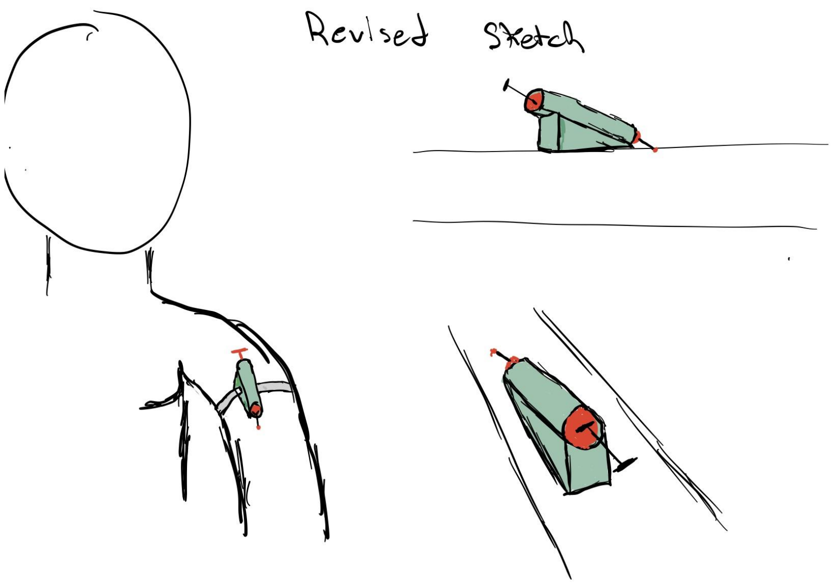
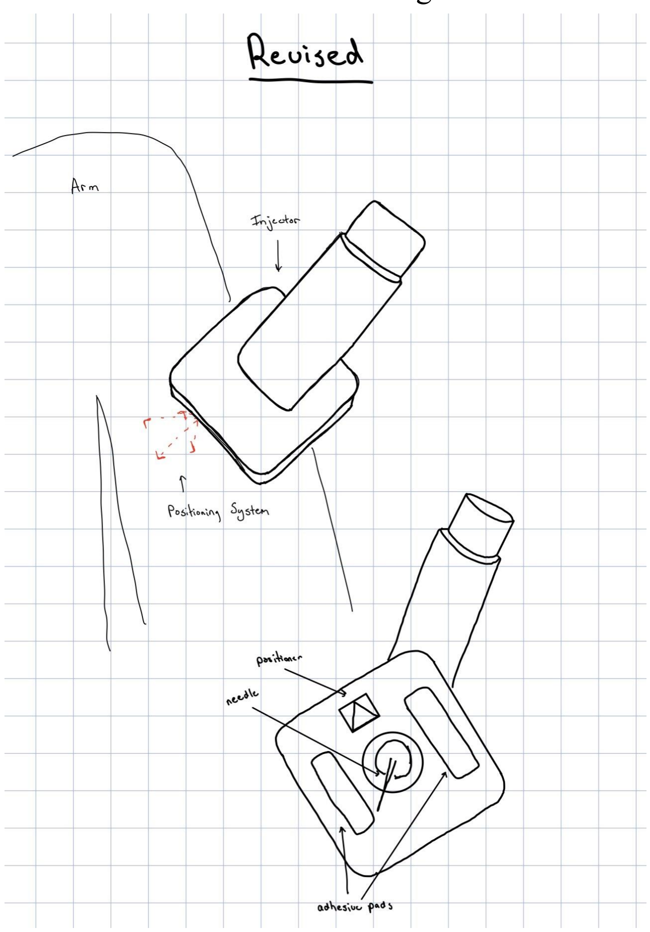
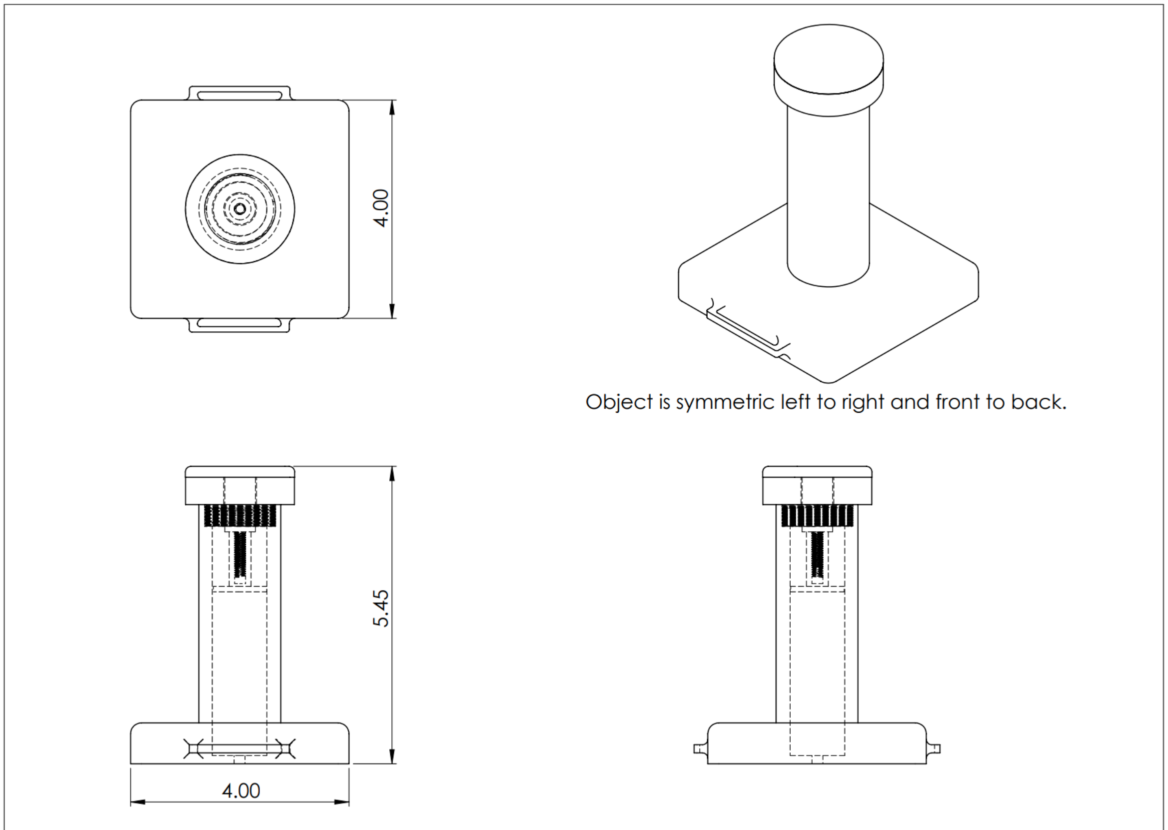


Figure 12. Revised Prototype Sketch



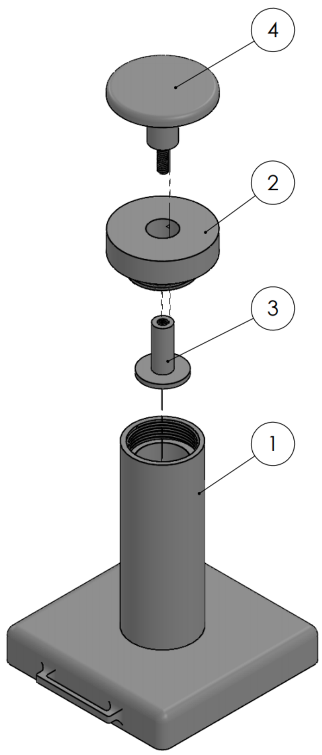
Drawing Packet

Figure 13. Completed Prototype Detailed Drawing



The Ohio State University First Year Engineering	Dwg. Title: Vaccine Administration Device Detailed Drawing	Inst.: Sundeep	Scale: 1:2	Dwg. No.: 1
	Drawn By: Team K	Hour: 9:35	Units: INCH	Date: 4/23/21

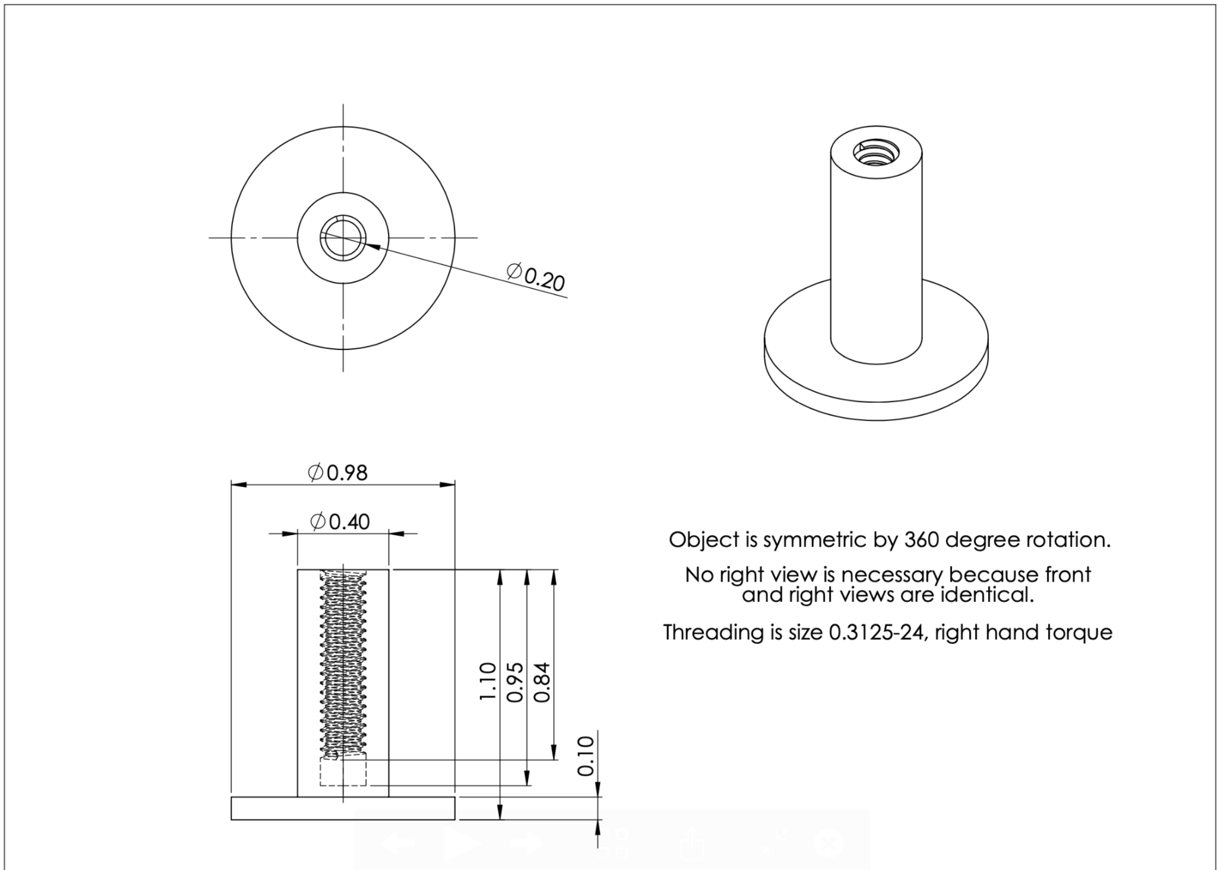
Figure 14. Completed Prototype Exploded Assembly Drawing



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Vaccine Main Body	Main Body of Administration Device	1
2	Button Attachment	Screw-On Top To Lock Vaccine in Device	1
3	Vaccine Plunger	Screw-In Shaft to Push Down on Inserted Vaccine	1
4	Button Top Part	Threaded Button for User to Push Down On	1

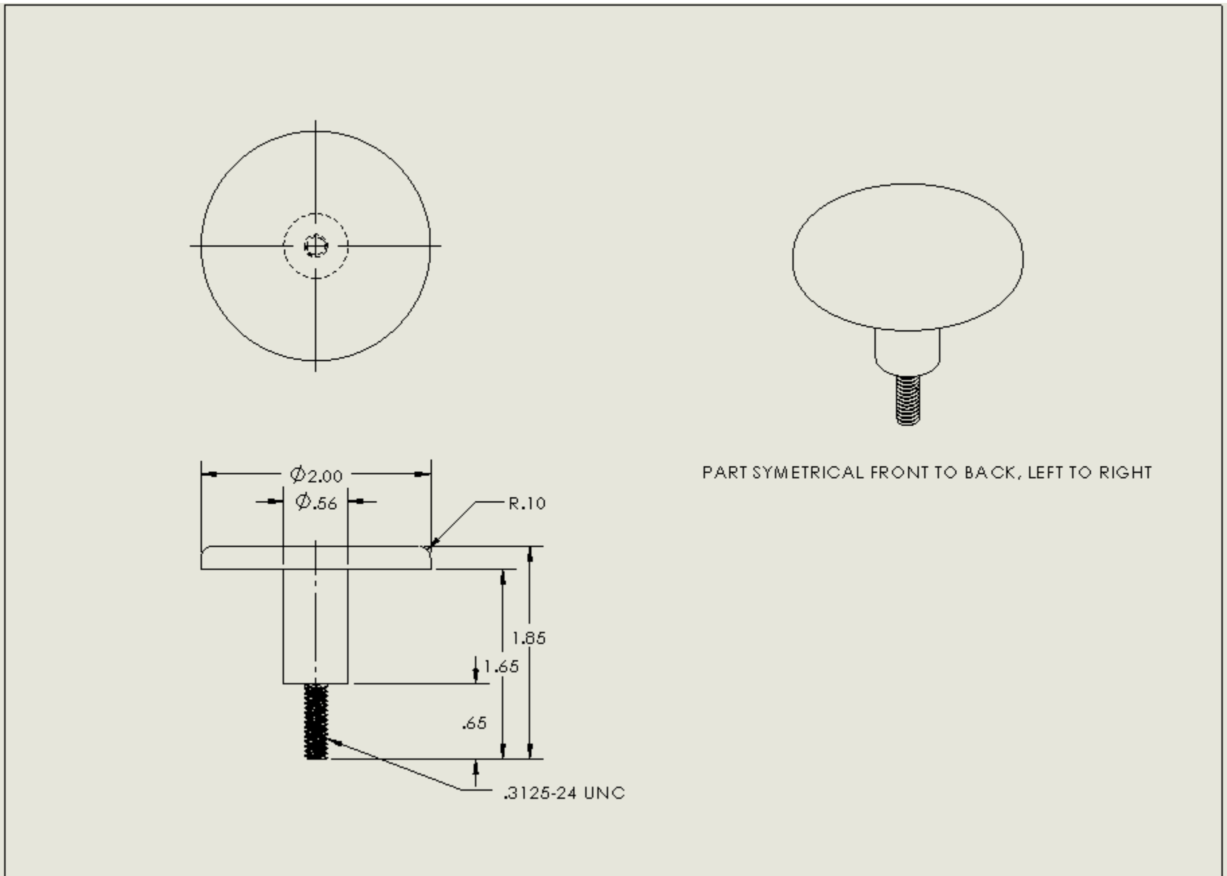
The Ohio State University First Year Engineering	Dwg. Title: Vaccine Administration Device Exploded Assembly	Inst.: Sundeep	Scale: 1:2	Dwg. No.: 2
	Drawn By: Team K	Hour: 9:35	Units: INCH	Date: 4/23/21

Figure 15. Plunger Detailed Drawing



The Ohio State University First Year Engineering	Dwg. Title: Vaccine Plunger Detailed Drawing	Inst.: Sundeep	Scale: 2:1	Dwg. No.: N/A
	Drawn By: Sam Jablonski	Hour: 9:35	Units: INCH	Date: 4/23/21

Figure 16. Button Top Detailed Drawing



The Ohio State University First Year Engineering	Dwg. Title: BUTTON TOP	Scale: 1:1	Section: 9:10	Units: INCH	Dwg. No.: 1
	Drawn By: NOLAN LITTLE	Mass: 0.03 LBS	Volume: 0.88 IN^3	Seat: N/A	Date: 4/6/21

Figure 17. Button Attachment Detailed Drawing

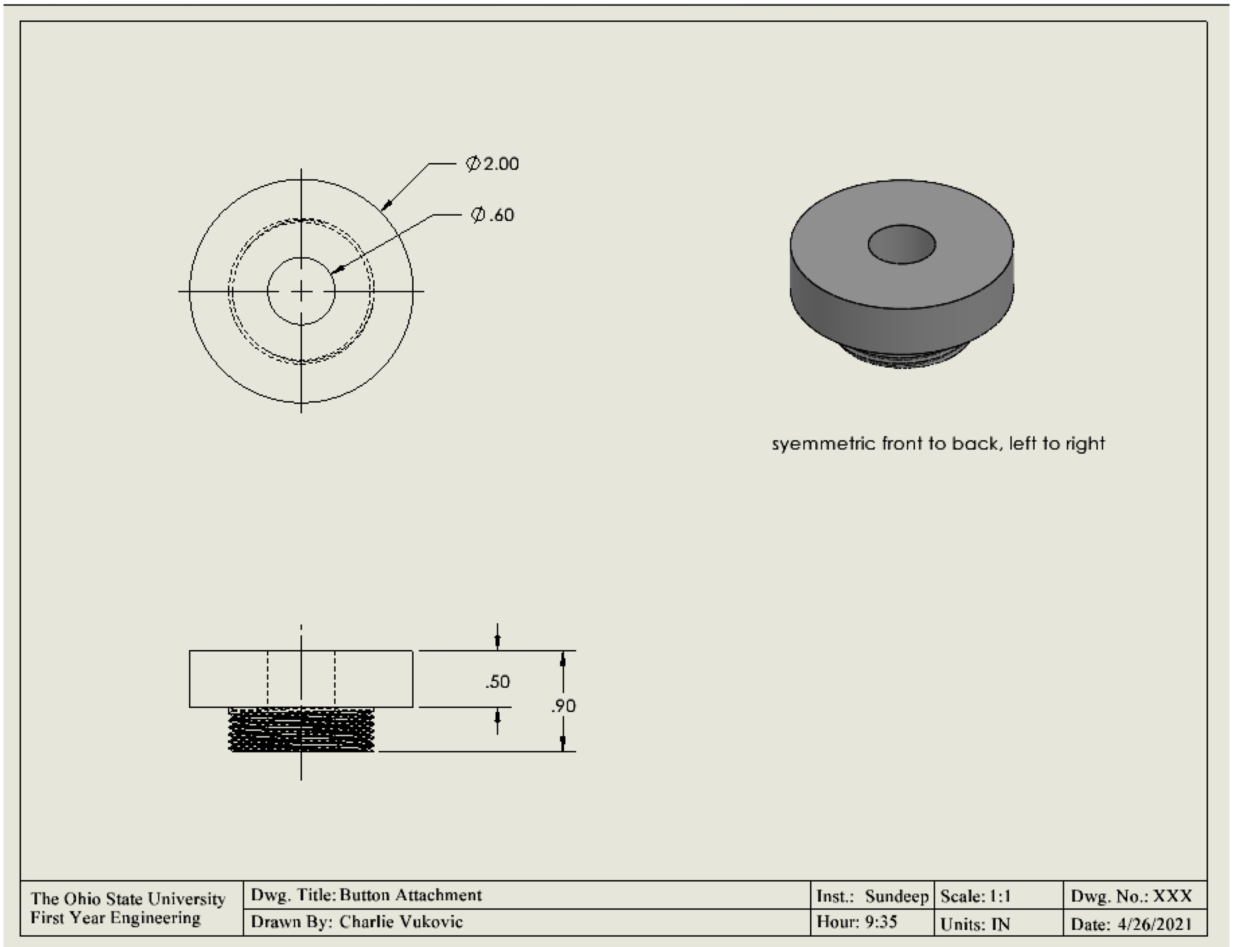
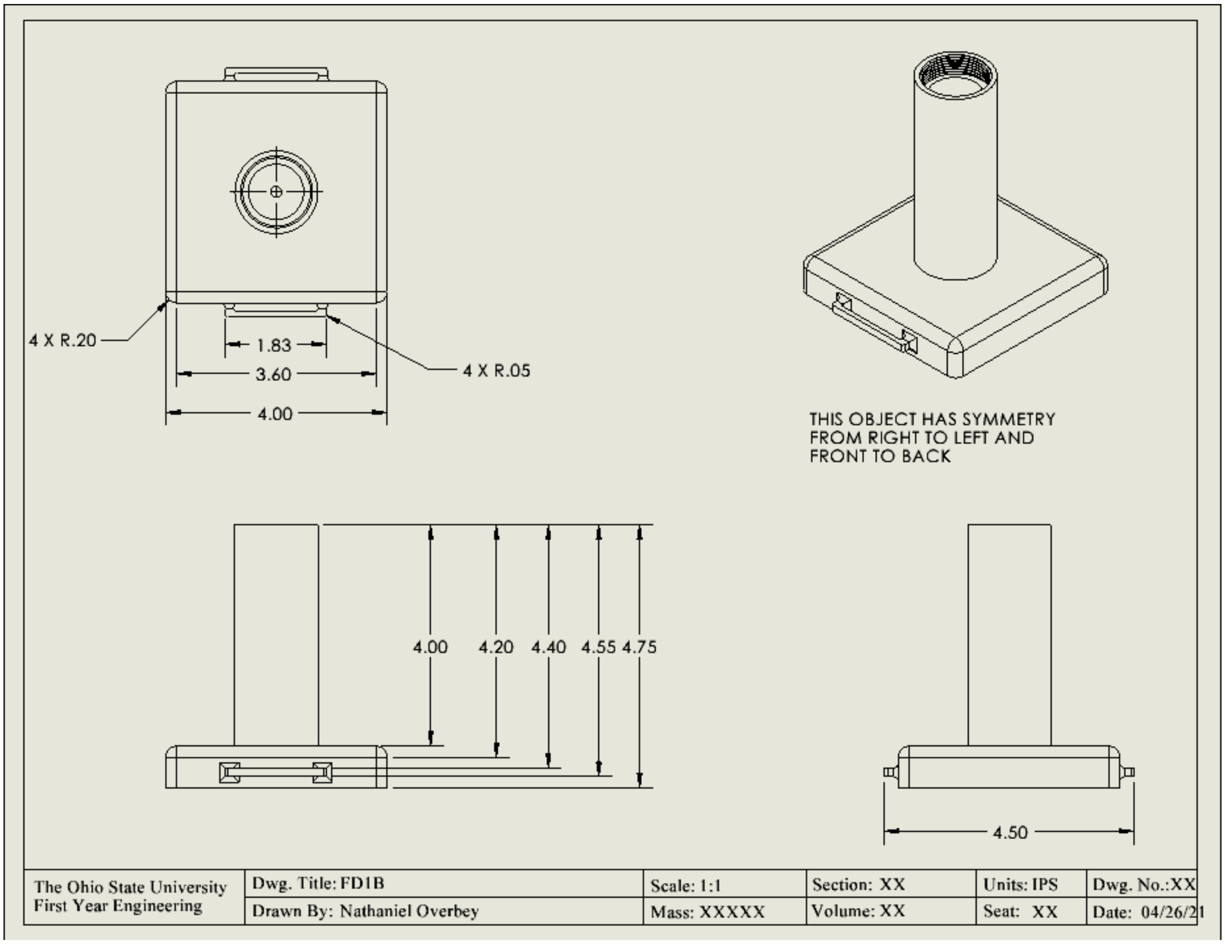


Figure 18. Main Body Detailed Drawing



Video 1. Timed Testing Video

https://osu.box.com/s/xao2q9tmnb86r4laju4q7n5e6jpq4as2