

Apportech™
Final Report



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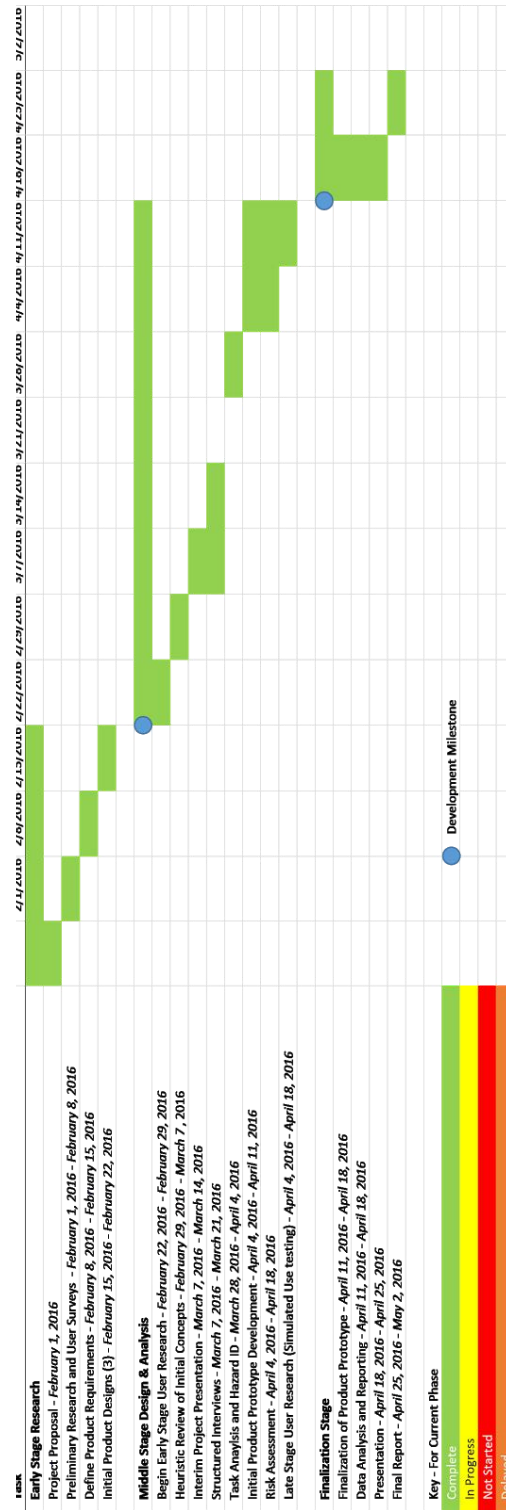
Introduction & Project Background

VFT Design was excited to partner with GreenThumb in order to create a state-of-the-art 3-in-1 horticultural tool equipped with the ability to dispense water, seeds, and fertilizer from the same unit. GreenThumb required a device that is portable and can switch quickly between the three types of materials. Furthermore, GreenThumb requested that the device should have variable speed settings and should be suited to deliver materials at short and long ranges. For VFT Design, the scope of this project was the development of the container unit and the handpiece/nozzle. GreenThumb expected the finalized design to be completed by May 2, 2016, a deadline which the team has delivered on.

Through careful application of the Human Factors design process, VFT Design brings Apportech™ to GreenThumb and to the horticultural market. Apportech™ strives to put the user first and offers an innovative solution to simplify the plant nourishment process. The following report details the team's progress with in-depth explanations of the methods employed and the results obtained. Also included is our development timeline, a description of the VFT Design research team, and a discussion of our overall conclusions at the end of this project. We have included results and findings of the various design steps in the Appendices.



Development Timeline



Please note that this Gantt chart has changed over the course of the project in order to align with the shifting class schedule.

The Research Team



Project Manager

Jacob facilitated communication on this project and coordinated meeting times. His primary responsibility was to ensure that the design team met deadlines and that the Human Factors process was applied efficiently and smoothly.



Product Designer

Alexander was responsible for sketching the conceptual designs and completing the design finishes of the prototype iterations. He was an active contributor to all of the user research and product refinement. He was also the group chauffeur.



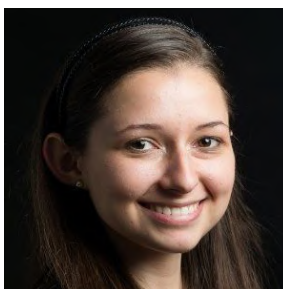
Fabricator

Caroline actively contributed to each step throughout the design process from conceptualization to the final Apportech™ product. Specifically, she played a key role in early design sketches as well as further modifications and improvements based on data from the in-depth interviews, risk assessments, and usability tests.



UX Researcher

Sam helped conduct and analyze research to conceptualize and refine the Apportech™ product. Specifically, he contributed to the initial design process and consulted on certain product features related to both the handpiece and containers.



Product Designer

Heather was an active participant throughout this project and helped come up with potential designs for the final product. She also helped analyze the results obtained from user testing and as well as contributed potential modifications to the final prototype.

Methodology & Outcomes

The team engaged in each of the following processes and techniques in order to optimize the design of Apportech™. Generally, each component of the design process supplied input for the next, thus enabling the team to create the best possible gardening tool.

Preliminary Web Research

Method Description

The VFT Design team had little experience with gardening tools and processes prior to the development of Apportech™. In order to get a better understanding, the team started the design process by conducting initial web-based research. Specifically, the team looked at gardening store websites, videos, product reviews, and general gardening information.

Outcomes

Through this preliminary web research, the team learned more about the common scopes of gardening (indoor, outdoor, large scale, small scale, etc). The team also learned that fertilizer can come in both liquid and solid forms, although dry solid fertilizer is the most widely used. Furthermore, the team learned that fertilizer should not be spread by hand and looked at both automatic and manual ways to distribute fertilizer. The team assessed the pros and cons of existing products for fertilizing, watering, and seeding, learning that many customers valued multi-function devices but were unhappy with the quality and durability of their gardening tools. The team utilized the review sections on websites that sell gardening materials and tools to gain further insight into customers' likes and dislikes of products already on the market. Finally, the team analyzed the rapidly-growing gardening industry economy to look for market opportunities for Apportech™. See Appendix A for our full research notes.

Conclusions

This preliminary research helped the team gain a better grasp on current gardening practices and tools. With this initial context in mind, the team was able to brainstorm a list of questions that we still had about gardening and various gardening tools. Once we had these questions, along with our initial research, we were able to begin thinking about our informal observation visits.

Informal Observation Visits

Method Description

The preliminary web research provided the team with a better understanding of the gardening industry. To conduct our informal observations, the team visited two different locations. The purpose of these observations was to get a firsthand look at some of the products currently on the market. The first location visited was Home Depot in Assembly Square, MA. The second site visited was Mahoney's Garden Center located in Winchester, MA. Mahoney's had three greenhouses with a variety of plants to purchase.

Outcomes

At Home Depot, the team looked at and photographed various gardening tools and materials including weed whackers, power cleaners, dispensers, and various types of fertilizer. At Mahoney's, the team observed some of the watering tools the employees used to nourish the plants. Numerous photos were taken during these visits. Please see Appendix B for some examples.

Conclusions

With our initial research and informal observations complete, the team still had some questions about gardening practices and tools. Keeping the research and observations in mind, the team moved on to begin creating an initial survey to help address some of these unanswered questions.

Initial Survey Creation & Administration

Method Description

To create this initial survey, the team used Google Forms to assess what aspects of this 3-in-1 tool would be the most important. Please see Appendix C for the full survey. We asked participants about the tools they currently use to water, fertilize, and seed. We were interested in the advantages and disadvantages of their current tools and we wanted to understand, in a general sense, what potential users would value most in a new product across dimensions such as price, durability, ease of use, etc. We returned to Mahoney's Garden Center to administer this initial survey.

Outcomes

After collecting five responses using iPhones and an iPad, we realized that there were several issues with the initial survey. Several of our questions did not provide us with relevant information for our research. Some of the wording for both the answers and the questions was also confusing and ambiguous. In terms of presentation, the mobile interfaces (iPhone and iPad) were difficult for participants to interact with. Specifically, it was hard for participants to click on choices and type in long answers to open-ended questions. Overall, the format of the questionnaire itself did not integrate well on a mobile device.

Conclusions

The reactions of participants to this initial survey were extremely valuable. The team was able to find several issues with this initial survey that needed fixing. With these issues in mind, the team moved on to revising the survey and collecting more results.

Revised Survey Creation & Administration

Method Description

To address the issues with the initial survey, the team began removing certain questions and revising the wording of the ambiguous ones. We determined that the most relevant information for our purposes had to do with the issues associated with current products. Thus, we focused on including questions that uncovered these shortcomings. Another issue with the initial survey had to do with the fact that it was presented on a mobile device. This made us rethink how we were going to present our survey; Google Forms is significantly more conducive to online data collection as opposed to in person collection, thus we decided to send the survey out by email and through online gardening forums.

Outcomes

Utilizing an online forum was extremely useful to gather participants, since there were few gardeners present at Mahoney's during the winter. Although 17 responses were collected, only 10 were considered when moving forward (this was due to survey responses submitted after analysis). Most of the participants in the survey gardened outside. They also ranked durability and functionality as some of the most important factors for the tools they used. Many participants

were unhappy about getting their hands dirty while using their gardening tools. Please see Appendix D for the revised survey and full results.

Conclusions

The results of the survey provided us with very important information for what our device needed to accomplish and what factors were most important for users of the device. With this information in mind, we closely analyzed the different responses to begin thinking about user needs and requirements.

Defining User Needs and Requirements

Method Description

Based on the results of our survey, we came up with a list of user needs and requirements. The full list of needs and requirements, along with justifications, can be found in Appendix E.

Outcomes

A sample of our user needs is displayed on the right. One important user need we discovered from the survey results was that users needed the device to be able to distribute different types of fertilizer. This required us to design a device that would distribute both granular and liquid fertilizer, an important characteristic that would affect the

mechanics our design. Users also needed a device that did not leak, which was a very important characteristic since fertilizer can be harmful if a user comes in direct contact with it. Durability was also found to be particularly important among our user preferences. Therefore, we defined a requirement for our design that it be able to withstand repeated dropping from a height of five feet. One of the most complained about features in current on-the-market products was the lack

Source	Reference	User Need	User Requirement	Justification	Reference
Functionality was the highest rated characteristic (4.1)	Revised Survey Results	Users need the device to be durable.	The device shall be able to withstand a repeated drop test of 4 feet.	3.36 ft is the average elbow height of a standing person. This is a reasonable estimate of the height at which the handpiece will be dropped.	Ergonomics Data & Mounting Heights (2014) Ergotron Ergonomics Data. Retrieved from: https://www.ergotron.com/Portals/0/literature/whitepapers/english/ergonomics_arms_data.pdf
9/10 respondents reported gardening outdoors.	Revised Survey Results	Users need the device to be able to withstand outdoor use.	The device shall be water resistant.	"More precipitation is occurring in heavy rainfall events (more than 2 in / 48 hrs), and this trend is expected to continue."	Wolfe, D., Beem-Miller, J., Chambliss, L., Chatrchyan, A., Menninger, H., (2014) Climate Change Facts - Farming Success in an Uncertain Climate. Cornell Climate Change PWT. 2014. Retrieved from: http://climatechange.cornell.edu/wp-content/uploads/2013/03/climate_and_farming.pdf
9/10 respondents reported gardening outdoors.	Revised Survey Results	Users need the device to be able to withstand outdoor use.	The device must be operable within the range of 32-100°F	"The number of summer heat stress days (e.g., exceeding 90°F) is expected to increase substantially, while winters grow milder."	Wolfe, D., Beem-Miller, J., Chambliss, L., Chatrchyan, A., Menninger, H., (2014) Climate Change Facts - Farming Success in an Uncertain Climate. Cornell Climate Change PWT. 2014. Retrieved from: http://climatechange.cornell.edu/wp-content/uploads/2013/03/climate_and_farming.pdf

of portability. Users said that many of their devices were cumbersome and frustrating to move around. Therefore, we defined a requirement that our device shall be able to be moved 100 meters by the 25th percentile female adult without experiencing unsafe levels of strain. We defined this to be a requirement after researching the average yard size in the United States, taking into consideration that a user would likely move more than the length of their yard with the device during a single gardening session.

Conclusions

At this stage, the team felt that these needs and requirements could be successfully verified and validated once we settled on our winning design concept. Furthermore, these user needs and requirements were important to keep in mind moving forward. Ultimately, our designs needed to adhere to these requirements. The next stage was initial concept creation, for which the team brainstormed different designs, keeping the recently created requirements in mind.

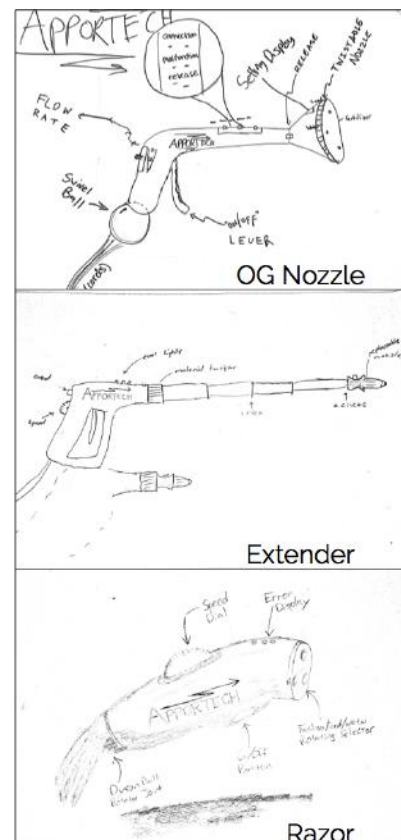
Note: These needs and requirements were revised after the final presentation to match the quality and form learned through the Individual Assignment 2 revision opportunity.

Creating Initial Design Concepts

Method Description

After defining our user needs and requirements, we participated in a creativity session to come up with an initial design for the handpiece. With our recently created requirements, we brainstormed a list of features and solutions. We wrote different ideas on sticky notes and pinned them to a board with different category groupings. After this initial brainstorm, each team member voted on a few features and ideas that they liked. We strongly considered the features that received the most votes.

Outcomes



waist strap to help distribute the weight of the material. The third and final design is the “the Dolly” or the “Mail-Carrier Cart,” (seen in Appendix F). It features two off-roading wheels with a handle at waist height. Users can easily push down the handle to leverage the containers off the ground. The two wheels allow users to easily turn and pull or push the containers across rough terrain. All concepts generated at this stage were hand drawn.

Conclusions

The team was satisfied with these initial concepts. With three concepts for both the handpiece and the container, the team had a solid array of design options, each boasting a variety of different features. In order to test the feasibility of our designs against some pre-defined standards, the team conducted a heuristic review.

Heuristic Reviews of Initial Concepts

Method Description

After designing these initial concepts, the team met to perform a heuristic analysis of the designs. The heuristics set used was Nielsen’s Heuristics for User Interface Design. While these heuristics are specifically meant to address digital user interfaces, we determined that they would still be applicable to the physical design of Apportech™. To begin, the team conducted a group heuristic review on our first nozzle design. After this review, each member of the team conducted a solo heuristic review on one of our five remaining nozzle or container designs. Once these heuristic reviews were conducted, the team met again to discuss the findings.

Outcomes

These reviews allowed us to implement many key changes to enhance our designs. First, we determined that it was important to dual encode features and error states using both text and images. Second, we determined that it was important to add a safety on the nozzle to prevent accidental activation of the device. Third, we determined that it was important to add an error state locking mechanism that prevents the user from operating the device if an error has occurred. Finally, the team was concerned about the weight and size of the device (especially the backpack), making a note to understand this issue more precisely during interviews. Please see Appendix G for the complete heuristic reviews.

Conclusions

Ultimately, the heuristic reviews allowed the team to compare the initial concepts to widely accepted standards. This allowed us to see what gaps in the design we had not previously considered. These reviews helped us to ensure that we had covered our bases. With more confidence in our initial concepts, the team met to narrow down our design options.

Consolidation of Concepts

Method Description

After conducting a heuristic review on each of our six concept designs, the team decided to refine the concepts before taking them to the field for use in structured interviews. The team aimed to create two polarizing design concepts both for the handle and container, for a total of four design concepts (see Appendix H).

Outcomes

For the handle designs, we decided that the Razor aptly adhered to our heuristic standards, so we continued with that design with only slight modifications. We combined aspects from our initial handle design and our extendable handle into a single design concept we dubbed “the Raygun.” We incorporated the Dyson ball and flow rate control slider, as well as the error display to this design. The Dyson Ball was included to account for the required range of motion for the handle design. The slider was included in the Raygun design to serve as an opposing option to the wheel in our Razor concept. We made the error display in the Raygun different than the Razor’s by including two lights per error state, rather than just one. We also decided to make the material dispensary mode selection wheel on the Raygun much larger and thicker than the selection wheel located on the head of the Razor. We maintained the extendable design, and also added a joint at the end of the nozzle to facilitate different spraying angles. Lastly, we incorporated the trigger covering from the original extender design, and included a safety on the trigger, which was a conclusion reached after our heuristic reviews.

For our container designs, the team again tried to narrow the options down to two polarized concepts. After our heuristic reviews, we found that two of our designs were much stronger than the last option (the Shop-Vac). We eventually decided to drop this design

altogether, especially due to the fact that we felt it was ill-suited to navigate uneven terrain. We proceeded to work on our Mail Carrier design as well as our Backpack design. We further specified details of the Mail Carrier and Backpack. For example, we specified that the Mail Carrier would have an uneven distribution capacity of water, seed, and fertilizer, while the Backpack would hold 15 pounds of each. Additionally, both designs had transparent tanks to allow users to better gauge their available resources. We further defined the loading methods for both designs. For the Mail Carrier, the user must open a cap and fill each container from the top. For the Backpack, each container is removable, and the lids themselves are fully removable and fillable from the top. The Backpack design was redrawn for the sake of better consistency across presentation of designs.

Conclusions

Creating two polarizing concepts for both the handpiece and the containers prepared the team to discover which features were the most valuable through in-depth interviews. These interviews would ultimately enhance our understanding of what users would want out of a product such as Apportech™.

In-Depth Interviews

Method Description

The participants (N=5) for the team's in-depth interviews mainly specialized in home, flower, and vegetable gardening as well as yard landscaping. Four participants were females with ages ranging from 52-57, and one was an 18-year-old male. The interviewees all had substantial gardening experience, ranging from 6 to 30 years, which included both indoor and outdoor gardening. The interviews were administered over the phone or in-person. Results can be found in Appendix I.

Outcomes

In terms of the handpiece design, four of the interviewees preferred the Raygun design and one preferred the Razor. Overall, the error displays were well received on both designs, as people liked the error lights and their location. Other features that were received positively on the Raygun included the on/off lever, the rotating material dial, and the "Dyson" swivel ball. The

participants did not have very strong feelings regarding the extender feature, as some people thought it would be useful and some were indifferent (no one was opposed). While a majority of the participants preferred the Raygun to the Razor, three out of five people strongly preferred the scroll dial to the sliding switch (for changing dispensing speed) and named it as the number one feature they would combine from the Razor to the Raygun. Across the board, people also said they liked how durable and familiar the Raygun looked in terms of gardening equipment. People were most concerned about the weight of the Raygun and the potential for clogging in both designs. At first glance people said they liked the aesthetics of the Razor, as it looked more ergonomic and aesthetically pleasing, but once they took a closer look at the features, a majority preferred the Raygun. However, it is still important to note this gut-reaction from consumers when marketing the product. It is also important to note that the 18 year-old male was the only participant who preferred the Razor, while the women in their 50s all preferred the Raygun. Hence, a wider demographic should be considered.

Similarly, the four females in their 50s preferred the Dolly or Mail Carrier design while the 18-year old male preferred the Backpack design. The biggest concern with the backpack was weight, as two people expressed doubt that they could safely carry 45 pounds on their back. Recommendations were made to ensure that the straps distributed the weight evenly, yet the weight concern was enough for most people to select the dolly over the backpack design. People really liked the mobility of the backpack, however, and noted that it could be used both inside and outside and would allow for maneuverability into small, tight places. Conversely, one concern with the dolly design was its lack of mobility, especially indoors and in tightly packed gardens where it might ruin plants. All participants agreed that the water container needs to be the biggest container, the fertilizer container should be the next biggest, and seeds the smallest. There was some controversy over whether or not the containers/tubes could be removeable from both designs; regardless, most preferred that the containers be removable, as it would make them much easier to fill up. Funnels were recommended to additionally ease the filling process. Interviewees also liked the clear labeling on the backpack design and recommended that this be combined into the dolly design. Overall, people preferred the dolly due to weight concerns, yet

were still fond of the backpack design, particularly the mobility, and may reconsider if the weight burden was mitigated in some way.

Conclusions

These interviews proved to be very useful as they not only indicated strong preference to a handpiece and carrier design over the others, but also brought forward some universal concerns as well as helpful recommendations for the designs moving forward. The team consolidated this feedback into a single design for both the handpiece and the container. The handpiece design kept most of the features from the Raygun concept, but added a scroller dial for speed flow selection based on participant's reactions. For the container, the team selected the Mail Carrier Cart design due to weight concerns with the backpack, and made the material containers removable from the cart body to enable easier fill up. Finally, the in-depth interviews confirmed that the water container should be the largest of the three material containers.

Task Analysis

Method Description

To prepare for the hazard identification process, the team began to put together a hierarchical task analysis for the different steps involved in using Apportech™ to water and fertilize a ten foot garden. To do this, we brainstormed some of the larger steps associated with a hypothetical gardening session in a spreadsheet and then began breaking down those steps into smaller sub-steps. We stipulated that users could not walk through the garden for this task because we wanted to analyze the extension and flow rate capabilities of the device.

Outcomes

Below is the result of the hierarchical task analysis. A larger copy can be found in Appendix J.

Goal:	Steps	Sub-Steps	
Watering and fertilizing a ten foot garden. (You cannot walk through the garden)	1 <u>Fill containers</u>	Grab Apportech	
		Ensure that tubes are connected to bottom of the containers	
		Open desired container lid	
		Fill container with appropriate material (water, seed, fertilizer)	
		Close container lid	
		Ensure containers are properly locked into the cart	
	2 <u>Check error states</u>	Turn it on (on cart)	
		Remove handpiece from holster	
		Check Error Lights on Handpiece	
		If nozzle needs to be replaced, go to step ____	
	3 <u>Replace 24 HR Nozzle (if necessary)</u>	If nozzle is not clicked into place, fix nozzle.	
		If device is clogged, take handle apart and clean clogs	
		Twist off nozzle	
		Retrieve a new nozzle	
	4 <u>Fertilize Garden</u>	Click and twist new nozzle on	
		Ensure that the error light is off	
		Place handpiece back into holster	
		Roll the cart to the work site	
		Remove handpiece from holster	
		Twist dial to select "Fertilize"	
	5 <u>Water Garden</u>	Aim nozzle at desired target	
		Extend nozzle as needed	
		Press down the trigger to dispense fertilizer	
		Move nozzle to spread fertilizer to various plants	
		Roll thumb along speed dial to increase flow and distance	
		Release trigger when done	
	6 <u>Clean Apportech</u>	Reholster the handpiece	
		Bring cart over to garden site	
		Remove handpiece from holster	
		Twist dial to select "Water"	
		Aim nozzle at desired target	
		Press down the trigger to dispense water	
		Move nozzle to spread water to various plants	
		Roll thumb along speed dial to select flow setting	
		Release trigger when done	
		Return handpiece to holster	
		Turn off Apportech using switch on cart	
		Roll cart away from gardening site	
		Disconnect tubes from container and handpiece	
		Dump out leftover materials	
		Spray water through tubes to clean (likely with hose)	
		Reconnect tubes to container and handpiece	
		If clog is in tubes, run hose water through until clog is cleared.	
		If clog is in containers, run water through (Let water drain through the bottom)	
		If clog is in handpiece, clean with pipe cleaner.	

Conclusions

Overall, the tasks involved in operating the device seemed fairly simple and reflected the major design aspects of Apportech™. We were able to break down the tasks into six major steps and break down those major steps into at least five sub-steps. This HTA served as direct input to our hazard identification, a method which considers potential failures at each stage of a task.

Hazard ID

Method Description

For the hazard identification process, the team began brainstorming different use errors and hazardous situations for the steps of the HTA. Once we had a comprehensive list of use

errors and hazardous situations, we began filling in the rest of the hazard identification table. For each situation, we assessed the type of harm to the user, the level of severity, and the justification for that severity level. Once we had completed these columns, we assessed the different P2s, or the probability of the hazard leading to harm. Finally, we reviewed the hazard ID table again to verify and validate that the hazards and the P2s we initially came up with were accurate.

Outcomes

Hazard ID	Hazard	Hazardous Situation	Harm to user	Severity Level [1]	Severity Level Description [2]	P2 - probability of hazard leading to harm	Potential cause/ Severity justification/ Comment
1	Use Error	User drops handpiece on foot	Bruise or Abrasion	Very Low	The handpiece does not weigh that much to cause significant damage	Remote	Older adults may have weaker feet
2	Use Error	User rolls over foot with carrier	Bruise or Abrasion	Low	It will be painful, however, it will almost certainly not require medical attention	Remote	
4	Use Error	User hits himself in the face with the extender	Bruise, abrasion, or broken bone	Moderate	Moderate if a bone is broken	Occasional	If user has hit themselves in the face, it will likely hurt or leave a bruise -> Should add requirement about the speed of the extender
5	Use Error	User pinches fingers when pressing trigger	Bruise or Abrasion	Low	Pinching fingers may be painful but unlikely to require medical attention. Not enough force on trigger to cause severe harm	Remote	Remote chance that pinching fingers will lead to harm. Might just be harmful once in while.
6	Use Error	Fertilizer comes in contact with eyes	Ocular Irritation, Blindness	High	In rare cases, users could become permanently blinded	Probable	Probable irritation. Unlikely for permanent blindness
7	Use Error	Fertilizer comes in contact with mouth	Possible toxicity	High	Ingesting enough fertilizer can be poisonous.	Occasional	User needs to ingest a fairly large amount of fertilizer to actually be harmful
8	Use Error	Fertilizer comes in contact with skin	Chemical burn	High	https://www.nlm.nih.gov/medlineplus/ency/article/002841.htm	Unlikely	
9	Use Error	Water comes in contact with eyes	Ocular Irritation	Very Low		Occasional	Shooting water into one's eyes will typically be an inconvenience
10	Use Error	Seed comes in contact with eyes	Ocular Bruise or Irritation	Moderate		Probable	If you shoot a seed into your eye, it will likely result in either a Bruise or Irritation
11	Use Error	User trips over cables	Joint Injury, Bruise, or Abrasion	Moderate	Falling onto a rough surface can cause an injury that may require medical attention	Unlikely	People will catch themselves most of the time if they trip
12	Use Error	Cart tips over onto leg	Broken bone	Moderate	If the leg is broken	Remote	More likely among older populations

Above is a copy of the hazards identified during use of our product. A larger version can be found in Appendix K.

Conclusions

Our final hazard identification chart consisted of twelve different use errors and hazardous situations. Only two of the hazards were listed as “Probable” for the likeliness that they would lead to harm. The rest of the hazard P2’s were listed as “Occasional” or less. The

severity levels varied in their ranking from very low to high. After completing our hazard ID, the team had P2s and severity levels that could be used in combination with a use-related risk assessment to uncover risk ratings. In parallel with this risk assessment, the team created an initial product prototype.

Product Prototype Development

Method Description

Creating the initial product prototype was an essential step to the project as whole. Having a device that participants could physically interact with allowed the team to get specific input on our design (see the usability test section below). This task extended over the course of two weeks, and ran parallel with our risk assessment. In order to create this initial prototype, team members went to a local hardware store and purchased a caulk gun. The caulk gun was modded by removing the metal rod and bolting it to retain the trigger's elasticity. We then unscrewed a hose nozzle to separate the head, and attached the head to a roll of cardboard. This cardboard roll was slightly smaller than a cardboard sheath attached to the body of the caulk gun. This allowed the nozzle to slide in and out, representing the extender feature. We surrounded the body with cardboard and secured it with tape. A computer mouse was fastened to the body to mimic the speed flow scroll dial. Finally, the prototype was wrapped with duct tape for extra strength and style. Error lights, buttons, and labels were drawn on in sharpie.

Outcomes



Conclusion

The team was satisfied with the development of the initial prototype. The prototype was a product of the conclusions reached after conducting a wide variety of Human Factors methods. This initial prototype was used directly in our usability testing (see below).

Use-Related Risk Assessment

Method Description

The objective of a risk analysis is to identify potential risks involved in using the product. Once these risks are identified, mitigation strategies are employed to improve the overall design and safety of the product. We had already performed a task analysis and a hazard ID for our device, so we used the information gathered from those steps to inform our use-related risk assessment. The team outlined potential failure modes and their causes for each task. In addition, we noted the severity and P2 levels previously determined in our hazard ID. Referencing the corresponding table, we found the P1s for each failure mode, or the likelihood of the hazardous situation occurring. Using the P1 and P2 levels, we were able to determine the likelihood of each failure mode ($P1 \times P2$). The resulting likelihood level was then used with the severity level ($Likelihood \times Severity$) from our hazard ID to determine risk. A copy of our results can be found in Appendix L.

Outcomes

Fortunately, none of our risks fell into the “Not Acceptable” category; all were in the AFAP1 or AFAP2 categories. While these risk levels are acceptable, the goal at this point is still to mitigate risk “as far as possible.” Thus, for each failure mode we identified a strategy to mitigate potential risk. For three AFAP2 level risks, we did not suggest any mitigation strategies because they were either strictly user related and/or out of our design control.

Conclusions

The team implemented several design changes in the prototype prior to usability testing based off of the conclusions drawn from our use-related risk assessment. These included: marking a max fill line on the containers to prevent overfilling; including two LEDs for each error state indicator, one red and one green, to better indicate when there is an error; and

including a red LED light that indicates when the safety is on to better alert users of safety state. Other mitigation methods drawn from our risk analysis to be included in the final design (but not the prototype) included making the container lids lock to prevent spillage and to alert users that the lid is correctly closed, disabling the trigger if there is an error to prevent users from misusing the device, including multiple warnings in a manual to describe safety precautions while using the device, and preventing the extender from being too forceful in order to prevent accidental injury during use (the specific extender force should be determined by the product fabricators).

The risk assessment proved to provide valuable insights into how we could improve the safety and mitigate the risk of our device which, in turn, improved the overall design. After implementing all of the risk mitigating design changes we could, we used the newly improved prototype to perform simulated use testing with five different participants to observe how users physically interacted with our device and to identify further design changes to improve the overall usability and functionality.

Simulated Use Testing; Data Analysis and Reporting

Method Description

Overview

The last key method involving the testing of our Apportech™ design was simulated-use testing. The team started by creating a test plan. The plan was reviewed by Human Factors specialist Maureen Mulcare in order to ensure that it was complete and robust. This plan outlined objectives, test environment, target participants, objective measures, and subjective measures, to name a few components. Generally, our primary objective was to assess the usability of the device in relation to each task. Please see Appendix M for the complete list of objectives and the full test plan.

Each usability test started with a pretest interview to obtain some basic demographic data as well as to assess prior experience with gardening and gardening tools. Next, the participant completed a series of tasks. These tasks included the following:

- Fill Up the Material Containers
- Check for Any Device Errors

- Water Plants Out of Range
- Speed Adjustment
- Switch from Water to Seed

After each task, the participant was asked a few follow-up questions. These questions were designed to obtain subjective ratings of ease or difficulty of the task, as well as to obtain information about points of confusion and aspects to improve upon.

After the participant finished the tasks, they were asked questions for a post-task interview. These questions attempted to deduce ratings of overall quality, aspects in need of improvement, and aspects that participants liked.

Environment

The testing environment included off-campus housing and a study room in the Tisch Library of Tufts University. All testing environments were indoors. As noted in our test plan, we planned on testing indoors due to weather concerns. Furthermore, our tests were largely based on hypothetical situations and did not require specific or uniform testing environments.

Outcomes

Pilot Test

The pilot test proved to be an essential step for the successful completion of the remaining test trials. One result from the pilot was revealing a confusing aspect of the task of error determination. The pilot participant noted that all the lights were exposed, even though it should only have been a single light revealed. We fixed this error for the following tests. Perhaps the most important insight realized from the pilot was that conducting the test without a script lead to a choppy and disjointed experience. This realization prompted the team to create a standardized script and a spreadsheet for uniform data collection.

Participants

We compiled a large amount of data from our usability tests, though there were a few things in particular worth noting. Five participants took part in testing (N=5). The average reported age was 19.6 years old. Through our testing, we interviewed only college students. In addition, we had all right handed users, two users with corrective eyewear, and 40% people with backyard gardening experience. Our target population included users 18-55 years old, left and

right handed users, professional and backyard gardening, and users with various physical capabilities. Although not all of these demographic categories were represented, the information collected was still useful for analysis, and the participants' suggestions and difficulties were still valid.

Tasks

All users successfully identified material icons on our containers, and were able to fill the dolly-cart without difficulty. One participant noted that the container looked a bit big; we understood that dimensions would change based on the volume needed to carry 45 lbs of material.

Three out of five participants were confused about the error state meanings and their corresponding colors, as shown when they incorrectly identified that the device was ready to use. Some participants gave suggestions, such as preventing the device from functioning if there were errors or including a "ready to use" light if properly functioning. In addition, there was some ambiguity with the safety latch and light.

When participants were asked how they would go about watering out of range plants, all participants used at least one of

the three available components. Four participants extended the nozzle manually, two increased the flow rate, and two tilted the nozzle head. However, there was some confusion about the labeling of these features. Two participants did not notice the extender button and three did not notice that the nozzle could be tilted. In order to reduce the average difficulty rating associated with this task, it is important that these features be clearly labeled in the final design.

All five participants were able to correctly identify and use the speed adjustment dial, however, one participant was unsure if the speed dial was just for water based on the diagram.

Interesting Subjective Feedback
Participants were confused about error states.
Participants were confused about the nozzle tilt symbol.
Ambiguity about the speed flow diagram.
Participants thought that the containers were clearly labeled.
Participants correctly identified and operated flow rate dial.

Average Ratings of Ease/Difficulty (1-5, 5=Most Difficult)	
Task	Mean
Fill Containers	1.2
Error Recognition	2
Water Plants Out of Range	1.8
Speed Adjustment	1.3
Mode Switching	1

All five participants correctly demonstrated how to change between materials, however, two suggested including a line on the dial and body so that the user is sure that the dial is in the correct position for a given material.

Please see Appendix M for the complete results.

Conclusions

After analyzing common themes and calculating means from our quantitative data, the team made several improvements to our final design. Due to confusion with the error state lights, we decided to change the light configuration and labeling. The three states were renamed to clear up ambiguity: nozzle disconnected, device clogged, and replace nozzle. A single red LED would light up next to each label if there was an error. In addition, a “ready to use” label and green LED were included. If there were no errors, the “ready to use” LED would light up. Therefore, as long as the device is turned on, at least one light would be illuminated, letting the user know that the handle is being powered. The team is confident that these improvements will help reduce the average difficulty rating for error recognition. The safety button was changed to a latch with labeling that was less ambiguous.

Due to some confusion about tilting the nozzle, a clear diagram was drawn near the nozzle to indicate its capabilities. In addition, the diagram near the speed dial was clarified to indicate that it controlled all three materials (as opposed to just water).

Although there was no confusion with the material selection component, the team decided to include a line on the device and dial so that the user can be sure that the dial is in the correct position. Due to the low fidelity of our prototype, not all aspects could be represented. In the actual design, the dial would click into place so the user would get tactile feedback about the current material state.

Overall, the qualitative data was more valuable than the quantitative data. For example, time of completion for certain tasks were calculated, however, it was sometimes difficult to assess when the participants had actually completed a task. Therefore, this information did not really guide the team in terms of design improvements. Another limitation of the usability tests was the small sample size (N=5). In order to increase the validity of the results, the team should strive to conduct more tests moving forward.

In general, participants liked the prototype design and found it generally easy to use. Although the prototype needed a few changes and improvements, all five participants said that they would recommend the product. Following the usability testing, we made modifications to our final prototype based on our analysis.

Final Prototype

Our product design evolved over the course of the project, as we learned new information from each step of the Human Factors design process. From paper to a physical prototype, improvements were made and design changes occurred. Our final prototype is a two part system: a handpiece connected by tubes to a carrying cart. After receiving the necessary materials, we completed the carrier and handpiece.

The final carrying cart prototype is roughly 3.25' x 2.5' x 1' in volume, made out of cardboard. The containers are detachable and connect by velcro; the water container is shaped like an upside down "T" (in order to better distribute the weight of materials), and the seed and fertilizer containers are regular boxes. Containers have transparent tracks on their sides to indicate the volume of material present in the containers; we represented this with grey duct tape. The entire system was spray painted white. Each container is dual coded with text and an image in order to avoid ambiguity. The tops of each container have a lid with a handle, which stays connected when opened. Tubes come out from the bottom of each container and are joined together for ease of use. The entire system is connected to a rolling dolly cart. Ideally, the wheels would be on the outside of the container unit but, due to material constraints, the prototype looks slightly different than our ideal design.

The handpiece is composed of several everyday objects. A caulk gun handle was modified to mimic the trigger and handle of our design. Attached at the end of the caulk gun is a garden hose nozzle. The handpiece was designed with cardboard and duct tape to mimic the extending nozzle head. The actual nozzle tilts up and down. A rotating material selector was included, surrounding the middle of the handpiece. A computer mouse was adhered to the back of the caulk gun to mimic our rolling speed dial. To create the "dyson ball" tube containment system, a tennis ball was housed in a plastic cup. A notch was cut into the tennis ball and tubes

were inserted. This design should illustrate the range of movement that our prototype is capable of handling. The entire handpiece was spray painted white. Labels were added for the error states, safety, extension, and nozzle, and a logo was added to the side.



Conclusion

Overall, the team has successfully followed the predetermined Gantt chart/project plan and, when needed, adjusted it accordingly. Each step in the process has helped inform our actions in the next, as recommended. The preliminary web research on gardening methods/tools and informal observation visits to Home Depot and Mahoney's proved to be very useful, as the team was not very experienced with gardening prior to this project proposal. After gathering general information from these steps, the team was able to create an initial user survey which was revised as a result of participant feedback. This survey creation and administration step was very useful in determining important characteristics of potential users and the device itself. The survey data directly informed the next steps in defining user needs and requirements. As expected, these requirements gave a basic structure for the team to design initial concepts. Once three distinct handpiece and three distinct container designs were determined, each were analyzed through heuristic reviews internally within the team, then consolidated down to two

designs each. These designs were then reviewed again through in-depth interviews. After in-depth interviews, the team settled on a single concept for both the handpiece and the container unit. From there, a task analysis provided direct input to a hazard identification, which then allowed for the completion of a risk assessment. An initial prototype was created and enhanced after risk mitigations from the assessment were discussed. Simulated-use testing gave us some final considerations before polishing and completing our prototype.

Throughout this process, the team strived to use the knowledge learned from each method to inform the next, in order to best serve the users' needs and preferences through design. We are confident that both the Human Factors design process and our application of the methods have culminated in an innovative solution to a 3-in-1 horticultural product. We thank GreenThumb for selecting VFT Design to bring Apportech™ to the gardening market. If you have any remaining questions about the application of the Human Factors process, please direct them to Jacob Caccamo.

References

Nielsen, Jacob (1995). 10 Usability Heuristics for User Interface Design. *Nielsen Norman Group*. Retrieved from: <https://www.nngroup.com/articles/ten-usability-heuristics/>

The URLs for the preliminary research are included in the Appendix A.

Appendix A - Preliminary Web Research

Research:

- Gardening opportunities
 - Home use (backyards, home gardens)
 - School landscapes
 - Golf courses
 - Athletic fields
 - Nursery
- Existing Products
 - Fertilizer: come in large bags (dry; granulated or powder, prills) or spray bottles
<http://www.ncagr.gov/cyber/kidswrld/plant/label.htm>
 - dry fertilizer is more commonly used, and grass usually needs to be watered directly after spreading fertilizer
 - fertilizer should never be spread by hand
 - Scott's fertilizer Spreader: <https://www.youtube.com/watch?v=pVRahU6k5qs>
 - This video shows a wheel-based dispenser that fans out fertilizer. It is on wheels.
 - Hard to move around obstacles.
 - Fertilizer spreader types:
<http://www.scotts.com/smg/goART3/Howto/how-to-feed-your-lawn/33500034>
 - Broadcast spreader (fans out) vs. drop spreader (rectangular)
 - Hand Spreader (Seeds): <http://bit.ly/1PPH90U>
 - A hand cranked system that dispenses seed
 - 110 Cubic Inch Capacity
 - Review Cons: Large pieces get stuck, hard to unjam
 - Sprinklers:
<http://www.homedepot.com/b/Outdoors-Garden-Center-Watering-Irrigation-Lawn-Sprinklers/N-5yc1vZc63c>
 - usually move around in an arc or circle
 - stay stationary, can be left alone to water an area but needs to be moved to water other areas
 - BioLogic 2-Gallon Hand-held Sprayer
 - Great for applying herbicides, fertilizers, & more
 - Anti-clog filter keeps the sprayer spraying
 - Long 47" clear hose for exceptional reach
 - Miracle-Gro Liquefeed All Purpose Plant Food Advance Starter Kit
 - <http://www.miraclegro.com/smg/goproduct/miracle-gro-liquefeed-advance-hose-end-feeder/prod140002>

- Now any watering device can be a feeder at the flip of a switch, convenient
 - Feeder attaches to spigot and then hose attaches
 - Features 4 pattern sprayer and locking trigger
- HD Hudson Hose End Sprayer
 - <http://www.planetnatural.com/product/hose-end-sprayer/>
 - Attaches to end of hose, mixes fertilizer and insecticide
- Gardening Industry in the Economy
 - <http://www.prnewswire.com/news-releases/report-despite-challenges-10-billion-lawn--garden-equipment-market-shows-resiliency-300091147.html>
 - Battery power tends to be popular, and market sector expected to grow with battery technology
 - Highly concentrated retail. Mass marketers (Home Depot, Lowe's, etc.) account for 75% of market sales and 80% of outdoor power tool sales.
 - Consumers aggressively shop online, seeking price comparisons and product features.
 - <http://www.freedoniagroup.com/brochure/27xx/2797smwe.pdf>
 - Demand forecasted to rise 4.8 percent in 2015, to \$18.9 billion.
 - North America and Western Europe are and will continue to be dominant markets
 - 85% of demand in 2015.
 - Consumers have high per capita income levels.
 - Home to majority of world's golf courses, which are major consumers.
 - Lawn owners are largest percentage of sales.
 - New housing markets will facilitate growth among lawn owner group.
 - Turf and grounds equipment to post fastest gains
 - Continuing growth in number of professional landscapers.
 - Demand for electric powered equipment will grow faster than for gas, with battery leading.
 - <http://www.freepatentsonline.com/article/Business-Economics/148960915.html>
 - Preference for multifunction devices
 - Consumers seek efficient yet affordable products.
 - Older audience tends to be more willing to purchase high end gear.
 - Concern with noise pollution
- Design considerations
 - Overview of Ergonomics of Hand Tools
 - <https://www.ccohs.ca/oshanswers/ergonomics/handtools/tooldesign.html>
 - <http://www.cdc.gov/niosh/docs/2004-164/pdfs/2004-164.pdf>

Some Questions:

- What is the most important ingredient: seeds, water, or fertilizer?
- What are some common ratios of ingredients?
- What's the most and least favorite activity: planting, watering, or fertilizing?
- How long are people spending seeding/fertilizing/watering in a given instance?
- How frequently are people seeding/fertilizing/watering?
- How often do the acts happen in conjunction vs independently
- Wired or wireless?
- Gas or electric?

Some more Questions:

- What kinds of fertilizer (liquid vs solid)?
- What types of seeds (different sizes)?
- Will this be used on large areas or smaller pots and gardens?

Observation Checklist

- ☐ Note how loud equipment is.
- ☐ Note posture of equipment users
- ☐ Note how bulky or cumbersome the equipment may be (does it get in the way)
- ☐ Are the products being used/sold mostly gas, electric (corded), or battery powered?
- ☐ Price ranges of available products
- ☐ How are the tools mounted on the user during use? Check product packaging for intended use and also observe any instances of use.

Fertilizer

- Fertilizer can clump, causing clogs in fertilizing machines
- Most fertilizers use spreaders for easy distribution (the best is a cyclone spreader)
- Important to wash equipment after use
- Want to be able to easily put remaining fertilizer back in bag
- Anti-clog filter
- Long reach

Seed

- Large pieces can get stuck
- Important to make it easy to unjam
- Different rates of seeding (depends on square footage and pounds of seed)

Water

- Adjustable spray patterns

- Nozzle needs to be easy to clean
- Nozzle needs to be easy to install
- Durable nozzles (most common con)

<http://www.homedepot.com/p/Melnor-Metal-Hose-Nozzle-505S/203136335>

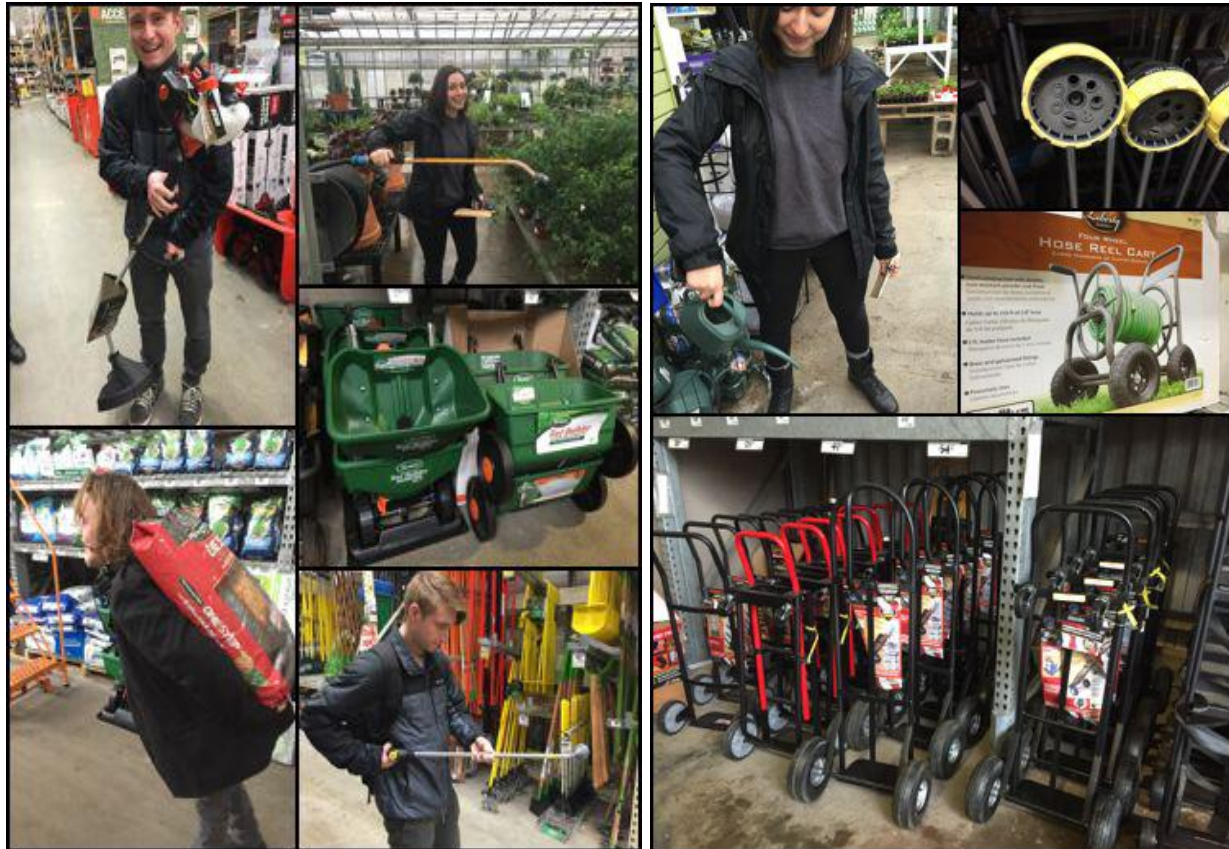
Apply seed and fertilizer at the same time

<http://homeguides.sfgate.com/apply-lawn-seed-fertilizer-together-48324.html>

- Fertilize first, really need to rake it into the soil
- Apply seeds after, important to distribute evenly
- Seeds are distributed at ½ the drop rate as the fertilizer
- Soil goes on top of seeds and fertilizer, then lightly watered

Appendix B - Preliminary Observations

Photo documentation of our trip to Mahoney's Garden Center and Home Depot for our early observational research. The team handled and inspected a wide array of seeding, watering, and fertilizing tools, as well as took stock of the various options available for purchase such as liquid vs. granular fertilizer.



Appendix C - Initial Survey

This survey was created and administered using Google Forms. Below is a script of the questions. Only 5 responses were collected using the initial survey. The responses and the experience of the participants informed the creation of the revised survey.

3-in-1 Gardening Tool

We are designing a new 3-in-1 horticultural tool to deliver water, fertilizer, and seeds. We want to better understand your gardening needs in order to build the best product.

Instructions: Please complete the following survey about your gardening habits. This information will be used to help us design the new tool. Your answers will be kept confidential and your identity anonymous. You may stop participation in this survey at any time.

Please specify your gender.

Male

Female

Other

How old are you?

Please select what level of gardening you most identify with:

Beginner

Intermediate

Expert

Other

Where do you typically garden?

Indoors

Outdoors

Semi-Enclosed

Other

What types of gardening are you involved with (i.e. ornamental plants, fruits & vegetables, forestry, public green areas, etc.) Please describe.

Please rank the following characteristics of your gardening product in order of importance to you (1 is most important, 7 is least important):

Durability
Price
Functionality
Ease of Use
Ease of Maintenance*
Mobility
Versatility

What do you currently use to fertilize your plants?

How often do you use this tool(s)? (Please be as specific as possible.)

What has been your experience with the equipment you use to fertilize?

1 - Extremely Poor
2
3 - Poor
4
5 - Good
6
7- Extremely Good
N/A

What is your least favorite aspect of your fertilizer tool(s)? (Please be as specific as possible.)

What do you currently use to water your plants?

How often do you use this tool(s)? (Please be as specific as possible.)

What has been your experience with the equipment you use to water?

1 - Extremely Poor
2
3 - Poor
4
5 - Good
6
7- Extremely Good
N/A

What is your least favorite aspect of your watering tool(s)? (Please be as specific as possible.)

What do you currently use to distribute seed?

How often do you use this tool(s)? (Please be as specific as possible.)

What has been your experience with the equipment you use to seed?

1 - Extremely Poor

2

3 - Poor

4

5 - Good

6

7- Extremely Good

N/A

What is your least favorite aspect of your seeding tool(s)? (Please be as specific as possible.)

Would you be interested in a multi-functional device that can seed, water, and fertilize?

Yes

No

Additional Comments

Note:

*There was a typo that said “East of Maintenance” as opposed to “Ease of Maintenance.”

Appendix D - Revised Survey

This survey was created and administered using Google Forms. Below is a script of the questions. Only ~10 responses were collected before the team moved on to defining needs and requirements.

3-in-1 Gardening Tool

We are designing a new 3-in-1 horticultural tool to deliver water, fertilizer, and seeds. We want to better understand your gardening needs in order to build the best product.

Instructions: Please complete the following survey about your gardening habits. This information will be used to help us design the new tool. Your answers will be kept confidential and your identity anonymous. You may stop participation in this survey at any time.

Please specify your gender.

Male

Female

Other

How old are you?

Where do you typically garden?

Indoors

Outdoors

Semi-Enclosed

Other

Please rate how important each of the following characteristics is in your gardening tools and equipment. (1 - Not Important At All -- 5 - Very Important)

Durability

Price

Functionality

Ease of Use

Ease of Maintenance*

Mobility

Versatility

What types of fertilizer do you use, if any?

Granular

Powder

Liquid

N/A

Other

What equipment or tools do you use to fertilize, if any? (Please be as specific as possible. (i.e. shovel, push carts, hand cranks, etc.)

What is your least favorite aspect of your fertilizer tool(s)? (Please be as specific as possible.)

What equipment or tools do you currently use to water your plants, if any? (i.e. Hose, watering can, sprinklers, water barrel, dropper hose, etc.)

What is your least favorite aspect of your watering tool(s)? (Please be as specific as possible.)

What equipment or tools do you currently use to distribute seeds, if any? (i.e. hands, shovel, seed spreader)

What is your least favorite aspect of your seeding tool(s)? (Please be as specific as possible.)

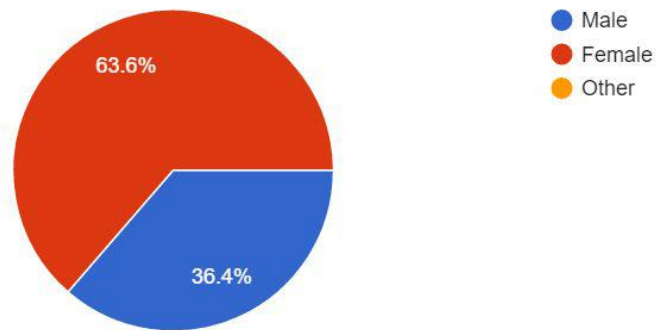
Additional Comments

Note:

*There was a typo that said “East of Maintenance” as opposed to “Ease of Maintenance.”

Results: The following images show most of the results gathered from the revised survey. The full data set can be provided upon request.

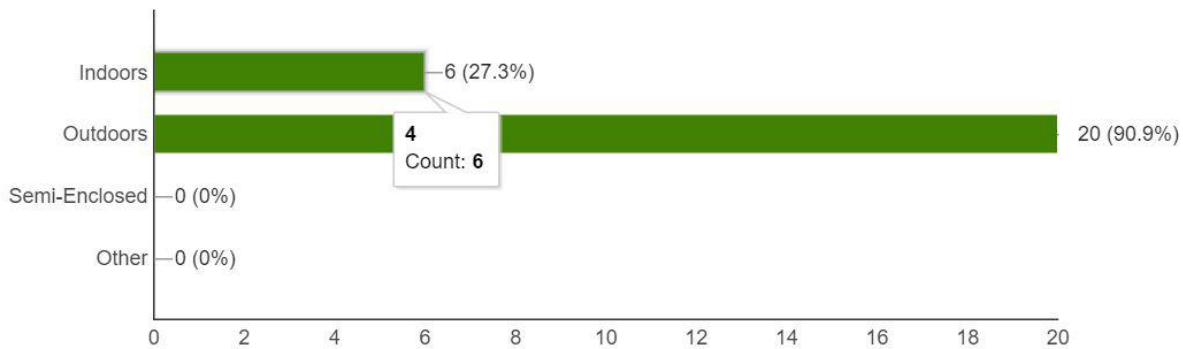
Please specify your gender. (22 responses)



How old are you? (22 responses)

21
21
21
21
44
44
20
20
46
25
52
18
53
79
55
63
28
81
80
85
59
Senior

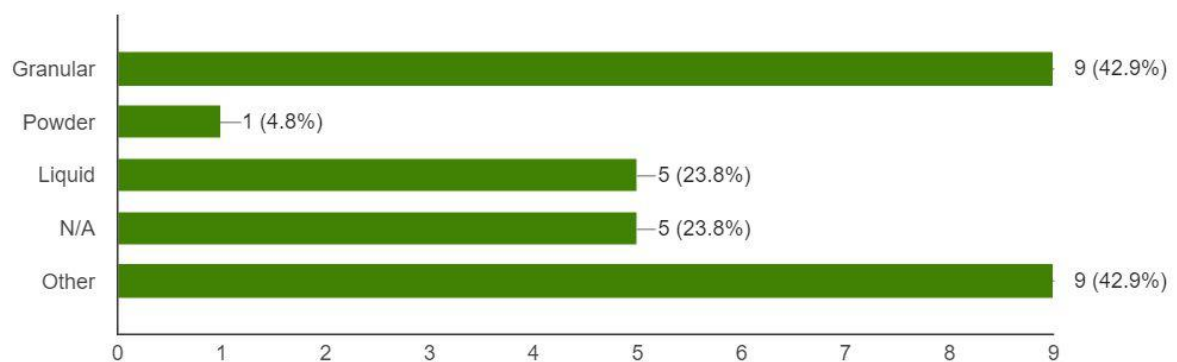
Where do you typically garden? (22 responses)



Please rate how important each of the following characteristics is in your gardening tools and equipment.



What types of fertilizer do you use, if any? (21 responses)



What equipment or tools do you use to fertilize, if any? (20 responses)

Often
Often
once per year
2@week appr
As much as possible
push cart with spinning bottom piece, or hand
hand cranks
Foam bottle, by hand
Shovel, rake
rotatiller
I was doing small scale planting so I just used my hand to sprinkle it.
Pour out container
hand, trowel, shovel, watering can
None
Hand spread and sprayer
Jar that attaches to the hose.
I fertilize very little. I use a bucket and scoop.
Hose application, cart spreader.
wheelbarrow and shovel
Shovel with Home compost

What is your least favorite aspect of your fertilizer tool(s)? (20 responses)

I don't use a *tool*
That I have to keep fertilizing
Sideaffects
Difficult for large areas
lack of even distribution
cleaning
The Chems
N/a
bulky
Dirty and using hands lack a certain amount of accuracy.
dust clouds
uneven spread
Fertilizer gets stuck in applicator
N/A
sprayers
Making sure I have followed the directions correctly of amt. of fertilizer to water.
Having to carry it around.
Running out of product.
none
Natural. Available. Cheap

What equipment or tools do you currently use to water your plants, if any?

(22 responses)

Watering can
Watering can
hose
hose
Hose, watering can
Hose, watering can
a hose
Water barrel & watering can, hose and dropper hose
Water container
Sprinkler system
watering can, hose with spray attachment, and sprinkler
watering can
Can
Spray bottle
hose outdoors, bowl with spout indoors or watering can
hose, watering can
Overhead irrigation, hoses, watering can, Drip irrigatin
Hose, watering can, and sprinklers.
Hose, watering can, sprinklers. I do very little watering.
Hose, watering can, sprinklers.
hose and watering can
Rain. Or hose

What is your least favorite aspect of your watering tool(s)? (19 responses)

the nozzle breaks pretty easily
Heavy
Water level unseeable
Difficult to control
Jose gets water all over me and damages my plants, watering can is inconvenient
portability
Size
Heavy, hose catches on things and what I need to water is too far from spigot
variable spray, high pressure
I would kind of like a middle ground between watering can and spray bottle. Doesn't produce much water.
drips from the watering can or bowl
coiling and uncoiling hose
Having to refill it
leaking nossles and broken pipes
Hooking up sprinkler so that it covers area I want.
Having to lug the hose around and figureing out were the water will fall.
Having to move sprinklers to water area.
cumbersome
Mother natural doing it for me

What equipment or tools do you currently use to distribute seeds, if any?

(21 responses)

Hands
Hands
Hands
Hands
Hands
Hands
hands
hands
hands
hands
my fingers
My hands
Shovel
push cart with spinning bottom piece
Hands, seed broadcaster
grass seed hopper
hands so they can be spaced out properly
hand, seed spreader
N/A
hands, shovel, seed spreader
Hands.

What is your least favorite aspect of your seeding tool(s)? (19 responses)

N/A
N/A
N/A
Dirty hands
Dirty hands
Pain to dig tons of holes
seeds sit on the surface, which allows them to be eaten, fly away, etc.
n/a
nah
Too many or too few seeds are scattered.
seed falls out
Never had much of a problem with this part. I think hands seem to be the best way.
do not use a tool
uneven cast
none
No negative aspect...my hands work best.
It's a slow process.
uneven distribution
No least favorite

Additional Comments (9 responses)

seeds don't need to be fertilized

Make sure you share your results/report!

Gardening 4 life

For reference, I tend a small vegetable and flower garden. My comments do not refer to grass lawns. Sometimes I plant seeds indoors to start the sprouts and then transfer to the garden ground when they are mature enough. Sometimes I will put the seeds directly into the ground. I mostly fertilize the rose bush and use a pour out container for that. Wondering if you are envisioning a certain size space and distinguishing between vegetable gardens, flower beds or the larger lawn. Good luck!

good luck

Survey was a pain in the assana to fill out.

None

It's great to have people considering this.
Good Luck!

My garden is small and easily handled

Appendix E - User Needs & User Requirements

Source	Reference	User Need	User Requirement	Justification	Reference
Functionality was the highest rated characteristic (4.1)	Revised Survey Results	Users need the device to be durable.	The device shall be able to withstand a repeated drop test of 4 feet.	3.36 ft is the average elbow height of a standing person. This is a reasonable estimate of the height at which the handpiece will be dropped.	Ergonomics Data & Mounting Heights (2014) <i>Ergotron Ergonomics Data</i> . Retrieved from: https://www.ergotron.com/Portals/0/literature/whitePapers/english/ergonomics_arms_data.pdf
9/10 respondents reported gardening outdoors.	Revised Survey Results	Users need the device to be able to withstand outdoor use.	The device shall be water resistant.	"More precipitation is occurring in heavy rainfall events (more than 2 in / 48 hrs), and this trend is expected to continue."	Wolfe, D., Beem-Miller, J., Chambliss, L., Chatrchyan, A., Menninger, H., (2014) <i>Climate Change Facts - Farming Success in an Uncertain Climate. Cornell Climate Change PWT. 2014</i> . Retrieved from: http://climatechange.cornell.edu/wp-content/uploads/2013/03/climate_and_farming.pdf
9/10 respondents reported gardening outdoors.	Revised Survey Results	Users need the device to be able to withstand outdoor use.	The device must be operable within the range of 32-100°F	"The number of summer heat stress days (e.g., exceeding 90°F) is expected to increase substantially, while winters grow milder."	Wolfe, D., Beem-Miller, J., Chambliss, L., Chatrchyan, A., Menninger, H., (2014) <i>Climate Change Facts - Farming Success in an Uncertain Climate. Cornell Climate Change PWT. 2014</i> . Retrieved from: http://climatechange.cornell.edu/wp-content/uploads/2013/03/climate_and_farming.pdf
"Too many or too few seeds are scattered."	Revised Survey Results	Users need to be able to dispense seeds, fertilizer, and water at a predictable and reliable flow rate.	Users must be able to clearly tell what flow rate the device is set to before dispensing material.	It is crucial that gardeners can know how much water or other material they are dispensing prior to activating firing the device. There are many plants and seedlings that cannot withstand intense water pressure or over watering in general, so it is important that the gardener can tell how much material they are going to dispense before accidentally drowning their plants.	How to Water Small Seeds and Seedlings. <i>MrBrownThumb</i> . Retrieved from: http://mrbrownthumb.blogspot.com/2010/06/how-to-water-small-seeds-and-seedlings.html
Ease of use rated as second most important (3.8)	Revised Survey Results	Users need to be able to easily tell what setting the device is on.	Users shall be able to determine what setting the device is on prior to dispensing any material.	It is important that gardeners can easily tell what state the device is in, because they might otherwise distribute the wrong material. This is a concern because a user may accidentally fertilize a plant when they intended to water it, and this could potentially overfertilize and damage the plant. Or perhaps a user accidentally distributes seeds where they intended to fertilize, then their garden would have misplaced plants, and they wouldn't have the benefits of fertilizer.	Over-Fertilization of Potted Plants. <i>Penn State Extension</i> . Retrieved from: http://extension.psu.edu/pests/plant-diseases/all-fact-sheets/over-fertilization

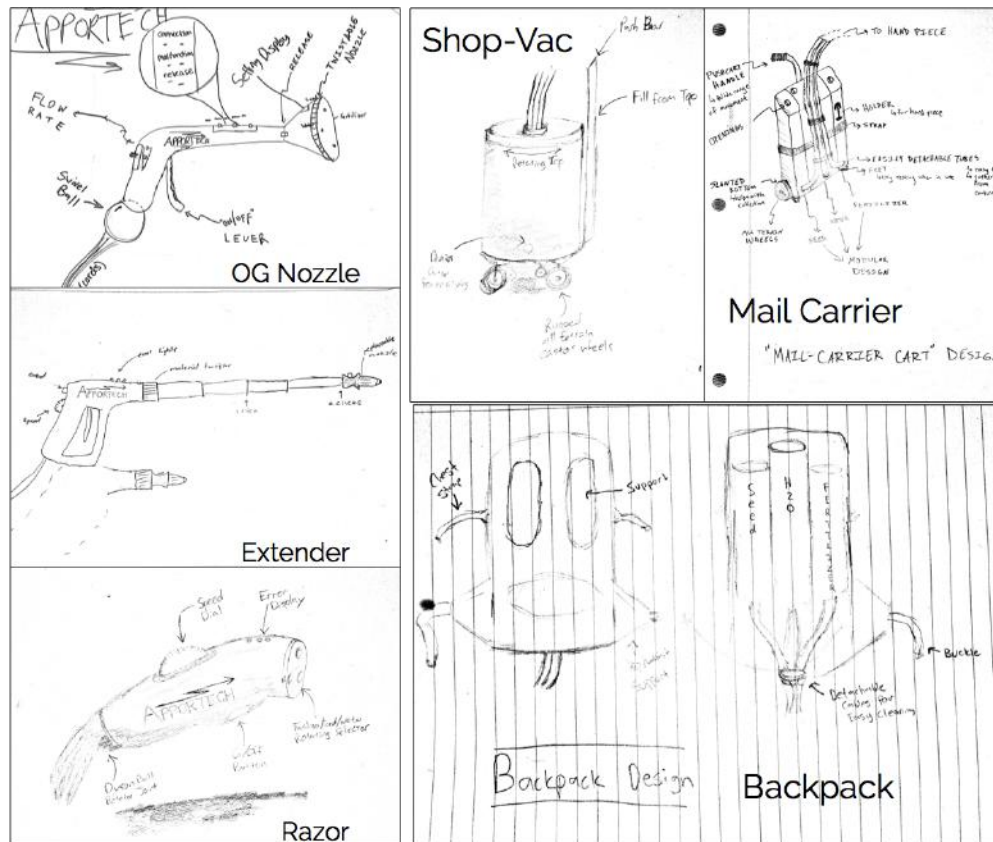
Respondents reported using granular and liquid fertilizer.	Revised Survey Results	Users need the device to be able to distribute different types of fertilizer.	The device shall be able to distribute granular and liquid fertilizer.	Fertilizers are commonly available in both granular and liquid form, so it is crucial that our device can handle both because they both make up such a large portion of the market.	A Rundown of Fertilizer Forms and Types. <i>Bonnie Plants</i> . Retrieved from: https://bonnieplants.com/library/a-rundown-of-fertilizer-forms-and-types/
Age range from survey was 18-79.	Revised Survey Results	A wide demographic of users need to be able to use the device.	The device shall be able to be operated by individuals aged 10-80.	"According to survey results released from the Mailorder Gardening Association (MGA), the mail-order gardener's average age is 50." This shows that both young and old gardeners are potential users.	Mosquera, G. (2003) Gardeners. <i>Target Marketing</i> . Retrieved from: http://www.targetmarketingmag.com/article/gardeners-28720/
"I would kind of like a middle ground between watering can and spray bottle. Doesn't produce much water."	Revised Survey Results	Users need the device to be able to distribute water at variable rates.	The device shall dispense material in between 6 gallons per minute and 24 gallons per minute.	"A 25-foot, 1/2-inch diameter hose attached to a faucet that supplies water at 40 psi has a flow rate of 24 gallons per minute, while a 100-foot hose only has a flow rate of 6 gallons per minute."	de Jauregui, R. What is the Flow Rate of a Garden Hose? <i>SFGATE</i> . Retrieved from: http://homeguides.sfgate.com/flow-rate-garden-hose-82928.html
One respondent's least favorite aspect of fertilizer tool: "Dirty and using hands lack a certain amount of accuracy."	Revised Survey Results	The device must not get users dirty during use.	The device shall have controls that are large enough to be effectively operated by users while they are wearing multiple types of gardening gloves such as latex, leather, nitrile, and cotton gloves.	It is strongly recommended that gardeners wear gloves to keep them clean, prevent cuts, and protect them from dangerous plants, chemicals, and tools. There are a range of different common glove types such as leather, latex, cotton, and nitrile, and it is important that our device be operable even with impaired dexterity while wearing various gardening gloves.	Watsemwa, E. (2016). Why you need gardening gloves. <i>Daily Monitor</i> . Retrieved from: http://www.monitor.co.ug/Magazines/HomesandProperty/Why-you-need-gardening-gloves/-/689858/3059182/-/faritrz/-/index.html

Ease of use rated as second most important (3.8)	Revised Survey Results	Users need to be able to easily switch between device settings.	Users shall be able to change what setting the device is on in less than 8 seconds.	New studies suggest that individuals' attention spans have gotten shorter, and on average are now around 8 seconds long. This is the time that people can spend on a task without losing concentration. Therefore, we are requiring that the design of Apportech is such that it does not take more than 8 seconds to complete a basic modality change.	McSpadden, K. (2015). You Now Have a Shorter Attention Span Than a Goldfish. <i>Time</i> . Retrieved from: http://time.com/3858309/attention-spans-goldfish/
Mobility rated as third most important (3.44) "Cumbersome"	Revised Survey Results	Users need a device that is portable.	The device shall be able to be moved 100 meters by 25th percentile female adults without experiencing unsafe levels of strain.	Gardening is a strenuous activity, and we would like Apportech to minimize user strain as much as possible. The average US lawn size is 0.2 acres, which is approximately 93 feet by 93 feet. We therefore require the user to be able to strainlessly move the device 100m, since they will likely need to make more than one pass of their yard while gardening.	Chapman, E. (2016). Lawn Size. <i>Grounds Maintenance</i> . Retrieved from: http://www.groundsmag.com/mag/grounds_maintenance_lawn_size/
One respondent's least favorite aspect of watering tool: "drips from the watering can or bowl"	Revised Survey Results	Users need a device that does not leak.	The device shall be able to hold seeds, fertilizer, and water for a year without any loss of liquid or material.	"Other causes of mechanical damage are puncturing or abrasion during transport when packages and containers rub against one another or against the sides of the truck travelling over uneven surfaces and rough roads."	Spills, leaks and disposal of containers and chemicals. <i>Agriculture and Consumer Protection</i> . Retrieved from: http://www.fao.org/docrep/v8966e/v8966e05.htm

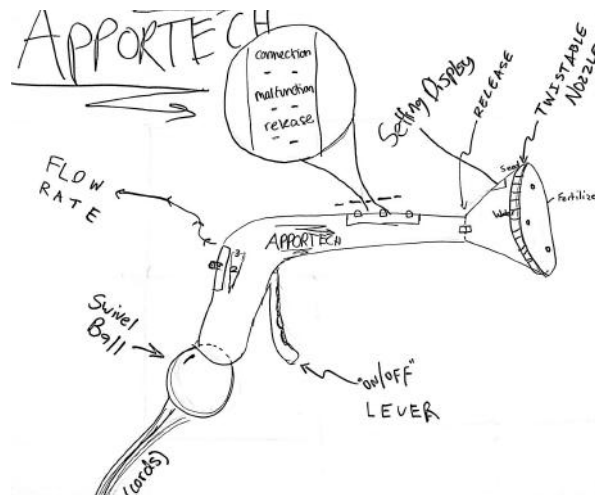
Functionality was the highest rated characteristic (4.1)	Revised Survey Results	Users need a device that will be functional for the total duration of the task.	The device battery shall last (at a minimum) for one hour without recharging.	"One downfall is that the battery takes almost 3 hours to charge completely but with an approximate 70 minutes of run time that can be understandable." Battery life a weed wacker, another type of gardening product.	What's the best battery powered weed eater? <i>bestWeedEaters</i> . Retrieved from: http://bestweedeaters.com/whats-the-best-battery-powered-weed-eater
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Appendix F - Initial Concepts

Pictured below are the team's initial concepts for Apportech™. We created three designs for the handpiece and three designs for the canisters. The OG Nozzle was created at Cambridge Consultants during a creativity brainstorming session, while the remaining concepts were created after, in a second brainstorm session at Tufts University.



Appendix G - Heuristic Reviews



1. Visibility of system status

The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

- System has appropriate locations for error states (on the top), speed control (side), type display (back of nozzle).

2. Match between system and the real world

The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

- Error states in English
 - Could benefit from images for error states
- Could benefit from images and text for labeling on nozzle.
- The inverted triangle for flow rate is useful (state 1 is low and state 3 is high)
- Change labeling for error state (malfunction = clog; release = change nozzle 24 hrs)

3. User control and freedom

Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

- Easy to change power, speed, and type
- User has a good level of control
- Lever provides an easy escape for dispense
- Possibly adding a safety could help

4. Consistency and standards

Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

- Controls are in a distinct place
- Labels will have picture and text

5. Error prevention

Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

- Lock on nozzle (Nozzle clicks in)
- Can't squeeze the trigger if any error is detected
- Dyson ball prevents cords from getting in the way

6. Recognition rather than recall

Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

- Everything has images and text to visually remind users of function
- Will include an instruction manual
 - Laminated sheet of quick instruction/labeled diagram

7. Flexibility and efficiency of use

Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

- Adding an adjustable nozzle for overhead use
- Ordinal and scale speed control

8. Aesthetic and minimalist design

Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

- We did not include many superfluous features
- Only three separate things you need to read/reach

9. Help users recognize, diagnose, and recover from errors

Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

- Three LED bulbs for error states
- Include pictures to make error states more clear

10. Help and documentation

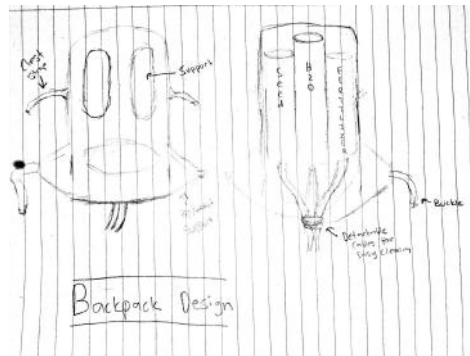
Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

- Simple labeled diagram/instruction manual will help explain the parts and functions of the device

- However, pictures included as labels on device in an effort to make it operable without documentation

11. Other comments

- May be heavy to hold (nozzle and shaft is long)
- Device has a non-adjustable shaft that could potentially be longer than a user would like in certain situations



1. Visibility of system status

The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

- Unclear by design but tubes should be clear
- Potentially add clog & detachment warning to backpack as well

2. Match between system and the real world

The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

- Should have pictures as well as words for labelling tubes
- Functionality of backpack otherwise generally intuitive and well-known (support straps)

3. User control and freedom

Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

- Potentially add a mechanism to identify if product put in wrong tube

4. Consistency and standards

Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

- Simple system, follows normal conventions

5. Error prevention

Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

- Design tubes so they are shape-coded to only allow the proper input
- Design system to not work unless tubes are closed

6. Recognition rather than recall

Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

- Include helpful directional symbols on the system to potentially not require use of instructions

7. Flexibility and efficiency of use

Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

- Relatively not applicable?

8. Aesthetic and minimalist design

Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

- Mostly pictures, design is very simple and only includes functional components

9. Help users recognize, diagnose, and recover from errors

Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

- Idea of adding clog, detachment and lid not secure warnings to backpack

10. Help and documentation

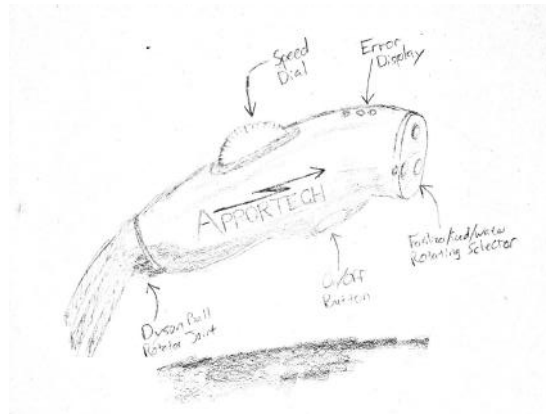
Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

- Simple labeled diagram/instruction manual will help explain the parts and functions of the device
 - Maybe include instructions potentially laminated or on tag on backpack
- However, pictures included as labels on device in an effort to make it operable without documentation

11. Other comments

- Must consider ergonomic factors of using a backpack design
 - Weight distribution, chest and waist straps should help with this
- Include stand on bottom of backpack to allow for use when not on back

- Potentially include wheels (or option of) to make it multi-functional



1. Visibility of system status

The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

- Clearly can tell what errors are happening
- Speed dial should be clearly labeled (maybe illustrated as well in some way)
- Might be nice to have a green indicator light showing system status is OK

2. Match between system and the real world

The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

- Labels for errors need to be clear and understandable
- Errors should also be associated with icons of some sort

3. User control and freedom

Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

- Could be useful to have a large red button to turn system completely off (maybe trigger gets stuck and stuff is spraying everywhere!)

4. Consistency and standards

Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

- Labels with text should also be associated with icons since the icons are fairly complex and could be hard to understand

- Red should be associated with error or problem
- Green should be associated with okay!

5. Error prevention

Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

- Lock the trigger if any errors occur
- Make the nozzle easy to snap on (give the user feedback with a click of some sort)
- Make the speed dial have some resistance and maybe even click into certain settings so users don't accidentally adjust it
- The type of material needs to be CLEARLY displayed before users press the trigger (perhaps associate different colors with different types of material)
 - i.e. blue is on the water part of the nozzle, green is on the seed part, etc..

6. Recognition rather than recall

Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

- See above for comments on material type selection and speed dial

7. Flexibility and efficiency of use

Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

- Perhaps an extension of some sort to reach down to ground or up into pots

8. Aesthetic and minimalist design

Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

9. Help users recognize, diagnose, and recover from errors

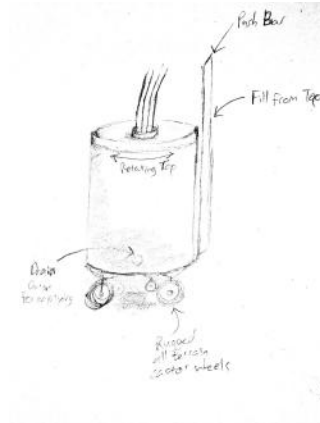
Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

- Use of images/icons and text can make this easier for users

10. Help and documentation

Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

- Error states and how to fix them should be CLEARLY displayed in documentation since this may be one of the few reasons users should need to refer to documentation
- Diagram of controls might be useful



1. Visibility of system status

The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

- System is an opaque container; perhaps making it clear will allow the user to easily see how much of each material (water, seed, fertilizer) is available or what type is being used.

2. Match between system and the real world

The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

- There are no writings or images on this container.
- Perhaps adding words/images to the drainage port will help the user more easily identify what its function is.

3. User control and freedom

Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

- There is no specific function that the user would choose on this container. For this design, all options would have to be chosen on the hand piece.

- The push bar/handle can be easily retracted or raised (like a suitcase handle), without any time delay between height options.
- The drainage port can be easily plugged or unplugged in case of emergency.
- A power button (on/off switch) may be necessary if it is electrically powered; the device may benefit from having the switch on this container, with easily distinguishable options and, in an emergency, the off switch can be quickly pressed.

4. Consistency and standards

Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

- The containers inside for each material (water, seed, and fertilizer) need to specifically line up to the correct tube such that when a certain option is chosen, the correct material is dispensed. The design would benefit from having each tube specifically labeled at this end for the certain material. However, the container itself doesn't need to be labeled. The user would just have to ensure that the tubes line up to the correct material.

5. Error prevention

Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

- On/off switch prevents the handle from accidentally dispensing material.
- Labeled tubes ensure that the specific material is being picked up by the correct tube.

6. Recognition rather than recall

Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

- The user does not largely interact with the container, except to push it around, fill/refill/empty the container, or to turn on the power. The user does not have to memorize any specific steps; instead, simple intuitive motions are necessary (turning the top will open and close it, plugging the drainage port to ensure that nothing spills out)
- Will include an instruction manual
 - Laminated sheet of quick instruction/labeled diagram

7. Flexibility and efficiency of use

Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

- Rugged wheels can allow the user to use the device on a home patio or in a more dense, long-distance terrain.

8. Aesthetic and minimalist design

Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

- We did not include many superfluous features
- Every part of the design has a specific function that is necessary for the wide range of user demographics to use the device.

9. Help users recognize, diagnose, and recover from errors

Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

- Users can easily move the tubes to the correct material container internally if the wrong material is dispensed.

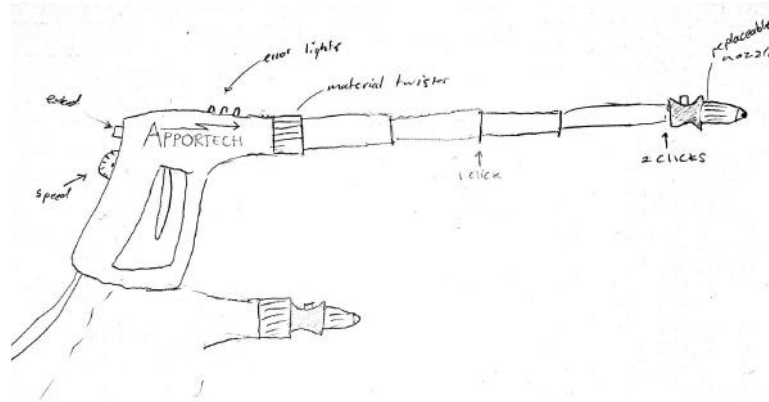
10. Help and documentation

Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

- Simple labeled diagram/instruction manual will help explain the parts and functions of the device

11. Other comments

- The four wheeled option may make it more difficult to move over grassy terrains. It may get more easily stuck in mud or dirt. Including extra wheels adds weight.
- The push bar needs to be adjustable such that people with different heights can still use the device.
- Each internal container must have its own drainage system.
- What do the internal containers look like? Is it cut into thirds like three triangles, or are they round containers, or are the different sizes for each material?



1. Visibility of system status

The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

- System has appropriate locations for error states (on the top), speed control (back), type display (near end of nozzle).
- All states are easily visible from the user's perspective

2. Match between system and the real world

The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

- Unclear if error states utilize text. Could benefit from images to relieve language dependency.
- Could benefit from images and text for labeling on nozzle.
- Speed wheel could use some kind of image to indicate higher or lower speed.

3. User control and freedom

Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

- Easy to change power, speed, and type
- User has a good level of control
- Lever provides an easy escape for dispense
- Possibly adding a safety could help

4. Consistency and standards

Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

- Controls are in a distinct place
- Labels will have picture and text

5. Error prevention

Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

- Lock on nozzle (Nozzle clicks in)
- Can't squeeze the trigger if any error is detected
- Add dyson ball to prevent cords from getting in the way
- Covering over trigger provides additional error prevention

6. Recognition rather than recall

Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

- Everything has images and text to visually remind users of function
- Will include an instruction manual
 - Laminated sheet of quick instruction/labeled diagram

7. Flexibility and efficiency of use

Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

- Adjustable length promotes varied usage
- Ordinal and scale speed control? If not, this duality would be nice.
- Could include angle adjustability in nozzle for additional user control.

8. Aesthetic and minimalist design

Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

- We did not include many superfluous features
- Only three separate things you need to read/reach

9. Help users recognize, diagnose, and recover from errors

Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

- Three LED bulbs for error states

- Include pictures to make error states more clear

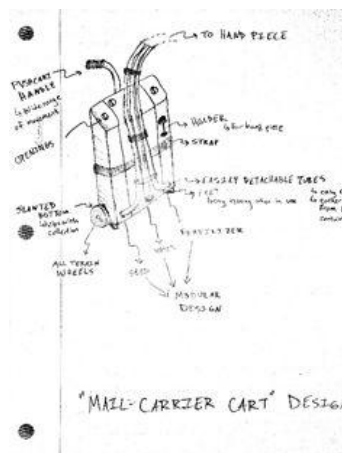
10. Help and documentation

Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

- Simple labeled diagram/instruction manual will help explain the parts and functions of the device
- However, pictures included as labels on device in an effort to make it operable without documentation

11. Other comments

- May be heavy to hold (nozzle and shaft is long)



1. Visibility of system status

The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

- It does not appear that this component of the device provides feedback
- A meter to describe the volume left in the tanks.

2. Match between system and the real world

The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

- Should include fertilizer, seed, and water symbols in addition to text on each compartment in order to make it clear

3. User control and freedom

Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

- Nothing much to do with function for this component of the design.
- Users can roll the cart to desired location if target was not hit the first time

4. Consistency and standards

Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

- Words and symbols used on handpiece should be the same on this cart as well

5. Error prevention

Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

- Are people pouring the wrong contents into the canisters?
 - Detachable canisters would make error correction easier.
- Need a way to confirm if tubes are attached to cart?
 - Possible addition of more LEDs

6. Recognition rather than recall

Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

- Everything has images and text to visually remind users of function
- Will include an instruction manual
 - Laminated sheet of quick instruction/labeled diagram

7. Flexibility and efficiency of use

Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

- Might be annoying to clean unless tubes detach
- It would be annoying to load material into the tiny holes
 - Consider adding a funnel somewhere?
- Would 45 pounds be too much to push with one hand?
- Handpiece holder makes storage and rest easier
- Easy navigability
 - Consider adding a bar for pushing and pulling

8. Aesthetic and minimalist design

Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

- We did not include many superfluous features
- Only three separate things you need to read/reach

9. Help users recognize, diagnose, and recover from errors

Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

- Not many error states here
 - Will need to consider if tubes can detach

10. Help and documentation

Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

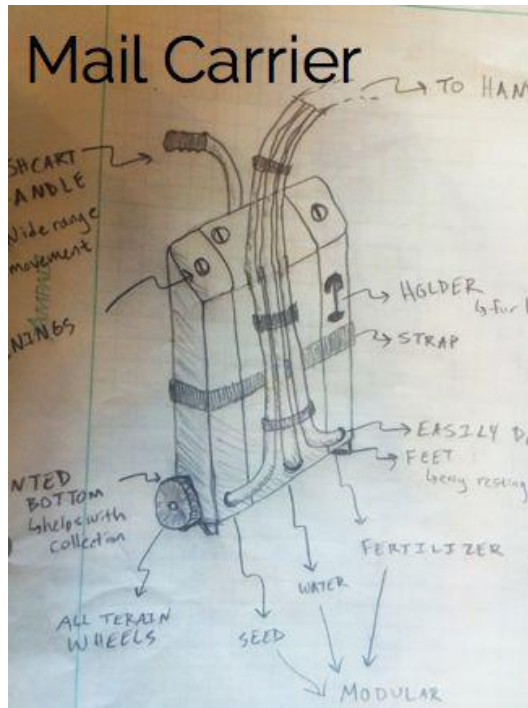
- Simple labeled diagram/instruction manual will help explain the parts and functions of the device
- However, pictures included as labels on device in an effort to make it operable without documentation

11. Other comments

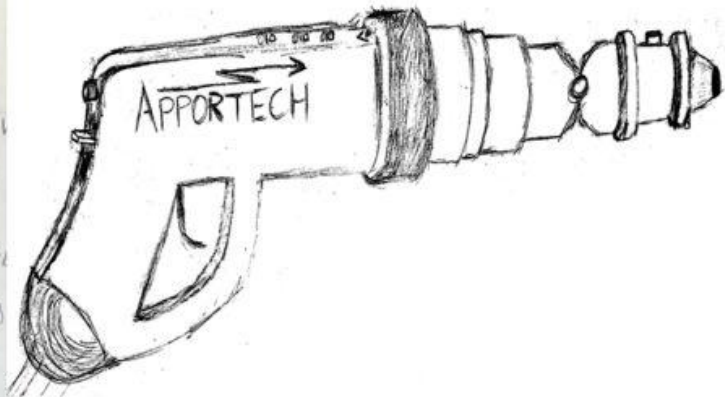
- I think this is a good design for rough terrain
 - Two wheels is much more easily navigable over such terrain than 4
- I like the single handle design which affords users the ability to hold the nozzle with their other hand
- Check on weight requirements for the carriage, however.
 - Might need to consider battery/electrical input
- Handpiece holder is nice
- What is the purpose of the strap?
- Define “Modular”
 - Can the different compartments detach?

Appendix H - Revised Concepts

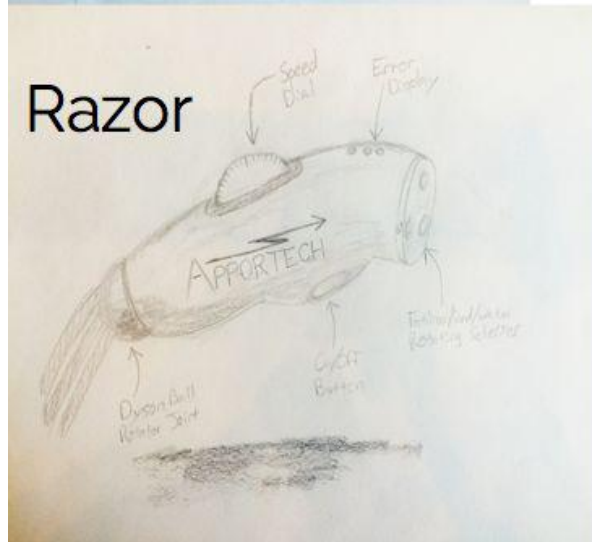
Mail Carrier



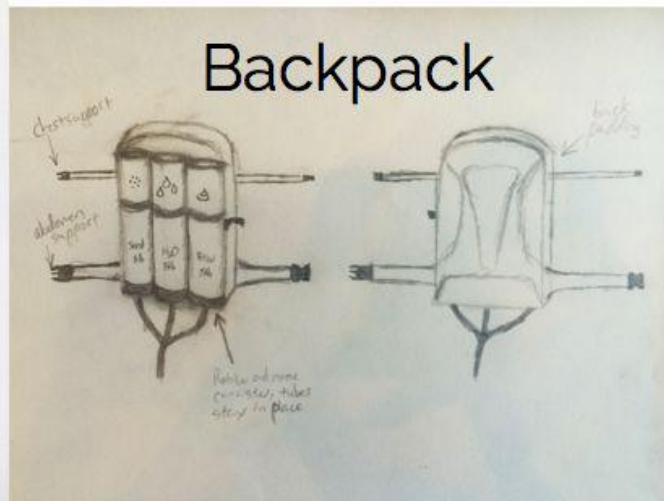
Raygun



Razor



Backpack



Appendix I - In Depth Interviews

P1

Part 1: Background Questions

- Basic Demographic Info
 - What is your age?
 - 18
 - What is your gender?
 - Male
 - How tall are you?
 - 5 feet 7.5 inches
 - Do you have any physical handicaps?
 - No
- Experience gardening
 - What type of gardening do you participate in?
 - Home gardening, small scale vegetable and flower planting, weeding.
 - Does plant seeds.
 - Does do fertilizer.
 - How many years have you been gardening?
 - About six years, probably since seventh grade
 - Do you garden indoors, outdoors, or both?
 - Outdoor
 - Can you describe the area you garden in? (Patch in backyard, baseball field, nursery, etc.)
 - Heavily wooded, forest area, plant in flower beds, probably about 15' by 15' areas at a time.
- Techniques and Tools
 - What tools do you use to water/seed/fertilize?
 - Hose, watering can
 - Hands for seeding and a little shovel
 - Just whatever the bagged product is, spread it with hands
 - What about these tools do you like?
 - I like the dexterity I have with my hands, you can put it as deep as you want it to, you have precision
 - Watering can is nice for seedlings and young plants
 - Hose is nice for wide area and less delicate plants
 - Shovel is nice to bury the seeds, easier on hands
 - Are there any features you wish these tools had?
 - Something that would spread fertilizer more evenly than a hand could

- Other than that my gardening experience is small enough that I've been good with my hands
- Do these tools present you with any problems or difficulties?
 - Knees start to hurt from bending down and kneeling.
 - Back hurts from bending.
- In what ways do you think these tools could be improved?
 - The shovel could be a sifter as well so you could sprinkle the fertilizer as well. Your hands could be hoses.
- Do you tend to have to reach up, to distant places, bend down, etc?
 - I have to bend down, but otherwise don't have to get too hard to reach places.

Part 2: Handpiece Design Questions (Razor and Raygun)

Present each of the handle designs together.

- What are your initial reactions/thoughts to the handpiece designs?
 - Razor: I like the design of the raygun more was my initial reaction. The raygun looks a little more sleek, but I dunno, it kinda doesn't. It feels like the raygun might be heavier, which I wouldn't like.
 - Raygun: Looks like a hot glue gun, which I kinda like. The trigger would be fun to use. I don't have much to complain about.
- What are your opinions on the speed dial (rolling dial vs vertical switch dial)?
 - I think I like the slider, for a small feature the dial seems pretty big. They both seem equally easy to use and reach while holding the device.
- Which on/off switch do you prefer (Lever with safety lock or holding down button)?
 - I like the button more if you can't lock it in, I think it would take less effort to push.
 - I would like to be able to lock it in the on position as well.
 - If I could lock both then I'd probably still prefer the button.
- What do you think about the rotating material changer (location of both, functionality, ease of use)?
 - I like the chunkier raygun design because it reminds me more of a hose.
 - It would be easier to grab the larger one if you ever needed to change it quickly or recover from a mistake
- What are your opinions on the error display (location, ease of understanding, usefulness, etc.)?
 - The location seems pretty comparable.
 - I like the top, there's less ambient stuff to look at, sleeker.

- What do you like about the physical shape? (how it might feel, is it comfortable, easy to hold, does it look pretty?)
 - Razor: I think this one seems like it would work well. My razor looks like that and I've had good experiences holding that. This is also curved at the end, so your hand doesn't necessarily dictate where it's going
 - Raygun: In terms of directing where you want to go it seems like this option would give you more control. I think they'd both be comfortable to hold.
- What are your thoughts on the extender? (does it seem useful, potential problems, etc.)
 - I think it's a cool aspect, and I think people will like that it can be made compact. I don't know if it's necessary or not, but I like that it gives the connotation that you can have more control over its direction.
- What do you like most about the Razor design?
 - The lights and the easy button on the bottom.
- What do you like most about the Raygun design?
 - I like the slider thing in the back, and if there were a lock then I'd love the lock. And it's directability.
- What problems do you foresee with these designs?
 - Gunk getting in the extender of the raygun.
 - Don't really foresee problems with the top one.
- If you had to pick a design, which would you choose?
 - Top, because I don't feel like worrying about the retractability, it just seems easier.
- If you could create a compromise, what features would you include?
 - Lights from the razor, slider from raygun, indifferent about button vs trigger to be honest, big rotator wheel.
- Any other comments?
 - No

Part 3: Carrier Design Questions (Dolly and Backpack)

Present each of the carrier designs together.

Important Note: The Dolly design has 25 lbs of water, and 10 lbs of seed and fertilizer. The backpack has equal distribution of materials. Both total 45 lbs.

- What are your initial reactions/thoughts to the carrier designs?
 - I like the top one. It looks simpler. I like the icons on the tubes.
- What do you think about the positioning of the tubes?
 - I would rather the backpack come from above and come over my shoulder. More like a camelback.
 - I like the tubes coming upwards from the mail carrier.

- Do you think all three material containers need to be of equal capacity? Do you think one should be bigger than the other (seed, fertilizer, or water)?
 - You usually need more water and fertilizer in terms of volume
 - 20lbs water 20lbs fertilizer 5lbs seeds
- How easy do you think it would be to fill these containers?
 - I think it would be easier to fill the backpack if you can take the individual canisters out.
 - I think that precision of filling up the mail carrier would be difficult. You might get fertilizer in your water.
- Do you think you could safely carry up to 45 pounds on your back?
 - Yes.
- What do you like most about the Dolly design?
 - The tubes coming out of the top.
- What do you like most about the Backpack design?
 - Removable canisters, I like that you wear it because you get more mobility. There's a ton of stuff in a garden that a dolly could get stuck on. It's dirt, not hard ground. I like the big icons on the canisters. Canisters are more visually appealing than the box shape of the dolly. Definitely mobility most of all.
- What problems do you foresee with these designs?
 - Rolling the dolly on dirt would be difficult. Also you don't really wanna roll over what you just planted.
 - Backpack might be a bit heavy, but like I don't think it would be a big deal for me
- If you had to pick a design, which would you choose?
 - Backpack
- If you could create a compromise, what features would you include?
 - I would just change the backpack to have the tubes coming out of the top.
- Any other comments?
 - Backpack for life

P2

Part 1: Background Questions

- Basic Demographic Info
 - What is your age?
 - 56
 - What is your gender?
 - Female
 - How tall are you?
 - 5'2"
 - Do you have any physical handicaps?

- Arthritis
- Experience gardening
 - What type of gardening do you participate in?
 - Vegetable and flower
 - How many years have you been gardening?
 - 30 years on and off
 - Do you garden indoor, outdoors, or both?
 - both
 - Can you describe the area you garden in? (Patch in backyard, baseball field, nursery, etc.)
 - Small patch in backyard, and small flower pots in house
- Techniques and Tools
 - What tools do you use to water/seed/fertilize?
 - Outside, use watering can; small spade and gardening “fork” (she didn’t know the correct name) to plant; big shovel to turn over dirt in beginning; use hose for big bushes
 - Inside, use measuring cup to water
 - Use liquid grow (plant food not really fertilizer, according to her) inside and outside
 - Used gardening gloves when planting “partially grown” plants
 - What about these tools do you like?
 - Nothing really stands out to her
 - The gardening fork made it easy to put seeds in
 - Are there any features you wish these tools had?
 - n/a
 - Do these tools present you with any problems or difficulties?
 - Big shovel was heavy
 - Sometimes too much water came out of watering can and she felt like she was drowning the plants
 - In what ways do you think these tools could be improved?
 - Simple fixes to fix the above problems (shovel weight and watering can)
 - Do you tend to have to reach up, to distant places, bend down, etc?
 - Bending down to garden; kneel down to garden outside; some hanging plants, was hard to water these plants at times; gardening indoors was mostly at table level

Part 2: Handpiece Design Questions (Razor and Raygun)

Present each of the handle designs together.

- What are your initial reactions/thoughts to the handpiece designs?
 - The ray gun design seems to be more useful
 - Ray gun Looks like a hose with the nozzle handpiece that normally goes with it
 - Ray gun seems like it might be heavier and harder to hold
 - Ray gun would be useful for a short person since it can extend
 - Dyson swivel ball looks useful
- What are your opinions on the speed dial (rolling dial vs vertical switch dial)?
 - Razor seems easier to work
 - Products in the past with vertical switch dial may get stuck or be harder to operate
- Which on/off switch do you prefer (Lever with safety lock or holding down button)?
 - Both seem like they would work, no preference with one over the other
 - Likes that you have to keep you finger on the trigger or button to function; doesn't like the "lock on" design idea
- What do you think about the rotating material changer (location of both, functionality, ease of use)?
 - Rotating part seems like it would be easy to use
- What are your opinions on the error display (location, ease of understanding, usefulness, etc.)?
 - Likes the concept that it will tell you what the problem is if something isn't working
 - Likes on top since it is easy to see
 - Likes the red light = something wrong concept
- What do you like about the physical shape? (how it might feel, is it comfortable, easy to hold, does it look pretty?)
 - Things ray gun is easier to hold; things men who shave all the time might like the razor type
 - She uses a hose that functions similarly to the ra gun so likes that
 - Thinks it's easier to direct the flow with ray gun
- What are your thoughts on the extender? (does it seem useful, potential problems, etc.)
 - Thinks extender very useful for people who are short or if you have to reach something (even if you're tall, the extender prevents you from bending down)
 - Potential problem: gets stuck in one position, jammed
- What do you like most about the Razor design?
 - Likes that nozzle is easy to see/function
 - Likes that it is light weight
- What do you like most about the Raygun design?
 - Seems like it would be efficient and easy to use
- What problems do you foresee with these designs?
 - Depending on material products are made of: metal can rust, plastic can crack

- Both designs can get clogged
 - Thinks it is important to easily take apart device to clean/"refill"
- If you had to pick a design, which would you choose?
 - Ray gun
- If you could create a compromise, what features would you include?
 - Likes roller ball (speed control) from razor; everything else from ray gun
- Any other comments?
 - What would the cost be? Would they be the same price? Cost effectiveness of one product over the other
 - If ray gun was more expensive, would possibly still buy it (if minimal difference yes, if greater difference in price maybe not)

Part 3: Carrier Design Questions (Dolly and Backpack)

Present each of the carrier designs together.

Important Note: The Dolly design has 25 lbs of water, and 10 lbs of seed and fertilizer. The backpack has equal distribution of materials. Both total 45 lbs.

- What are your initial reactions/thoughts to the carrier designs?
 - Backpack seems like better design: can go anywhere if a place is narrow/going upstairs; however for her, backpack might be too heavy
 - Dolly would be okay if it stayed in shed and was for outdoor use only
- What do you think about the positioning of the tubes?
 - Positioning seems easy to fill containers/take out material to handpiece; clean
 - Dolly design seems like it would be more comfortable (for the way it connects to the handpiece)
- Do you think all three material containers need to be of equal capacity? Do you think one should be bigger than the other (seed, fertilizer, or water)?
 - Water should be the most
 - Seed and fertilizer can be the same
 - it might be harder to carry the backpack if you have more water (understands they are the same weight since 15 lbs = 15 lbs no matter the material but still thinks this)
- How easy do you think it would be to fill these containers?
 - Dolly seems easier to fill
 - Doesn't understand how to fill backpack- do you lay it down? Do you have to take each cannister out?
- Do you think you could safely carry up to 45 pounds on your back?
 - She doesn't think so
- What do you like most about the Dolly design?

- Looks like it would be easy to move, there would be no physical effect (backpack you have to take off to take a break)
- Ease of use and “does not affect you physically”
- Seems like it would work well in her backyard gardening setting
- What do you like most about the Backpack design?
 - Aesthetically looks nice- compact, can get into tight places or get up to another level
 - Easier for indoor use compared to dolly
- What problems do you foresee with these designs?
 - Backpack can be heavy- person can be uncomfortable, especially outdoors in sun
 - Backpack- if different people use, may have to keep adjusting to size (dolly used by everybody)
 - Tubes may get clogged
 - Material can rust or crack
- If you had to pick a design, which would you choose?
 - dolly
- If you could create a compromise, what features would you include?
 - Would do backpack if it weight less (5 lbs 5 lbs 5 lbs)
 - However, I bring up that the 45 lbs weight is the maximum weight and that she doesn’t have to fill the whole container- then she stated it may be annoying to keep filling it up
- Any other comments?
 - Dolly is hard to carry upstairs (indoors)

P3

Part 1: Background Questions

- Basic Demographic Info
 - What is your age?
52
 - What is your gender?
Female
 - How tall are you?
5’7”
 - Do you have any physical handicaps?
No
- Experience gardening
 - What type of gardening do you participate in?
Landscaping at home, plant tomatoes, berries

- How many years have you been gardening?
15 years
- Do you garden indoor, outdoors, or both?
Outdoor
- Can you describe the area you garden in? (Patch in backyard, baseball field, nursery, etc.)
Backyard
- Techniques and Tools
 - What tools do you use to water/seed/fertilize?
Water: automatic sprinkler, hose with showerhead
Fertilizer: Miracle grow that you attach to the hose
Seed: Usually buy seedling plants, spade and put the plants in there
 - What about these tools do you like?
The shower head allows you to keep the hose on
Spade or shovel are basic
Miracle Grow: I know the fertilizer is getting diluted so it won't burn or ruin the plants
 - Are there any features you wish these tools had?
Not really
 - Do these tools present you with any problems or difficulties?
Not really
 - In what ways do you think these tools could be improved?
The fertilizer thing is messy, trying to pour in material, gets all over the place
Hard to dig a hole in hard dirt
 - Do you tend to have to reach up, to distant places, bend down, etc?
Definitely a lot of bending for everything besides the raised beds
Messy

Part 2: Handpiece Design Questions (Razor and Raygun)

Present each of the handle designs together.

For this interview, 1 refers to the Raygun and 2 refers to the Razor.

- What are your initial reactions/thoughts to the handpiece designs?
 - 1) Seems easier to control in your hand, I like the selector ring (the other design isn't as clear what material is dispensing "shooting material into my face")
 - 2) Speed dial looks cool
- What are your opinions on the speed dial (rolling dial vs vertical switch dial)?
The rolling one seems more user friendly
- Which on/off switch do you prefer (Lever with safety lock or holding down button)?

The trigger would probably be easier to control

- What do you think about the rotating material changer (location of both, functionality, ease of use)?

In #2 you'd have to look at the front to see it

The first one is more familiar

- What are your opinions on the error display (location), ease of understanding, usefulness, etc.)?

#1 looks like it would be easier to see based on angle of holding

Both would work fine

- What do you like about the physical shape? (how it might feel, is it comfortable, easy to hold, does it look pretty?)

When I first saw them, I liked the look of #2.

But when thinking about using theme #1

- What are your thoughts on the extender? (does it seem useful, potential problems, etc.)

Extender could be useful if you were trying to get fertilizer to the back of a plant.

Would be rare

The angle could help, trying to think of situations where it would be useful.

Not really that useful

- What do you like most about the Razor design?

It looks cool.

- What do you like most about the Raygun design?

The most familiar in terms of usability

- What problems do you foresee with these designs?

The weight is a big factor for #1

Trying to hold the gun without pressing trigger, but you might press it accidentally if it weighs too much, (like a gasoline hose)

- If you had to pick a design, which would you choose?

1

- If you could create a compromise, what features would you include?

The speed dial button and put it on the top of #1

Generally likes #1

Number 2 reminds me of a sprinkler head thing that didn't work very well

"Oh it's gonna get clogged"

Not sure you would need three holes

If number 2 would allow different size seeds to come out, that would work better.

- Any other comments?

N/A

Part 3: Carrier Design Questions (Dolly and Backpack)

Present each of the carrier designs together.

Important Note: The Dolly design has 25 lbs of water, and 10 lbs of seed and fertilizer. The backpack has equal distribution of materials. Both total 45 lbs.

For this interview, 1 refers to the Mail Carrier Cart (Dolly) and 2 refers to the Backpack.

- What are your initial reactions/thoughts to the carrier designs?
 The backpack part is nice for mobility and getting to different places
 #1 would be better if you needed to carry more weight
 45 pounds is quite a bit of weight, especially if you are bending over
 Stability issues
- What do you think about the positioning of the tubes?
 No comments on where the tubes are
 As long as they are functional, either is fine
- Do you think all three material containers need to be of equal capacity? Do you think one should be bigger than the other (seed, fertilizer, or water)?
 Water would definitely need to be the biggest, next fertilizer, the seed should be really small (a seed packet size, or a spice jar would be a lot, grass seeds would also probably be pretty small)
- How easy do you think it would be to fill these containers?
 They both look like they are pretty easy
 For fertilizer you need a pretty big hole or a funnel (don't want to spill)
 Any could benefit from a funnel but fertilizer and seed especially
- Do you think you could safely carry up to 45 pounds on your back?
 I probably could but it would not be comfortable for very long
 Especially bending
- What do you like most about the Dolly design?
 I like that the weight is not on the pack
 I like that I like all three materials right there not having to run back and forth
- What do you like most about the Backpack design?
 I would want it to be smaller and lighter, but it would be easier to take it places than the mail carrier cart
 But the straps should help with the load
- What problems do you foresee with these designs?
 Backpack: weight for the backpack
 Mail Carrier Cart:
- If you had to pick a design, which would you choose?
 1)
- If you could create a compromise, what features would you include?

I would just go with 1) but maybe consider adding longer tubes to increase range and mobility

Cant see anything from 2 that 1 needs

The one thing that 2 has is that you can get away from an area (mobility)

- Any other comments?

P4

Part 1: Background Questions

- Basic Demographic Info
 - What is your age?
 - 52
 - What is your gender?
 - Female
 - How tall are you?
 - 5' 7"
 - Do you have any physical handicaps?
 - Not really (sore neck?)
- Experience gardening
 - What type of gardening do you participate in?
 - Vegetable and yard work/landscaping
 - How many years have you been gardening?
 - About 20
 - Do you garden indoor, outdoors, or both?
 - Outdoors
 - Can you describe the area you garden in? (Patch in backyard, baseball field, nursery, etc.)
 - Vegetable garden, large backyard, front yard
- Techniques and Tools
 - What tools do you use to water/seed/fertilize?
 - Drip irrigation, sprinklers, hose
 - Spade, shovel, wheel barrow
 - Lawn mower (cut grass is used to fertilize lawn), weed wacker
 - Top soil and potting mix
 - What about these tools do you like?
 - Easy to use and don't have to think about watering because sprinklers are on a timer
 - Convenient and simple
 - Are there any features you wish these tools had?
 - Not really – maybe a hose that's easier to move around

- Do these tools present you with any problems or difficulties?
 - The hose is annoying to take out and put away
 - Electric lawn mower doesn't last long enough to mow entire lawn when grass is long (don't like the gas mowers) – same with weed wacker
- In what ways do you think these tools could be improved?
 - Longer battery life on the lawn mower and weed wacker
- Do you tend to have to reach up, to distant places, bend down, etc?
 - Yes – gets really tiring, especially with older age (no more kids to help out)

Part 2: Handpiece Design Questions (Razor and Raygun)

Present each of the handle designs together.

- What are your initial reactions/thoughts to the handpiece designs?
 - Looks pretty crazy, might be kind of fun to use
 - Curious to see how it would work
 - Raygun looks kind of like a power washer
 - Raygun looks kind of heavy/bulky
- What are your opinions on the speed dial (rolling dial vs vertical switch dial)?
 - Likes the switch because she thinks she might accidentally move the rolling dial
 - Also skeptical that rolling dial could break more easily
- Which on/off switch do you prefer (Lever with safety lock or holding down button)?
 - Likes the lever because it reminds her of a hose nozzle
 - Button could get tiring to hold with one finger
- What do you think about the rotating material changer (location of both, functionality, ease of use)?
 - Harder to see on the raygun with the different things on the nozzle
 - Worried the rotating piece could break (had this happen with two plastic hose nozzles that had rotating head for different spraying styles)
 - Seems pretty easy to use though
- What are your opinions on the error display (location, ease of understanding, usefulness, etc.)?
 - Likes the error display
 - Location is nice because it's out of the way but easy to see
- What do you like about the physical shape? (how it might feel, is it comfortable, easy to hold, does it look pretty?)
 - Both look nice, raygun looks a little heavy
- What are your thoughts on the extender? (does it seem useful, potential problems, etc.)
 - Seems useful – less need to bend over
- What do you like most about the Razor design?

- Looks easier to use
- What do you like most about the Raygun design?
 - Likes that it extends so you don't have to bend over as much and it looks easy to grip
- What problems do you foresee with these designs?
 - Pieces could wear out or break
 - Hose parts might make it difficult to move around
 - Worried about battery life
- If you had to pick a design, which would you choose?
 - Raygun
- If you could create a compromise, what features would you include?
 - Likes the features of the ray gun
- Any other comments?
 - How much would it cost? How long does battery last?

Part 3: Carrier Design Questions (Dolly and Backpack)

Present each of the carrier designs together.

Important Note: The Dolly design has 25 lbs of water, and 10 lbs of seed and fertilizer. The backpack has equal distribution of materials. Both total 45 lbs.

- What are your initial reactions/thoughts to the carrier designs?
 - Backpack looks nice and easy to figure out
 - 45 lbs seems like a lot to carry so maybe the dolly is better
- What do you think about the positioning of the tubes?
 - Seem fine on the backpack
 - Worried they might cause the dolly to tip over
- Do you think all three material containers need to be of equal capacity? Do you think one should be bigger than the other (seed, fertilizer, or water)?
 - Water container should be bigger than seed and fertilizer
 - Not too much water though because it is heavy
- How easy do you think it would be to fill these containers?
 - Seems easy with the dolly
 - Looks a little hard with the backpack because of hoses on the bottom (could tip over while trying to fill it)
 - Easy to fill with removable containers
- Do you think you could safely carry up to 45 pounds on your back?
 - No
- What do you like most about the Dolly design?
 - She doesn't have to carry the weight on her back
 - Seems pretty easy to move around

- What do you like most about the Backpack design?
 - Very straightforward - likes the labeling
 - Mobility
- What problems do you foresee with these designs?
 - Backpack is too heavy and might wear out or get dirty
 - Dolly might tip over and could break if made of plastic
 - Cleaning of containers (mold)
 - Tube clogging
- If you had to pick a design, which would you choose?
 - Dolly
- If you could create a compromise, what features would you include?
 - Icons from backpack onto dolly
 - Make the dolly have a lower center of gravity so things don't spill
 - Make containers removable in dolly
- Any other comments?
 - How long are the hoses from the container to the handpiece?

P5

Part 1: Background Questions

- Basic Demographic Info
 - What is your age?
 - 57
 - What is your gender?
 - Female
 - How tall are you?
 - 5'2"
 - Do you have any physical handicaps?
 - No
- Experience gardening
 - What type of gardening do you participate in?
 - Gardening in my front and back yard, mostly flowers, some vegetables
 - How many years have you been gardening?
 - 25+
 - Do you garden indoor, outdoors, or both?
 - Mostly outdoor but both
 - Can you describe the area you garden in? (Patch in backyard, baseball field, nursery, etc.)
 - Pots indoor and outdoors, garden in front yard and boxed in vegetable garden

- Techniques and Tools
 - What tools do you use to water/seed/fertilize?
 - Watering can, hose, my hands, gloves, shovels- not much more than that
 - What about these tools do you like?
 - I don't use much equipment, at least not fancy equipment
 - I like the sprayer I have attached to my hose
 - Are there any features you wish these tools had?
 - It'd be nice to not fertilize with my hands
 - Do these tools present you with any problems or difficulties?
 - Not that I can currently think of
 - In what ways do you think these tools could be improved?
 - They're so basic it's hard to say
 - Do you tend to have to reach up, to distant places, bend down, etc?
 - Sometimes I have to reach up to water my hanging plants and my watering can nozzle doesn't reach

Part 2: Handpiece Design Questions (Razor and Raygun)

Present each of the handle designs together.

- What are your initial reactions/thoughts to the handpiece designs?
 - The Razor seems really ergonomic and good for smaller scale gardening and fitting in small places
 - The Raygun looks heavier but easy to use and heavy duty
 - The Raygun extend feature looks convenient for outdoor gardening
- What are your opinions on the speed dial (rolling dial vs vertical switch dial)?
 - Personally the rolling dial just seems more fluid to use, ergonomic if you will
- Which on/off switch do you prefer (Lever with safety lock or holding down button)?
 - I like the lever with the safety lock because I have other equipment with a similar function
- What do you think about the rotating material changer (location of both, functionality, ease of use)?
 - I like the rotating material changer as long as it both easily locks in to place and turns. I prefer the location of the changer on the Raygun just because it's further from the actual nozzle so I'm less likely to get my hands dirty.
- What are your opinions on the error display (location, ease of understanding, usefulness, etc.)?
 - They seem good. Are they LED lights? And I can't tell if there's two or one. I'm just concerned you might not be able to see them lit up in sunlight.

- What do you like about the physical shape? (how it might feel, is it comfortable, easy to hold, does it look pretty?)
 - I like them both. The razor seems more natural to hold but the Raygun seems more like a gardening tool to me.
- What are your thoughts on the extender? (does it seem useful, potential problems, etc.)
 - As long as it worked well consistently I think it'd be useful. I guess it's usefulness depends on how strong the current/stream coming out of the nozzle would be. It'd be nice if it meant I had to bend down less. Older gardeners would definitely agree.
- What do you like most about the Razor design?
 - I really like the scrolling wheel and how it appears to be pretty ergonomic and low stress on the hand and wrist.
- What do you like most about the Raygun design?
 - I really like the safety lock/lever feature and the extending feature.
- What problems do you foresee with these designs?
 - I'm a little concerned about the Razor's trajectory. Also since there are three different types of materials I feel like they might get clogged easily. I don't know if that's something you guys need to worry about though.
- If you had to pick a design, which would you choose?
 - The Raygun I think. It just seems more durable.
- If you could create a compromise, what features would you include?
 - I would put the scrolling wheel on the Raygun.
- Any other comments?

Part 3: Carrier Design Questions (Dolly and Backpack)

Present each of the carrier designs together.

Important Note: The Dolly design has 25 lbs of water, and 10 lbs of seed and fertilizer. The backpack has equal distribution of materials. Both total 45 lbs.

- What are your initial reactions/thoughts to the carrier designs?
 - I'm concerned about the weight of backpack design but backpacks are definitely easier especially if you're on uneven terrain, which is likely when gardening. The wheels on the cart are definitely key in terms of maneuverability.
- What do you think about the positioning of the tubes?
 - Both seem good. Can you take the bins out of the carrier? That seems like a useful feature.
- Do you think all three material containers need to be of equal capacity? Do you think one should be bigger than the other (seed, fertilizer, or water)?

- Water definitely bigger. But that also would make it heavier, wouldn't it? Hmm. Makes me think you gotta go with the cart design then because people definitely use more water.
- How easy do you think it would be to fill these containers?
 - Seems easy enough. Funnels might help.
- Do you think you could safely carry up to 45 pounds on your back?
 - If the straps distributed it properly. I'm not sure someone in their 70s could though.
- What do you like most about the Dolly design?
 - I like the containers- how you can take them out and that the water one is bigger.
- What do you like most about the Backpack design?
 - I think it'd make life easier so you wouldn't have to worry about rolling the cart or dropping your bags over your flowers and plants.
- What problems do you foresee with these designs?
 - The one handle on the Dolly seems convenient so you can use the other hand on the nozzle but I'm worried it would get unbalanced especially if one container was full and one wasn't.
- If you had to pick a design, which would you choose?
 - I would pick the Dolly I think because of weight but I do like the backpack.
- If you could create a compromise, what features would you include?
 - I think it'd be cool to have a combo between the two but I'm not sure if that'd be too hard to do.
- Any other comments?
 - I'm looking forward to seeing what the final design is!

Appendix J - Hierarchical Task Analysis

Goal:	Steps	Sub-Steps	
Watering and fertilizing a ten foot garden. (You cannot walk through the garden)	1	<u>Fill containers</u>	Grab Apportech
			Ensure that tubes are connected to bottom of the containers
			Open desired container lid
			Fill container with appropriate material (water, seed, fertilizer)
			Close container lid
			Ensure containers are properly locked into the cart
	2	<u>Check error states</u>	Turn it on (on cart)
			Remove handpiece from holster
			Check Error Lights on Handpiece
			If nozzle needs to be replaced, go to step ____
			If nozzle is not clicked into place, fix nozzle.
			If device is clogged, take handle apart and clean clogs
	3	<u>Replace 24 HR Nozzle (if necessary)</u>	Twist off nozzle
			Retrieve a new nozzle
			Click and twist new nozzle on
			Ensure that the error light is off
			Place handpiece back into holster
	4	<u>Fertilize Garden</u>	Roll the cart to the worksite
			Remove handpiece from holster
			Twist dial to select "Fertilize"
			Aim nozzle at desired target
			Extend nozzle as needed
			Press down the trigger to dispense fertilizer
			Move nozzle to spread fertilizer to various plants
			Roll thumb along speed dial to increase flow and distance
			Release trigger when done
			Reholster the handpiece
	5	<u>Water Garden</u>	Bring cart over to garden site
			Remove handpiece from holster
			Twist dial to select "Water"
			Aim nozzle at desired target
			Press down the trigger to dispense water
			Move nozzle to spread water to various plants
	6	<u>Clean Apportech</u>	Roll thumb along speed dial to select flow setting
			Release trigger when done
			Return handpiece to holster
			Turn off Apportech using switch on cart
			Roll cart away from gardening site
			Disconnect tubes from container and handpiece
			Dump out leftover materials
			Spray water through tubes to clean (likely with hose)
			Reconnect tubes to container and handpiece
			If clog is in tubes, run hose water through until clog is cleared.
			If clog is in containers, run water through (Let water drain through the bottom)
			If clog is in handpiece, clean with pipe cleaner.

Appendix K - Hazard ID

Hazard ID	Hazard	Hazardous Situation	Harm to user	Severity Level [1]	Severity Level Description [2]	P2 - probability of hazard leading to harm	Potential cause/ Severity justification/ Comment
1	Use Error	User drops handpiece on foot	Bruise or Abrasion	Very Low	The handpiece does not weigh that much to cause significant damage	Remote	Older adults may have weaker feet
2	Use Error	User rolls over foot with carrier	Bruise or Abrasion	Low	It will be painful, however, it will almost certainly not require medical attention	Remote	
4	Use Error	User hits themselves in the face with the extender	Bruise, abrasion, or broken bone	Moderate	Moderate if a bone is broken	Occasional	If user has hit themselves in the face, it will likely hurt or leave a bruise -> Should add requirement about the speed of the extender
5	Use Error	User pinches fingers when pressing trigger	Bruise or Abrasion	Low	Pinching fingers may be painful but unlikely to require medical attention. Not enough force on trigger to cause severe harm	Remote	Remote chance that pinching fingers will lead to harm. Might just be harmful once in while.
6	Use Error	Fertilizer comes in contact with eyes	Ocular Irritation, Blindness	High	In rare cases, users could become permanently blinded	Probable	Probable irritation. Unlikely for permanent blindness
7	Use Error	Fertilizer comes in contact with mouth	Possible toxicity	High	Ingesting enough fertilizer can be poisonous.	Occasional	User needs to ingest a fairly large amount of fertilizer to actually be harmful
8	Use Error	Fertilizer comes in contact with skin	Chemical burn	High	https://www.nlm.nih.gov/medlineplus/ency/article/002841.htm	Unlikely	
9	Use Error	Water comes in contact with eyes	Ocular Irritation	Very Low		Occasional	Shooting water into one's eyes will typically be an inconvenience
10	Use Error	Seed comes in contact with eyes	Ocular Bruise or Irritation	Moderate		Probable	If you shoot a seed into your eye, it will likely result in either a Bruise or Irritation
11	Use Error	User trips over cables	Joint Injury, Bruise, or Abrasion	Moderate	Falling onto a rough surface can cause an injury that may require medical attention	Unlikely	People will catch themselves most of the time if they trip
12	Use Error	Cart tips over onto leg	Broken bone	Moderate	If the leg is broken	Remote	More likely among older populations

Appendix L - Use-Related Risk Assessment

Risk ref	User Task	Potential Failure Modes	Potential Failure Cause(s)	Effects to Patient/ User/ Environment (Hazard)	Severity	P2	P1	Likelihood (P1 x P2)	Risk (Likelihood x Severity)	Mitigation Strategy
1. Fill Containers	User overfills containers	User overfills containers	User cannot see how much material is in container	Potential chemical burn if filling fertilizer. Overflowing and spillage if filling water or seeds.	High	Unlikely	Occasional	Unlikely	AFAP1	Clearly show max fill mark on container
		User trips, knocks it over, loses grip	Potential chemical burn if filling fertilizer. Overflowing and spillage if filling water or seeds.	Potential chemical burn if filling fertilizer. Overflowing and spillage if filling water or seeds.	High	Unlikely	Occasional	Unlikely	AFAP1	Make containers with lower center of gravity to make them less likely to tip over
		User spills material	No feedback for looking lid	Potential chemical burn if filling fertilizer. Overflowing and spillage if filling water or seeds.	High	Unlikely	Occasional	Unlikely	AFAP1	Make sure lid clicks to let user know it has been properly shut
2. Check Error States	User does not properly close container, causing spillage at some point	User comes into contact with hazardous material	Error state indicators may not be bright	Potential chemical burn if material is fertilizer	High	Unlikely	Occasional	Unlikely	AFAP1	Show green LED for okay and red LED for not okay to make it easier to distinguish
			Malfunctioning LEDs	Potential chemical burn if material is fertilizer	High	Unlikely	Remote	Incredible	AFAP2	N/A
			User forgets to check error states and 24 Hr nozzle was not locked in	Potential chemical burn if material is fertilizer	High	Unlikely	Probable	Unlikely	AFAP1	Trigger cannot be pressed if nozzle is not connected (or there is another error)
3. Replace 24 Hour Nozzle (if necessary)	User comes into contact with hazardous material	Fertilizer remnants on handpiece	Potential chemical burn if material is fertilizer	Potential chemical burn if material is fertilizer	High	Unlikely	Probable	Unlikely	AFAP1	Include warning in manual that user should flush handpiece with water after fertilizer has been dispensed.
		User misinterprets feature	Joint injury, bruise, abrasion	Joint injury, bruise, abrasion	Moderate	Occasional	Remote	Unlikely	AFAP2	Include warning in manual and place icon on device signalling to the user that they should not point the device at themselves
		Extender is too forceful	Joint injury, bruise, abrasion	Joint injury, bruise, abrasion	Moderate	Occasional	Occasional	Remote	AFAP1	Design extender such that the force does not exceed ...N
4. Fertilize Garden	User dispenses fertilizer onto skin	User accidentally squeezes trigger while nozzle is pointing at themselves	Chemical Burn	Chemical Burn	High	Remote	Unlikely	Incredible	AFAP2	Include warning in manual and place icon on device signalling to the user that they should not point the device at themselves. Include warning that user should run water through the handpiece after using fertilizer.
		User not sure if safety is on or off	Chemical Burn	Chemical Burn	High	Remote	Remote	Unlikely	AFAP1	Add a red LED that is turned on when safety is active. Add a label next to the light that says "Safety On"
		User dispenses fertilizer into eyes	User accidentally squeezes trigger while nozzle is pointing at themselves	Ocular Irritation, Blindness	High	Probable	Unlikely	Unlikely	AFAP1	Include warning in manual and place icon on device signalling to the user that they should not point the device at themselves. Include warning that user should run water through the handpiece after using fertilizer.
	User not sure if safety is on or off	User not sure if safety is on or off	Ocular Irritation, Blindness	Ocular Irritation, Blindness	High	Probable	Remote	Remote	AFAP1	Add a red LED that is turned on when safety is active. Add a label next to the light that says "Safety On"
		User accidentally squeezes trigger while nozzle is pointing at themselves	Possible Toxicity	Possible Toxicity	High	Occasional	Unlikely	Unlikely	AFAP1	Include warning in manual and place icon on device signalling to the user that they should not point the device at themselves.
		User not sure if safety is on or off	Possible Toxicity	Possible Toxicity	High	Occasional	Remote	Unlikely	AFAP1	Add a red LED that is turned on when safety is active. Add a label next to the light that says "Safety On"
5. Water Garden	User dispenses water into eyes	User accidentally squeezes trigger while nozzle is pointing at themselves	User and possibly the directly surrounding environment will be wet	User and possibly the directly surrounding environment will be wet	Very Low	Occasional	Unlikely	Unlikely	AFAP2	Include warning in manual and place icon on device signalling to the user that they should not point the device at themselves.
		User not sure if safety is on or off	User and possibly the directly surrounding environment will be wet	User and possibly the directly surrounding environment will be wet	Very Low	Occasional	Remote	Unlikely	AFAP2	Add a red LED that is turned on when safety is active. Add a label next to the light that says "Safety On"
										Tubes can be brightly colored or white to catch the attention of the user. The color should stand from the ground (should not be green or brown).
(4-5) Both Watering & Fertilizing	User trips over tubes	User does not see tubes on the ground	Joint injury, bruise, abrasion	Joint injury, bruise, abrasion	Moderate	Unlikely	Occasional	Unlikely	AFAP2	Include warning in manual and place icon on device signalling to the user to properly stow handpiece when not in use.
		Tubes got tangled in carrier wheels	User did not properly stow hand piece and tubes	If cart tips over: Broken bone/bruise/abrasion	Moderate	Unlikely	Remote	Incredible	AFAP2	Handpiece should be designed with a non-slip rubber grip to prevent the user from dropping the handle.
		User drops handpiece on foot	Loose grip or slips out of user's hand	Bruise or Abrasion	Very Low	Remote	Occasional	Unlikely	AFAP2	
	User rolls over foot with center	User has poor proprioception	Bruise or Abrasion	Bruise or Abrasion	Low	Remote	Occasional	Unlikely	AFAP2	N/A
		User hits themselves in the face with the extender	Bruise, abrasion, or broken bone	Bruise, abrasion, or broken bone	Moderate	Occasional	Remote	Unlikely	AFAP2	Include warning in manual and place icon on device signalling to the user that they should not point the device at themselves
		User misinterprets feature	Bruise, abrasion, or broken bone	Bruise, abrasion, or broken bone	Moderate	Occasional	Occasional	Remote	AFAP1	Issue warning in manual and place icon on device signalling to the user that they should exercise caution. Could add a gyroscopic to the handpiece that prevents the user from extending the device unless it is held at a safe angle.
	User pinches fingers when pressing trigger	User has poor or incorrect grip	Bruise or abrasion	Bruise or abrasion	Low	Remote	Occasional	Unlikely	AFAP2	Include diagram in manual to describe the proper way to hold the handle.
		User is using both hands in trigger area	Bruise or abrasion	Bruise or abrasion	Low	Remote	Occasional	Unlikely	AFAP2	Include diagram in manual to describe the proper way to hold the handle.
		Fertilizer debris is removed from tubes via hose and splashes user with left over fertilizer	Potential chemical burn from contact with left over fertilizer	Potential chemical burn from contact with left over fertilizer	Very Low	Unlikely	Occasional	Unlikely	AFAP2	N/A
7. Clean Approach	Contact with latent materials	User hits themselves in the face with the extender	Bruise, abrasion, or broken bone	Bruise, abrasion, or broken bone	Moderate	Occasional	Remote	Unlikely	AFAP2	Include warning in manual and place icon on device signalling to the user that they should not point the device at themselves

Appendix M - Usability Tests

Test Plan

Usability Test Plan Outline

- Background
 - VFT Design is designing Apportech, a state-of-the-art 3-in-1 horticultural tool equipped with the ability to dispense water, seeds, and fertilizer from the same unit. The device is designed to be portable and can switch quickly between the three types of materials. Furthermore, the device will be equipped with variable speed settings and will be suited to deliver materials at short and long ranges. For VFT Design, the scope of this project is the development of the container unit and the handpiece/nozzle.
- Objectives
 - Test the usability of our handpiece and container to ensure that users are able to understand how to use the different functions on the handpiece and distribute material when the handpiece is connected to the container.
 - Test whether the user can change the dispensary mode of the handpiece while holding it at different angles.
 - Test whether the user can change the dispensary speed of the handpiece while holding it at different angles.
 - Test whether users can comprehend the meaning of the error indicators.
 - See if the user is capable of moving the container piece and whether they think it is an appropriate size.
 - See how the user feels about the extendable feature.
- Methods
 - Materials
 - Prototype
 - Cardboard boxes
 - Duct tape
 - Dolly
 - Caulk gun
 - Hose nozzle
 - Cardboard tubes
 - Background Questionnaire (Handout)
 - Environmental Hazards (rocks, incline, etc. to be placed as an obstacle course)
 - Timer

- Camera (photos/videos)
- Tape
- Tape measure
- Study Logistics
 - Study Duration: Approximately 15 minutes
 - Introduction and Demographic Interview: Approx. 2 minutes
 - Prototype Testing: Approx. 10 minutes
 - Final Interview: Approx. 3 minutes
- Participants
 - Desired Number of Participants: 5
 - Demographics:
 - We will attempt to collect data from the following demographic categories:
 - Men and women
 - Age Range: 18-55
 - Left and right handed
 - Impairments (hand-grip strength, weight-carrying capacity, visual, bending over)
 - We would ideally like to have a participant that has a hindrance such as arthritis. If we are unable to find such a participant, we would like to evaluate our product at least one time using a hand hindering device such as the ones presented to us at Cambridge Consultants
 - Professional and casual gardeners
- Environment
 - To be performed: Indoor Test Environment
 - Justification: Due to weather concerns, we will not test our prototype outside. Furthermore, our tests are largely based on hypothetical situations and do not require specific or uniform testing environments.
- Data Collection and Analysis
 - What: Time to complete tasks, ease of task completion, ability to complete each task, feature functionality
 - Time it takes to identify error states, find and operate speed adjustment, and to select proper material.
 - Ease and ability of filling containers, switching between modes, changing dispense speed, extending device, replacing nozzle, identifying error state

- How: Timer, Likert Scale, Subjective User feedback
 - Time from start to finish of certain tasks
 - Have users verbally respond to questions assessing the ease/difficulty of each task
 - Likert Scale Rating and User Feedback
 - Collect user feedback on the perceived usability of each feature and device as a whole
 - Objective observation of the functionality of each feature
- Researchers (roles)
 - Jake Caccamo
 - Sam Gates
 - Heather McSherry
 - Caroline Kingsley
 - Alexander Golin
- Discussion Guide
 - Introduction
 - Thank you for participating in this usability study. We are interested in seeking your feedback in terms of use with Apportech™. Please feel free to say anything and everything that comes to mind. We would like to note that we are testing the device, not your ability or aptitude with the device. We will not take offense to any of your comments on the prototypes. You are also welcome to stop at any time without consequences. You will receive no compensation for the completion of this usability session, however, your feedback will be very useful to the researchers. Your data will be kept anonymous as we will not ask for personal identification.
 - Background Questions (Pre-Test Questions)
 - Basic Demographic Info
 - What is your age?
 - What is your gender?
 - How tall are you?
 - Do you have any physical handicaps?
 - Are you left or right handed?
 - Gardening Experience
 - What types of gardening do you or have you participated in?
 - If the answer to this is no, you may skip to the Tasks
 - How many years have you been gardening?
 - Do you garden indoor, outdoors, or both?
 - Can you describe the area you garden in? (Patch in backyard, baseball field, nursery, etc.)

- Techniques and Tools
 - What tools do you use to water/seed/fertilize?
 - What about these tools do you like?
 - Are there any features you wish these tools had?
 - Do these tools present you with any problems or difficulties?
 - In what ways do you think these tools could be improved?
 - Do you tend to have to reach up, to distant places, bend down, etc?
- Tasks (Including Prompts)
 - Fill up the material containers
 - Please walk us through the process of filling up the water container.
 - How would you fill it (how to open container)?
 - What material would you put in each container?
 - How would you connect the containers to the dolly
 - Are there any Issues that you foresee with filling or lifting the containers?
 - Post Task Questions
 - How difficult was the task you just completed?
 - What, if anything, did you find difficult or confusing about the task?
 - Are there any aspects of the task that you think could be improved?
 - Check for Any Device Errors
 - Please tell us whether or not Apportech™ is ready to use right now (are there any errors?)
 - Does Apportech need a new nozzle?
 - How would you replace it
 - Does Apportech have any malfunctions right now?
 - Is Apportech's nozzle attached?
 - Post Task Questions
 - How difficult was the task you just completed?
 - What, if anything, did you find difficult or confusing about the task?
 - Are there any aspects of the task that you think could be improved?
 - Water plants out of range:
 - How would you water a plant that is hanging out of your reach?
 - See if they figure out extender, tilting the nozzle, or increasing flow rate

- Post Task Questions
 - How difficult was the task you just completed?
 - What, if anything, did you find difficult or confusing about the task?
 - Are there any aspects of the task that you think could be improved?
- Speed Adjustment
 - How would you increase the speed at which materials are dispensed?
 - Post Task Questions
 - How difficult was the task you just completed?
 - What, if anything, did you find difficult or confusing about the task?
 - Are there any aspects of the task that you think could be improved?
- Switch from Water to Seed
 - Please put Apportech on the “Seeding” setting.
 - Post Task Questions
 - How difficult was the task you just completed?
 - What, if anything, did you find difficult or confusing about the task?
 - Are there any aspects of the task that you think could be improved?
- Post-Task Questions
 - How difficult was the task you just completed?
 - What, if anything, did you find difficult or confusing about the task?
 - Are there any aspects of the task that you think could be improved?
- Post-Test Interview
 - How would you rate the overall quality of the Apportech experience?
 - Are there any design aspects that you feel need improvement, either the handpiece or the nozzle?
 - What aspects or features of Apportech™ did you like?
 - Would you ever use or recommend a device similar to the Apportech? If not, what would help you change your mind?
- Debrief:
 - That concludes this usability session. This test was conducted in order to assess the usability of an early stage prototype of a three in one gardening tool. We really appreciate your participation in this study and your

feedback is very valuable to us. The data we collected from this session will remain anonymous. Have a great day.

Test Plan Results

Participant		P1	P2	P3	P4	P5	Results	Std Dev
Date of Interview		4/12/2016	4/13/2016	4/13/2016	4/13/2016	4/14/2016		
Demographics	Age	21	19	19	18	21	19.6	1.341640786
	Gender	F, F	F	M	M			
	Height	5'3" 5'5"	5'7"	5'8"	5'6.5"			
	Handicaps	contacts, N/A	N/A	No, but he has glasses	No			1.949358869
	Handedness	right, right	right	right	Right			
Gardening Experience	Gardening Experience	none, Yes	yes	yes	Yes			
	What Type of Gardening	n/a, weeding, basic gardening	flower beds, also some low key vegetable gardening	small scale backyard	Home gardening when I was younger, lots of landscaping for my house			
	How Many Years	n/a	12	5	3	10	7.5	4.203173404
	Indoor/Outdoor/Both	n/a, outdoor	outdoor	outdoor, indoor for science projects	Outdoors			
	Description of Garden Area	n/a, around edge of house	flower beds surrounding the house, much area with bushes and flowers, garden plot for vegetables	outside it's a penined in area, maybe 6 feet by 10 feet enclosed by a fence	Patches in the front and back yard, large yards			
Techniques and Tools	What Tools Do You Use	n/a, watering can, hose, never planted anything	fertilizer device- plastic container that you attach a hose to that sprays fertilizer along with water (miracle gro), for watering a standard hose, nozzle, seedling and planting, I use shovels or rakes	seeds I just use my hands, fertilizer I take a scooper and spread it around, watering can or hose for watering. The hose had different spray settings	Watering can, gotta keep it classic.			
	Liked Aspects of Tools	n/a, n/a	nice when the nozzles are tight so theres no leakage, good grip is nice	Hand is very flexible and you can do what you want, fertilizer nothing in particular, just the easiest way	Portable, handle is nice ergonomically			
	Desired Features	n/a, n/a	N/A	For planting seeds, maybe a way to do it standing up	Sometimes it can't hold enough fluid, annoying to have to carry fertilizer and water separately			
	Problems/Difficulties	n/a, n/a	wear and tear on hose, sometimes the nozzles get blocked up from usage or they start leaking around the edges	n/a	Have to keep refilling it, if it's filled all the way it's kinda heavy			
	Suggested Improvements	n/a, n/a	durability	Fertilizer would be nice to have a way to spread it over a larger area over shorter time, and maybe being able to plant more than one seed at a time	Hold more water, if I didn't have to hold it the whole time			
Fill Containers	Reaching/Bending	n/a, n/a	Bend down more than reach up	bend down mostly	Reach up and bend down			
	How To Fill	Open lid to water container and pour water in. Wondering about the power button. Shouldn't press it, to fine	open, stick hose in, watch until it to fine	close the lid on top of the hose to keep it in place	Open the lid and fill to the max fill line.	Open the lid, take a hose, fill it all the way up, up until the max fill.		
	Material Location	Used icons	used icons	used icons	successfully identified	successfully identified		
	Forseen Issues	Losing materials through lid if the container falls over. Lifting fertilizer into container could be difficult. Funnel might be nice.	don't think so. Don't look that big so don't think it will be too heavy	the water might be a little heavy when full but based on the size it'd probably still be full, if you're gardening hopefully you have some heavy muscles on ya	I don't think it would be too heavy or anything. I think it's very cool that it's modular.	No I think they're pretty clearly labelled, I don't think I would mess that up. One thing is that the max fill is on the outside, maybe there should be a max fill line on the inside		
	Difficulty (1-5)	1	1	2	1	1	1.2	0.4472135955
Errors	Difficulties/Confusions	Nothing	nothing	Well really nothing, more so hypothetically I could see some confusions actually putting the hose in. The actual task I just did would be a 1	Nothing	Max fill line (?), but not really a big deal		
	Improvements	Might be difficult to move container to and from water source.	nothing	No	No	No, maybe if it's raining that could be a problem, as long as the lids are sealed, shouldn't be a problem		
	Ready To Use?	No, no		I think it's ready to use right now... (12 sec), when prompted by jake she found the error states and then said no it's not ready for use	I would say it is ready to use, based on appearance. Jake directed attention to error lights. There's a red so I would say you have to replace the nozzle	Says that he could start dispensing if it were connected. Yeah I think it would work. Started analyzing the errors and read through them but did not take note of different light colors		
	Need New Nozzle?	Yes and switch safter	yes	yes	Yes	User very confused about errors, even after researcher directed him to errors. He said he did notice the error states, "oh so does red mean nozzle should be replaced"		
						Correctly identified that it is not ready to use (2 participants). Incorrectly identified that it was ready to use. When prompted to look at error lights, correctly identified that it is not ready to use (2 participants). Incorrectly identified and was not prompted (1 participant)		
						Correctly identified error state "new nozzle" (4 participants). Confused about error state meanings and colors (1 participant)		

	Participant	P1	P2	P3	P4	P5	Results	Std Dev
	How To Replace Nozzle	Press eject nozzle button and put a new one in	looked for nozzle eject button, took 30 seconds to figure out eject nozzle button	I imagine I'd press the eject nozzle button (4 sec)	User wanted to hold off the nozzle, needed to be directed to eject button	Press eject	Correctly identified "eject nozzle button" (4 participants); Did not identify eject nozzle button and needed prompting (1 participant)	
	Any Malfunctions?	No	no	no malfunctions, just to replace nozzle	No	No	Correctly identified "no malfunctions" (5 participants)	
	Nozzle Attached?	Yes (took some time to figure out). A little confusing - labeling with "no nozzle" and green light is confusing	no- but wording was confusing on this error state	Yes	Yes	Yes	Correctly identified "nozzle attached" (4 participants); confused about error state meaning and colors (2 participants)	
	Time Taken	7 seconds	1 second		45 seconds, but only a few seconds after being directed to error states		1:51	41 50.57006538
	Difficulty (1-5)		2.5 2-3 (didn't see eject button)		2, because I didn't see it right away but I think it's my fault more than the design			2 0.612372457
	Difficulties/Confusions	Had to look around entire device to find malfunctions. Diagram on nozzle is very confusing (unclear what it is).	if it was a real button it would be more obvious	Once there are actual buttons/lights for these error states it will be much more clear what it's representing	Nothing in particular. I just wasn't thinking in terms of the lights right away so I didn't consider it	Wasn't hard, maybe a 2. This says replace nozzle and it's red so it's unclear if that means do or don't replace nozzle. I think it would have been more noticeable if it were lit up	Confusion about error state meanings and colors (3 participants); drawn on lights were confusing (3 participants)	
	Improvements	If any errors, it shouldn't let you spray things. Group things together (errors and safety).	don't think so, button in obvious place	Support seems extraneous (which is ok as it is just for the prototype)	No I think it's pretty clear. Definitely intuitive to have red and green, with LEDs I think it would be clear. I guess you could add a ready to use light, but I don't really think it's necessary	Green and red are confusing because not sure if it means green there is a malfunction, or green means go. If you could be more verbose with the labels, less ambiguous	Device shouldn't function if errors (1 participant); group error states together (1 participant); ready to use light if functioning properly (1 participant); symbols should be more intuitive (1 participant)	
Water Out Of Range Plants	Description of Actions	Turn selection to nozzle. Extend nozzle out and press button.	put on water state, looking to see if turn safely off. pulled extender out didn't see button at first, after probing, didn't see rotating head until pointed out.	I could increase the flow rate on the back, there's also something that says extend. And then if it goes up high I could tilt the nozzle down to reach over pots	Probably go for an arc motion with the spray to try to aim it. When asked if he sees any features, noticed the extender which he thought would be helpful. When told that it was not a manual extender, he easily found the extender button. I would then use the angling feature of the nozzle to aim it in	I would turn the flow rate all the way up. Make sure safety is off. Put it on the water setting, spray.	Extended nozzle manually (4 participants); increase flow rate (2 participants); tilt nozzle head (2 participants)	
	Difficulty (1-5)		2, 4- didn't see rotating head	1	1	1	1	1.8 1.303840461
	Difficulties/Confusions	Might be uncomfortable to hold up above head for a while. Didn't understand she could tilt the nozzle head. Didn't know what the extend button meant but understood that device could extend. Uncertain about the safety switch.	rotating head wasn't obvious; didn't see extend button	no, luckily I noticed the flow rate option	Nothing	Nothing. User noticed that gun extended, would you use it? Yeah maybe. Honestly this small extension wouldn't do much, with a longer extension maybe. Generally I'd just add more pressure on the hose, so I would just change the flow rate. User noticed button on back when asked how to extend if it were not manually extendable. comment that it was hard to tell what a button because it was just down on. User did not take note of retractable nozzle. I've just never seen a hose extend automatically. Not something I normally see. Didn't see the angled nozzle at all. Yeah could be useful. Trying to think of a time I would use that. Just seems that I could rotate the device and this ultimately wouldn't be necessary. I would just spray it upward and it would turn the water pressure up	Didn't notice extend button (2 participants); extender too short (1 participant); didn't notice nozzle tilt (3 participants)	
	Improvements	Put arrows on nozzle head to show that it bends/tilts.	button or picture to show you can bend head	if it wasn't automated an arrow for the extend feature would be good	No	Nape	diagram on device showing nozzle head tilts (2 participants); arrow for extend features (1 participant); might not need to be automatic extender, could be manual (1 participant)	
Speed Adjustment	Description of Actions	Turn the flow rate button. Rotate up to increase, down to decrease.	rotated dial	I think I would use the flow rate back here	Flow rate on the back, I would push it up to increase flow	Flow rate scroll up	Correctly identified flow rate dial (5 participants) (3 notes pushing up would increase)	
	Time Taken	7 seconds	1 second	6 seconds	1	4	2	4 2.549509757
	Difficulty (1-5)	2.5	1	1	1	1	1	1.3 0.670820362
	Difficulties/Confusions	Doesn't love the control. Hard to grip handle and adjust flow rate at the same time. Location makes it difficult with one hand. Also had to look around to find the button.	n/a	I guess it isn't clear if the flow rate is just for water (because there's an image of droplets) or if it's for seed and fertilizer too	None	no	Difficult to use flow rate and trigger at same time (1 participant); unclear if it was just for water (droplets image) (1 participant)	
	Improvements	Amount that you squeeze trigger could just change the flow rate. Might be nice to put it on different levels.	no	see above	None. I like the location of the flow rate. Seems pretty operable by one hand other than material selection. Everything is accessible by thumb.	Nape	amount you squeeze trigger can increase flow rate (1 participant)	
	Participant	P1	P2	P3	P4	P5	Results	Std Dev
Mode Switching	Description of Actions	Twisted thing to seed	rotated material to seed	twisted rotating material dial immediately	User immediately rotated dial	Immediately rotated dial	Correctly rotated dial (5 participants)	
	Time Taken	1 second	1 second		3.5	3.5	3	2.4 1.204217911
	Difficulty (1-5)	1	1	1	1	1	1	0
	Difficulties/Confusions	Nothing	no	No	Nothing	No	Nothing	
	Improvements	Make it a little smaller (large and bulky)	no	Depending on how finicky the device is, a line that indicates when the setting is set would be good. It's just kind of fluid right now. (Jake explains there will be click feedback) "User ignored out this feature before task"	Wondered if you could go either way, yes, he liked this feature. Liked that there would be haptic feedback snapping into settings	Maybe you could just have an arrow on the body so you know the top setting is the active one.	line indicating when the mode is set, at top (2 participants)	
	Overall Quality	It was good and easy to use. Things were well labeled.	pretty good, barring a few things were pretty simple.	I think it was pretty good how it combined all of your gardening materials into one device. (Did you think the weight was decent, operable with one hand) Yeah I think so, maybe when it's extended it might be hard to hold with one hand. Maybe slightly heavy overall if using for extended period of time	Very good, very easy to use. The one hand usability aspect is really nice. I really like the modularity of the containers. Easy to figure out how to fit. Size of container unit. I guess it would depend on the type of gardening you do. I would never need this much seed, but that's not necessarily a bad thing though I feel like it would still work as desired	I think it's a good device. Never seen a hose that extends which can be kinds useful, especially for reaching high places.	3 good, 2 easy to use, 1 well labeled, 1 liked combination of different gardening functions, 1 might be heavy for one hand when extended, 1 liked one handed usability aspect, 1 modularity of containers, 1 easy to figure out how to fit, 1 extender is unique and useful	
Post Test	Description of Actions	Lots of information going on though. Going between all the different functions while watering/shading could be annoying. Click the actual error button to eject nozzle (concomitates the buttons).	Containers are "mad big" - make it smaller. Could be a pain to have a cord connected to handpiece and containers. Make the cords like a vacuum cleaner (extend and contract in device).	Didn't explain that there were tubes coming from handle to container, so didn't know how materials were getting to it. But overall liked it	Everything previously stated, nothing else I can foresee	Nothing specifically new	1 click error button to eject nozzle, 1 make containers smaller, 1 make cord retractable, 1 ability to change nozzle output (jet, shower, etc), 1 make buttons look like actual buttons, 1 make error lights clearer and wording more specific, 1 have safety light right next to safety	
	Improvements							
	Liked Aspects	Liked the size of the device		Yeah totally the extender is especially helpful for water high plants, the flow rate is nice too because hoses don't really have that. Could also include different types of sprays which is very helpful on hose nozzles	I like the flow dial, I like the material selector, I like having the extend button on the back. Safety is good. (Thought that the least useful aspect, or the one I'd use least) is the extender cause normally I'm just spraying downwards. I think it's still really good to have though	I liked the three settings, pretty useful, doing this with three different devices would be cumbersome	1 liked size, 1 lights, 2 good dial readability, 2 material changer easy to understand, 2 extender helpful, 1 flow rate adjustability, 1 safety is good, 1 ability to switch between three materials	
	Would Recommend?	Yes		Probably, if I was getting back into heavy duty gardening I would depend on price	Definitely!	Yes	4 affirmations, 1 yes depending on price	