Lawn care at your fingertips

Team 8

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Executive Summary

Lawns are a staple of American home owner communities where they serve a plethora of uses from the functional to the aesthetic. To deliver on these functional and aesthetic qualities, lawns require a significant amount of upkeep that typically takes shape in the form of effort from the lawn owner that consequently puts a strain on several resources, most of which are environmentally unsustainable. These sustainability problems are as a result of pesticides, herbicides and fertilizers serving as potential soil toxins and water being overused to provide moisture to lawns that may be already sufficiently hydrated. A consequence of the latter sustainability issue is further aggravation of the first as excess water provides an avenue for pesticides, herbicides and fertilizers to run off into nearby water bodies causing eutrophication.

Of pertinence therefore, is engineering a method to ease the strain on both the lawn owner and environment. Our design efforts culminated in the creation of Groom, an integrated system that keeps track of relevant metrics regarding multiple aspects of a lawn and delivers it to the user in an unobtrusive and intuitive way. The result of this is a more aware and therefore more efficient lawn owner that generates minimum waste in lawn upkeep which we believe will eventually go a long way in quelling significant lawn sustainability concerns.

Lawn sustainability and lawn upkeep are not new problems and therefore we are not to first set of individuals to attempt to mitigate both issues. The advent of organic fertilizers were in response to the former issue, while lawn care companies and water sprinkler systems endeavor to ease the nuisance of the latter. The problem with these approaches however, is that they treat the two issues as mutually exclusive events while in reality, the issues are rather dependent.

Our design process was able to bring this dependency to the forefront and exploit it to yield a solution that does not treat the two issues as disparate. This is because our design process focused first on assessing a persona, in this case a professional suburban father, identifying what his needs and wants would be and then recognizing the objective metrics that would need to be met to satisfy the previously identified needs. With the metrics defined, the remaining work carried out were essentially trivialities. They included researching ways to consistently meet the specifications discovered prior with little risk of overcompensation and finally designing the software and hardware that would be responsible for relaying the specifications to the user in a way that would not be regarded as jargon. The results of our design efforts are fully embodied in our alpha design; a design that cohesively attends to both lawn sustainability and lawn upkeep pains.

This design method where a need was first identified (in our case through extensive use of ethnography), to maximize the amount of value delivered is one of the pinnacles of sustainable design. While our product does not make lawns sustainable as lawns will still consume resources, it goes a long way in increasing their eco-efficiency. Furthermore, the work we have completed so far can effectively serve as the foundation of a streamlined life cycle analysis should we decide to eventually carry one out. In the same vein of our project being an example of sustainable design, is the awareness our product imparts on the user. Use of Groom in the long run has the potential to educate the user and possibly change the way the user sees his lawn and the possible effects owning a lawn may have on his environment, health, or that of his loved ones.

Lawn care at your fingertips

Final Design Report

Contents

Introduction

In the era of modernization, the concept of a lawn has become an integral part of the typical American homeowner experience, especially within a suburban setting. Many homeowners care for their lawn themselves, not wanting to spend excess money or time. Many of the self-lawn tools and controller systems are too rudimentary, difficult to control, and only regulate one aspect of the lawn (i.e. basic sprinklers that water lawns and sidewalks uncontrollably). Convenience is a key factor when evaluating lawn care tools to invest in, but currently, there is a limited supply of tools on the market to improve convenience.

Additionally, while culturally important within the US, lawns have unfortunately become a threat to the environment [1]. Some of these issues include runoff from irrigation potentially causing eutrophication, chemical leaching from fertilizers and pesticides, and carbon emissions from mowers. There are resources available to educate homeowners about these issues and products to decrease environmental impact in various lawn care areas; however, there is nothing currently on the market that helps homeowners reduce their environmental impact in all areas in a convenient way. Lawn care should be easy, fun, and result in a beautiful and functional lawn, while not hurting the environment. To solve this problem, we have developed Groom, a system that monitors the metrics of a lawn and relays the information to the homeowner through a user-friendly interface. Based on this information, Groom also provides recommendations such as when to water according to the weather patterns and what fertilizer to use to ensure the lawn remains at the highest quality. Similar to the Nest, a smart home air conditioning system, the system will learn the weather and lawn patterns to predict what lawn care is needed for the best results. This product is designed to be used by suburban lawn owners, but the stakeholders can be expanded to lawn care professionals, lawn care product suppliers, and environmental quality regulators. Ultimately, the Groom will positively affect not only those who use and take care of lawns, but the environment surrounding the lawn as well.

Literature Review and Baseline Definition

Whoever concluded that Baseball is America's pastime was clearly not looking closely enough. American's are far more obsessed with cultivating lawns, the neutral backdrop that sets the drama not only for baseball but also for American culture [2]. America is covered by over 60,000 square miles (160,000 km^2) of lawn, occupying more land than any single crop [3] [4]. As Pulitzer Prize winning author Ray Bradbury declared in Dandelion Wine "God bless the lawn mower" [5].

The first colonists introduced grass, the product of a millennial of evolution in northern Europe, due to its adaptation to the hard necessities of raising livestock and of pastoralism [5]. However, the lawn has evolved into a symbol of civic responsibility and has served to unify the American landscape. By domesticating the natural environment, the lawn satisfies the human desire for control and cleanliness. Newsweek Magazine clearly illustrated the purpose of the lawn when it stated, "In an era when almost everything is beyond our control, our lawns are not. We are a better country for our lawns, and we need more-not less-grass" [6].

Lawns have become so ingrained in American culture that an unwritten and unspoken social contract has been developed whereby the lawn serves as both a "common ground between happy neighbors, and a battlefield on which individual rivalries are displayed side by side" [3]. Author Frank J. Scott said, "A smooth, closely shaven surface of green is by far the most essential element of beauty on the grounds of a suburban house" [3]. It covers "a carpet before your house that will infinitely outlive any you can spread within" [5]. A national survey verified this claim when it concluded that 42 percent of yard and landscape-owners cite "to show pride in my home" as the most important reason to maintain and improve

their yard or landscaped area. This value far exceeded “to create an outdoor relaxing space” which ended in second place with 16 percent of adults [7]

In July 2013, The National Gardening Association revealed that 85 million, or 72 percent of all American households are involved in lawn care or home gardening [8]. The demand for quality lawns has resulted in a great need for upkeep and maintenance. As a result, the average household spends $347 annually on do-it-yourself lawn and garden care, totaling $29.4 billion nationally [8].

The prevalence of lawns and the demand for their excessive upkeep represent many environmental concerns. Grass is composed of nearly 85% water. As a result, lawns require constant watering. A square foot of lawn requires approximately 0.6 gallons of water per week (This includes all water sources) [9]. This equates to as much as 238 gallons of water per person, per day during the growing season [4]. Additionally, lawns must be mowed in order to maintain their aesthetic. Americans use an estimated 38 million lawn mowers to trim their lawns, according to the Outdoor Power Equipment Institute [10]. Spending an hour behind a lawn mower can release as much pollution into the air as 100 miles in a car or as much as 350 miles on a new car [10]. America's love affair with the lawn also accounts for much of the pesticide exposure humans receive in their home. Suburban lawns and gardens are blanketed with more pounds per acre of pesticides on average than agricultural land [11]. Each year, Americans pour more than 90 million pounds of herbicides on their lawns and gardens alone [11]. Many commonly used lawn pesticides are probable or possible carcinogens and have been linked to liver and kidney damage, childhood asthma, and disruption of the endocrine system [11]. Additionally, the pesticides leak into water tables used for drinking. In the United States, the EPA’s National Pesticide Survey found that 10.4% of community wells and 4.2% of rural wells contained detectible levels of one or more pesticides [12]. Lastly, fertilizers and pH regulators pose additional environmental risks. Fertilizer that leaks into the water stream can eutrophication. The abundance of nutrients in the water leads to increases in algae blooms that have the potential to deplete the oxygen in water, disrupting the ecosystem) [13].

We define the baseline of our project as the typical lawn care routine for our persona garnered from our interviews and research. This includes mowing the lawn every week, using fertilizer inconsistently (over- or underutilization), using pesticide/herbicide occasionally, and watering (excessively and/or inefficiently) [14].

By integrating smart technology to home devices, Nest labs designs products to both improve the household experience and optimize energy use. Products such as their thermostat and smoke alarm make the user more conscious of his or her energy use [15]. There is currently no product in the lawn care industry that matches Nest products in terms of their dynamic and integrative technology. However, there is an assortment of devices that attempt to serve the customers’ needs and improve the sustainability of lawns. For example, the Iro, manufactured by the company Rachio, is a smart sprinkler system that is able to adapt to different weather conditions [16]. In 2006, University of Michigan installed a new irrigation system called Maxicom. It allows for every gallon of water to be tracked by the University and for sprinklers to be manually turned on and off. The result is a savings to the University of approximately 22 million gallons of water on landscape irrigation each year, which is enough water to sustain an average household for 172 years. At current water rates, this results in annual savings of $141,000 [17]. However, while this product has greatly reduced the water consumption of University of Michigan’s lawns, many of the impacts from lawns remained unaddressed. We plan to develop a product to fit these needs by analyzing all of the metrics that determine the quality and impact of a lawn while still offering a convenient lawn care platform for consumers.

Design Ethnography

In order to design a lawn care product, we used the techniques of design ethnography to fully understand the needs of the customer. Design ethnography is the "scientific method to understand and represent perspectives and experiences in everyday life of design stakeholders" [18]. Techniques outlined in this process include observations, interviews, focus groups, and surveys. To create a plan to understand the needs of the customer, we went through the five guiding questions outlined by Prof. Daly on September 26, 2013. This process is outlined in Appendix A.

From the interviews, we learned that homeowners like to have their lawns mainly for two reasons: to look nice and to enjoy (kids playing, having people over, etc.). The people we interviewed take care of their lawn to a certain extent, but don't wish to spend a lot of money or go out of their way for this lawn care. Each person noted that additional lawn care would cost extra money that they were not willing to spend.

A major takeaway we found from these interviews is that the "quality" of the lawn is important to these consumers. The idea of quality may have a different meaning to different people. For one person, this may mean a well-manicured lawn that is perfect and presentable to their neighbors and homeowners associations. To another person, this may mean providing a safe place for children to play in. Whatever the specific definition is, we felt that this all fell into an expectation of quality for their lawn. Additionally, we found that our interviewees valued convenience. Whether they spend a lot of time or very little time on their lawn, they want it to be easy. People don't want to spend a lot of time/money on their lawn, yet they still want it to look nice and function how they want it to. Through further interviews, research and observations, our task will be to define "quality" and "convenience" in terms of lawn care with certain metrics. That way, we can figure out what needs to be measured/maintained in order to attain a certain quality that is tailored to the individual and how to most easily obtain and communicate those metrics.

To continue with the design ethnographic research, we interviewed 12 more homeowners using the above mentioned format to add to understand the use of lawns and attitudes toward lawn care. A compilation of the new interview summaries can be found in Appendix B. Overall, the homeowners put their lawn usage into two categories – functional purposes and aesthetic purposes. Most people said they use their lawn for their children to play on, for dogs to run around on, and for events such as parties. Concerns also surfaced regarding how chemicals used for lawn care affect their children and/or pets. Additionally, it is important that the lawn looks nice; it gives many homeowners a sense of pride and relaxation to be able to look over a beautiful lawn. There is also external pressure from neighbors and homeowners associations to keep a manicured lawn.

The most common lawn care activity that our homeowners cited was mowing. In a typical week, most people mow their lawn and water. Other less-frequent activities include applying fertilizer, pruning bushes and aerating the lawn. Some interviewees had lawn care services that do the work for them; they don't have to worry about the lawn care, however most of their lawn care money goes into these services. We also found that in general, homeowners who had lawn care services appreciate their feedback on the status of the lawn and look to the company to advise them what to do to help maintain the lawn. This suggests there is a need for feedback concerning state of the lawn, however only those with lawn care services can receive this type of feedback.

Homeowners expressed two categories of "annoying" lawn attributes – animals and grass quality. Animals that have a negative effect on the lawn include moles, dogs, and bugs. With regards to the grass quality, interviewees cited weeds and brown spots as the top annoyances. They expressed frustration with eliminating the weeds and keeping the watering consistent to avoid dying grass. When looking at the factors that drive people to take care of their lawns, we saw a connection between the factors and the annoyances. People want their lawns to look nice and be safe and whether it is an external motivation (neighbor, homeowners association) or an internal desire (health concerns), they will put work into their

lawn. The degree of this work may vary between people, however we found that our interviewees were willing to put at least a baseline of work into the upkeep of their lawn.

The final conclusion we drew from our initial interviews was regarding the desires our interviewees had in terms of their lawn care. Almost everyone said they would like to put more maintenance into their lawn if time and money were not an issue. Many people without lawn care services said they would prefer to have someone else upkeep their lawn. Interviewees also stated they want to improve the quality of the grass in their lawn (get rid of weeds, reseed with more dense grass, etc.). These thoughts tell our team that homeowners are looking to make their lawn care experience easier, however currently, the only solution that exists is to hire a lawn care company. We see a real need in providing a convenient, effective system for homeowners to regulate their lawn, receive feedback, and offer advice for the easiest lawn care strategies.

In addition to homeowners, we talked with experts to understand the finer details of lawn care metrics. We interviewed Rob Doletzky, the grounds maintenance supervisor of the University of Michigan, about the way the grounds service takes care of the university's lawns. The University of Michigan ground services have sustainability as a priority. Currently, the grounds services department is working to meet President Colman's initiative of reducing chemical use by 20%. To reduce carbon emissions, they have been tinkering with alternative fuels such as propane and have been implementing the meadow programs, which assigns certain fields to not be mowed. Plant matter is mulched in place. Soil samples are taken to measure pH, nitrogen, phosphorous, and potassium so they know what exactly they need to apply; when they do apply fertilizers, they use organic fertilizers they have approved through testing. Some pesticides are used, though the quantities are limited to minimum amounts. Water is controlled by Maxicom and is regulated based on the new weather station on campus; it waters only as needed based on the evaporation rates of the lawns and the amount of rain, and has reduced irrigation of water by 68% since it was implemented. The grounds services do a very effective job of using new information and technology to approach zero impact in their work, and it would be wise to follow in their footsteps.

Professor Steven J. Wright is a Ph.D. in Civil Engineering with a Bachelors in Agricultural engineering. He served to confirm much of our design ethnography. He used his personal experience owning a lawn and his engineering background in order to share the main impacts of lawn care and the major concerns of lawn owners.

Dave Marvin is a PhD candidate in the EEB Department at the University of Michigan. He has expert experience implementing Earth and Space Science techniques to conduct research on the conditions of forest biomass. As a result, Dave provided detailed observations on potential sensors for the Groom device. In particular, he provided specific analysis on moisture sensors, microcontrollers, and spectroscopy.

Jamie Kidwell is a sustainability associate of Ann Arbor. She works primarily on improving the energy efficiency of rental housing. She was able to provide insight on the administrative concerns for lawns. She pointed out that lawns are a large fighting ground but that the city currently has a limited amount of resources at its disposal to improve lawn care.

Overall, we learned a great deal about the needs of the potential users and stakeholders of our product. We also learned how our product could potentially fit into the other parts of society. As we heard from our interviewees, lawn care can be tedious and expensive and we believe our future product should be cleverly designed to alleviate the cumbersome burden that lawn care can be. We have great faith that the product will be a commercial success because we feel that the need we serve with Groom will result in a pull or demand from consumers as opposed to us coming up with a solution to push towards no particular need.

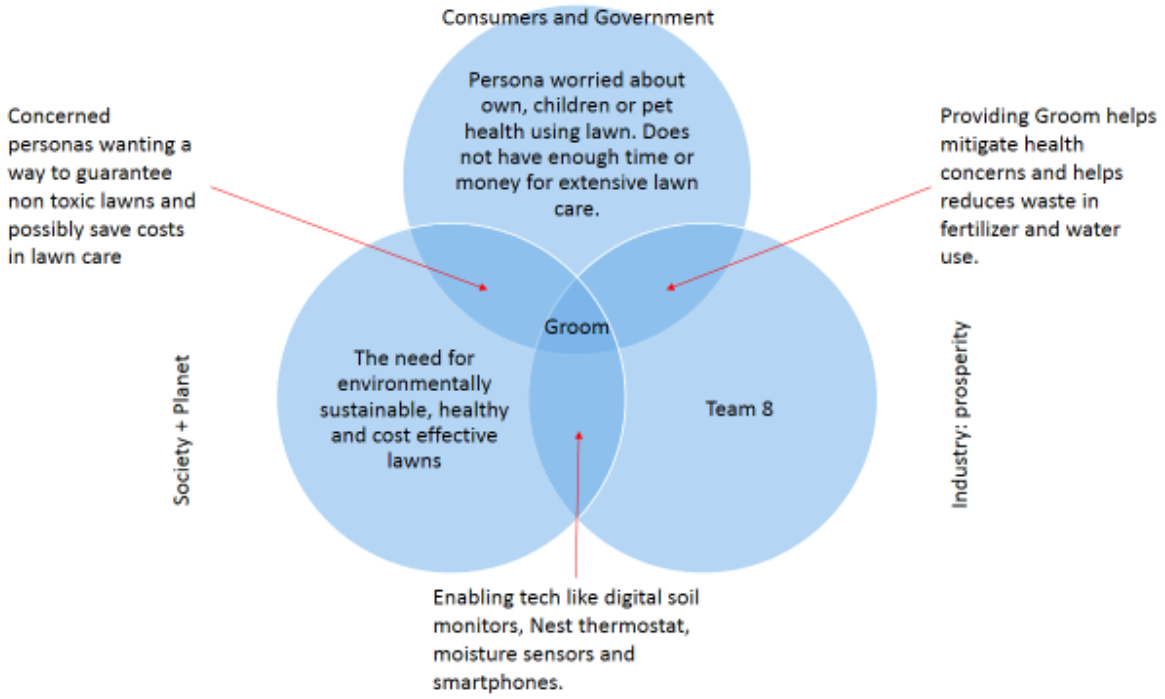

Figure 1: Venn diagram for working towards a sustainable design

The figure above shows the relationship between consumer need, the sustainability demand and our product. Our product was conceptualized in such a way that the relationship with sustainability and lawn maintenance is symbiotic, with the one area able to reap the benefits of the other.

Description of Persona

The target persona should be the market who would benefit most from the device. We decided to focus on homeowners because they represent 4/5ths of the lawn ownership in the US [6]. As such, we named our persona Burdened Brandon.

Burdened Brandon is father of two who is constantly juggling his time between taking care of his kids, his job, running errands, keeping in touch with his friends and extended family through activities and the occasional party, and enjoying life at home. He and his family are part of the upper-middle class and earn $100,000 per year. They live in a suburban neighborhood populated by friendly people and their lush lawns. Motivated by his neighbors' lawns, his homeowner's association, and his own beliefs about lawn care, Brandon wants his yard to be top notch to best reflect his family as responsible members of society. When his children are playing on the lawn, he is not only concerned with the children and how safe they are running around; he worries about how damaged the grass will be from his kids.

Burdened Brandon maintains his lawn regularly. Each weekend, he mows the lawn for an hour and, if there are weeds, spends some more time removing them. When necessary, he applies fertilizer and weed killer to the lawn, but worries about how safe the chemicals are for his kids. They own a programmable sprinkler system to water the lawn three times a week, but he has to update the programming when seasons change. Over the years, he has become frustrated with having to do lawn care.

When it comes to balancing his schedule and budget on his iPhone, Brandon's lawn care time is encroached by other duties, and there isn't enough room in the budget to hire a gardener who can take care of their lawn for them.

Product Requirements

In order to begin designing our lawn care convenience product, we first determined requirements and specifications using a functional decomposition analysis. Requirements describe what our product should accomplish for the persona and were gathered using our ethnographic research and persona development. It also takes into account indirect effects our product has on stakeholders. The requirements are divided into five categories:

1. Look/Aesthetics
Our product must address the look and aesthetics associated with lawns and make it easy for homeowners to regulate these attributes. The soil and water content must be regulated so that the grass is verdant green and remain dense with no brown patches. Weeds should be eliminated and a consistent type of grass should be recommended. The optimal height for the grass should also be determined and conveyed so that mowing the lawn can be optimized for the specific grass type.

2. Feel
Our product should deliver a lawn where the grass is firm and crisp under the feet. The lawn should be sturdy and functional for use, as this is an important quality to our persona. The product will regulate the qualities of the soil, grass type, and water level to give these results. The grass should also have uniform density throughout the entire lawn.

3. Health/Safety
Our product must address the concerns that our persona displays regarding the health and safety of the lawn users. These lawn users include themselves, their families, their pets, and other friends/family who visit. The persona also cares about making a positive impact on the environment, but is less of a concern than the health and safety for their family. The grass should be regulated as to not cause allergies. Harmful chemicals should be eliminated or at the very least limited. Our product should encourage the use of organic fertilizers and weed killers. The ground should also be well maintained with strong soil as to not result in sinkholes, rocks, or any other abnormalities that might cause a health hazard.

4. Convenience
Our product must make lawn care more convenient for the homeowner. The product must provide an organized system to catalog all of the requirements for proper lawn care. Integration of technology should allow the product to perform tasks typically left to homeowners and professionals. The product should provide statistics and alerts to inform the homeowner of the present condition of the lawn, removing the need for personal inspection. The product must educate the homeowner to better understand both the environmental impacts of the lawn and proper lawn care practices.

5. Cost
Our product must lower the cost for proper lawn care. The product should have a payback time that is well within its lifetime. The product will save the homeowner from performing improper lawn care techniques that may waste costly resources.

Of these requirements, the team considers health/safety as the most important. We concluded this through the interviews we carried out of various people who fit into our persona. Ultimately, a lawn is a facility for recreation that holds great aesthetic potential. A lot of interviewees showed great concern about the potential toxicity of their lawns because they had children or pets that frequented the area. Also, to segue

into another important point about our above requirements; they are all interrelated. A healthy lawn fit for use by humans and their pets inherently has all our requirements as a characteristic. It feels excellent, looks amazing and is functional because it is fit for human use.

Sustainability Evaluation

The Sustainability Evaluation Process and Status was developed by the Technical University of Denmark. Its aim is to provide an organized way for companies to determine the economic, environmental, and social impact of a product. We will use it to describe our product. The evaluation includes seven steps, the first four we used, which are as follows:

Step 1: Describe the use context
To understand the use context, we brainstormed the answers to the following questions:

What should the product be used for?

> The product should be used to assist in lawn care, making lawn care less time intensive, more cost efficient, and more environmentally sustainable.

What does the product do?

> It measures metrics of the lawn to determine what should be done to maintain it and make it healthier.

…for whom?

> A homeowner who takes care of their lawn.

…how long?

> The device should only be powered as long as it needs to be on to measure the metrics of the lawn accurately, then store that value.

…how often?

> The measurements should only occur a few times a day at interval, daily.

…where in the world?

> We will focus sales of the product in the United States in cities with a high percentage of lawn owners

Step 2: Create an overview of the environmental impacts
We collected our understanding of the environmental impacts of the device throughout its life into an organized table, as below. We found no significant concerns about the production of the product. If any, the category we should focus on is making the disposal of the product more efficient.

Table 1: Environmental impacts during lifetime of product

Materials	Manufacture	Transport	Use	Disposal
● mining for metals for the circuitry ● chemicals used to create plastic	● electronics byproduct waste ● plastics byproduct waste	● cross-country to suburban markets ● possible export to other countries	● electricity for measuring system/box ● electricity for smart device	● Suburban recycling – electronic, plastic ● Landfill for uninformed consumers

Step 3: Create your environmental profile and identify root causes
Developing table 1 from step 2, we then organized the impacts from each phase of the product life into different categories, namely, materials, energy, chemicals, and other. We copied points as necessary if they fell under multiple categories.

Table 2: MECO-matrix of the environmental impacts during lifetime of product

	Materials	Manufacture	Transport	Use	Disposal
Materials	• Mining for metals for the circuitry • Chemicals used to create plastic				• Suburban recycling – electronic, plastic • Landfill for uninformed consumers
Energy	• Mining for metals for the circuitry		• Cross-country to suburban markets • Possible export to other countries	• Electricity for measuring system/box • Electricity for smart device	• Suburban recycling – electronic, plastic
Chemical	• Chemicals used to create plastic	• Electronics byproduct waste • Plastics byproduct waste	• Cross-country to suburban markets • Possible export to other countries		
Other					• Landfill for uninformed consumers (space)

Step 4: Sketch the stakeholder-network
The stakeholder-network outlines the flow of information and materials between stakeholders and marks where environmental impacts are being made. This shows us where the most important areas of focus for environmental impact we should focus on.

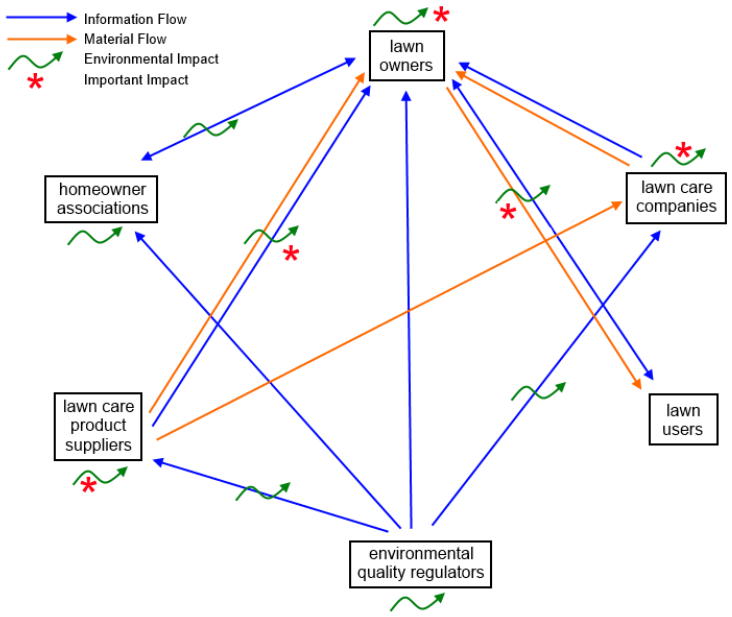

Figure 2: Stakeholder-network diagram

Quantified Specifications and Sustainability Evaluation of Baseline

From the defined requirements, we then determined the specifications of our product that will work to accomplish each requirement using a functional decomposition of the baseline, which takes lawn care as a whole and divides it into simpler, manageable sub-functions [19]. This decomposition focused our efforts into analyzing the environmental impacts of our product alone. The environmental impacts were quantified using specification targets that could yield quantifiable measurements that translate from the requirements desired. These specification targets for each sub-function, then, are the specification targets for Groom itself. The following are definitions of each specification.

1. Soil measurements

Nutrients and pH play large roles in the health and growth of grass. A healthy lawn is an aesthetically pleasing lawn and is thus important for the look/aesthetics requirement of a lawn. The use of fertilizers and pH regulators on the soil to control soil nutrients and pH can have a significant impact on the ecosystem. Adding fertilizer, which for the most part is an inorganic, synthesized chemical compound, can have strong negative impact on the environment through eutrophication (The abundance of nutrients in the water leading to increases in algae blooms that have the potential to deplete the oxygen in water, disrupting the ecosystem) [13]. This is because the amount of reactive nitrogen and in some cases phosphorus available in the soil is overabundant leaving it vulnerable to leaching by frequent lawn watering. pH regulators (sulfur or limestone) when used in excess can either make the soil too acidic or alkaline which has strong negative impact on the soil ecosystem rendering it inhabitable to several microorganisms, earthworms and other small creatures necessary for the maintenance of several soil biological processes [20].

a. <u>Soil nutrients</u>

In agriculture, plant nutrients can be categorized into 4 major sets: Major macronutrients, minor macronutrients, secondary nutrients and micronutrients [20]. As can be inferred from the nomenclature of the categories, major macronutrients are the most significant contributors to vegetation sustenance accounting for a whopping 95% of plant nutrition. Fortunately for us, these major macronutrients (oxygen carbon and nitrogen) are readily abundant in human settlements where lawns exist. Water and carbon

dioxide serve as the source for hydrogen and carbon respectively, while oxygen is sourced from either of the two [20].

The minor macronutrients however are not as readily abundant. They are nitrogen, phosphorus and potassium or the acronym NPK. These nutrients play the huge role of being the backbone for plant photosynthesis, energy, vigor and disease resistance [20]. Therefore, it is of utmost importance that lawns have access to NPK else it starts to look withered or dead, which is the least desirable aesthetic characteristic of a healthy lawn.

The last set, secondary nutrients, is also important but are not necessarily a huge concern as far as lawns go because lawns are fairly robust to their application. In fact, more often than not, applying these nutrients to lawns does more harm than good. This difference in importance is highlighted in Table 3 [21].

Table 3: Soil nutrients and their relative importance in percentages [19]

Category	Nutrient	Concentration (%)
Major Macronutrients	Oxygen	45
	Carbon	44
	Hydrogen	6
Minor Macronutrients	Nitrogen	2
	Phosphorus	0.4
	Potassium	1.1
Secondary Nutrients	Calcium	0.6
	Magnesium	0.3
	Sulfur	0.5

Of all these nutrients, the application of fertilizer to the lawns is usually in response to low levels of minor macronutrients. There are multiple ways to test for these minor macronutrients and they range in complexity from cutting edge soil spectroscopy to simple and straightforward digital meters.

An easy way to tell when these minor macronutrients nutrients are deficient is to follow the rule of thumb provided in the charts below. These values can be obtained through sensors, which through these guidelines will allow us to calculate when new fertilizer should be applied to the lawn. By controlling these values, one can not only keep the lawn healthy, but also prevent the overuse of fertilizers, reducing the ecological impact and lower the lawn owner's costs at the same time. We also aim to control the soil nutrients to fulfil the look/aesthetics and cost project requirements.

Table 4: Ideal soil minor macronutrients in ppm [21]

	Nitrogen	Phosphorus	Potassium
LaMotte Level:	**Nutrient level range in ppm**		
Low	0-15	0-25	0-60
Medium	15-30	25-50	60-100
High	30+	50+	100+

Table 5: Method of assessing soil quality through ppm [21]

4	3	2	1
Nutrient levels are in the "medium" range.	Nutrient levels slightly above or below "medium."	Nutrient in question is "low" or "medium low," and may be deficient.	Nutrient level is "medium high" or higher, and may be contributing to water pollution, even though crop growth is adequate.

b. Soil pH

Also key to lawn performance is the pH level of the soil it is growing in. Ideally most grasses tend to thrive in neutral to slightly acidic soil (pH range 6 -7) [20]. Therefore any adjustment to the soil is usually to get the pH in this optimum range. The key factor to consider here is where in the US your lawn is as soil in the northern United States tend to be more acidic so traditionally gardeners add limestone to soil each year to "sweeten" it [16]. Likewise, western US gardeners add sulfur to soil to reduce its alkalinity. Soil pH can be tested a number of ways; digital meters and lab soil tests are the most often used [20]. Keeping pH regulated helps the looks of a lawn and keep unwanted weeds from growing. pH regulation will help us fulfil the look/aesthetics and cost project requirements.

2. Chemical regulation

Herbicide chemicals are known to harm the environment and the health of the people. The most commonly used chemicals are glyphosate, atrazine, and 2, 4-D according to the EPA [22]. Herbicides are highly soluble and stable, thus should not be used near bodies of water (in danger of polluting the water through runoff). These chemicals also act as cell division inhibitors, which can adversely affect humans and animals that they come in contact with.

Groom does not promote the use of herbicides, however if the user decides to use these products, Groom will regulate the amount of chemicals used on the lawn and ensure the health and safety of the consumers. According to the EPA, the reference doses for the most common active ingredients in pesticides are as follows (table is adapted [13]):

Table 6: Reference doses of common pesticide ingredients

Active Ingredient	EPA Reference Dose (mg/kg body weight per day that humans can ingest with no effect)
2, 4-D	0.01
Carbaryl	0.01
Disulfoton	0.00013
Methylchlorophenoxypropionic acid (MCPP)	0.001
Trifluralin	0.025
Mercury	0.00001

Use of herbicide endangers the health and safety of the lawn. Adults, children, and pets can be exposed to the chemicals inadvertently by using the lawn. By discouraging the use of herbicides, we can fulfil the health/safety project requirements.

3. Water

Since the baseline is standard lawn care, the product will be compared relative to an ordinary automated sprinkler system. Most sprinkler systems have limited functionality. Settings are arranged through a controller that only allow the homeowner to input what days of the week, what time of the day, and for what duration to water. Due to such a rigid design, standard sprinkler systems do not take into account the moisture content of the soil or the weather conditions. This often leads to lawns being improperly watered. A Lawn and Garden Care Case Study performed in Seattle revealed that an organic lawn in the area can save approximately 220,000 liters compared to a conventional lawn for the average single family household's lawn. This results in savings of $42 annually due to reduced irrigation [19].

Water is required for grass to grow, stay healthy, and look aesthetically pleasing. The type of grass and the type of soil affects the amount of water required to keep the lawn healthy. For example, to keep grass verdant and growing during the summer months, Kentucky bluegrass requires as much as 2 inches of water per week while Buffalo grass lawns require one-two inches of water every two-four weeks [23] [24]. Additionally, the amount of water soil can retain varies greatly between types. A clay soil stores about 2 inches of available water per foot, whereas a sandy loam soil may hold only 1 inch per foot. Efficient sprinkler systems should only turn on when 50 to 60 percent of the available water has been depleted [25]. Rainfall as well as climate also determines the amount of irrigation necessary for lawns. A map of the precipitation throughout the United States is provided below. Regions such as Southern California require year around watering while grasses becomes dormant during the winter in higher latitudes.

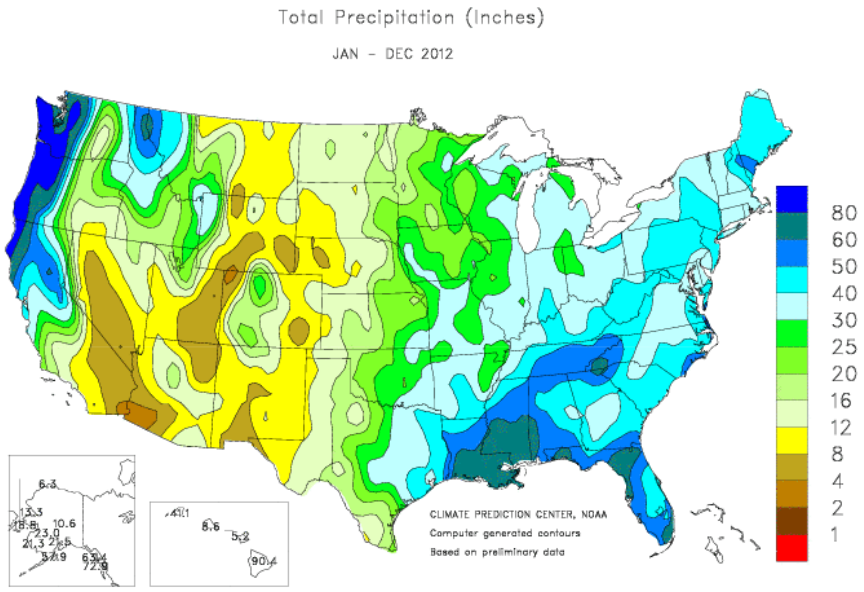

Figure 3: Map showing yearlong precipitation in different areas of the United States [26]

Water can be costly, especially in regions of low precipitation. Controlling the watering such that the grass only receives enough to be healthy, as well as watering during night to reduce the evaporation of water, are techniques to reduce the overall use of water, saving the owner money. Water control aims to help fulfill the cost and look/aesthetics project requirements.

4. Mowing

The growth rate of a lawn (distance/time) depends on several factors:

- Grass type
- Amount of sunlight
- Amount of water
- Amount of nitrogen

Sunlight, water, and nitrogen promote the growth of the grass, though the lawn can be kept healthy without saturating the grass.

The ideal height to mow a lawn depends on the type of grass and the stress it is under. Lawns must not be cut too low as it may prevent the roots from absorbing enough nutrients, and letting the grass grow too long will prevent nutrients from reaching the roots and reduce the aesthetics of the lawn [27]. According to the National Gardening Association, grass should be cut higher when conditions are not ideal for grass growth, such as hot seasons, periods of drought, and when and where there isn't enough sunlight. Otherwise, the grass can be cut shorter. Also, mowing is generally stressful to grass, hindering growth; consequentially, it is often recommended that no more than a third of the height of the grass to be cut at a time [28].

Table 7: Typical grass heights, according to the National Gardening Association [28]

Grass type	Height
Bahia grass; fescue, tall; blue grama; buffalo grass	2 to 3 inches
Bent grass	1/4 to 1 inch
Bermuda grass, common	3/4 to 1-1/2 inches
Bermuda grass, hybrid	1/2 to 1 inch
Centipede grass; zoysia grass*	1 to 2 inches
Fescue, fine; St. Augustine grass	1-1/2 to 2-1/2 inches
Kentucky bluegrass	1-3/4 to 2-1/2 inches
Ryegrass, annual and perennial	1-1/2 to 2 inches

Mowers come in three varieties: reel, gasoline, and electric. Reel mowers are the oldest of the three and use human effort only to cut the grass. Gasoline and electric horizontal mowers are more recent, more popular, and require another energy source to cut the grass. We can measure the energy use of these mowers per hour.

The average U.S. household will mow their lawn for a total of 65 hours per year. Of these households, 41% use riding mowers, 58% use powered push mowers, and less than 1% use reel mowers [29]. According to the EPA in their 2008 document "Summary and Analysis of Comments", gasoline-powered push mowers emit pollution per hour as much as 11 cars, and riding mowers as much as 34 cars. Annually, this contributes to about 5% of the pollution in the United States [30].

When gasoline undergoes combustion, it produces both carbon dioxide and water ($2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O$). Carbon dioxide, when in excessive amounts in the atmosphere, can contribute to global warming. In addition, gasoline combustion is not perfect, and can produce toxic carbon monoxide, smog-causing nitrogen oxide, and unburned hydrocarbons that lead to the production of ozone, which is toxic to humans [31].

Minimizing lawn mowing frequency maximizes the convenience of the lawn owner and reduces the amount of time which mowers are used. This, in turn, decreases the environmental impact by lowering the rate of carbon dioxide produced. This impact can be further decreased by convincing owners to replace their mower with a reel type at end of life. By controlling the frequency which one mows, we can fulfil the convenience project requirement.

Concept Generation

To start, we brainstormed, based on our design ethnography, the topics and problems in lawn care we could possibly address (see Appendix C). We found that these topics and problems fell into four categories.

- Soil nutrients & pH
- Herbicides/chemicals

- Watering
- Mowing

To simplify this task, we assigned each person in our group one of these categories to generate concepts for. Each person, based on their analysis of their section, the design ethnography results from both homeowner and professional interviews, and our analysis of competitor products, was able to come up with innovative ideas that would help Groom improve significantly upon the current baseline in his/her respective area. Improvements were to be in one or more of the five product requirement (look/aesthetics, feel, health/safety, convenience, and cost) or in terms of sustainability (decreasing the impact of the lawn, teaching the user sustainable ideas, etc.).

Within our sections, three major categories emerged:
- Physical products (robots, sensors, etc.)
- Phone app functionality (Calendar, Services, etc.)
- Informational and Educational (Tutorials, Recommendations, etc.)

After we did our initial brainstorming individually, we reconvened, listed all concepts on a blackboard, and then through discussion developed and branched out those concepts into a few more new concepts. Details and complete listing of these concepts is available in Appendix C.

A few concepts stood out to us. One was the calendar, which covers not only the mowing schedule, but can cover pesticide, fertilizer, and water use. Using predictive models from user input, information from the lawn sensors, and other information over the Internet such as weather patterns, the device can plan which days would be best to mow, apply pesticides, apply fertilizer, and water. This would give the user ample time to prepare for that day. It will also minimize the number of applications per year to both be convenient to the user and prevent the user from mowing too often, applying too much pesticides, applying too much fertilizer, and overwatering.

Another concept, which appeared during our interviews, was the concept of having tanks for fertilizer and pesticides that feeds into the sprinkler system. The reasons to implement this are for the convenience of the user and to directly control the timing and quantity of fertilizer and pesticide application. While this could guarantee that the fertilizers and pesticides are applied correctly, there were several other potential problems we were worried about. One was that a fertilizer soluble in water is unheard of, so we do not know if this is a physical possibility. Another worry was that having fertilizer and pesticides in the sprinkler water supply could potentially contaminate the rest of the water supply. The third worry was how safe would it be to have these chemicals in water that a human or animal could potentially drink. This will need much more research and will probably be considered for future iterations instead.

The last popular concept among us, which was not listed as any one concept but was the amalgamation of a lot of them, was to have a database on the phone app which will have all the informational and educational concepts in it. This is nearly a catch-all for anything we cannot deliver functionality for. Though it will likely not be as effective as doing something with a system, it is better than not mentioning it at all. The challenge will be to make the database something the user will and want to use.

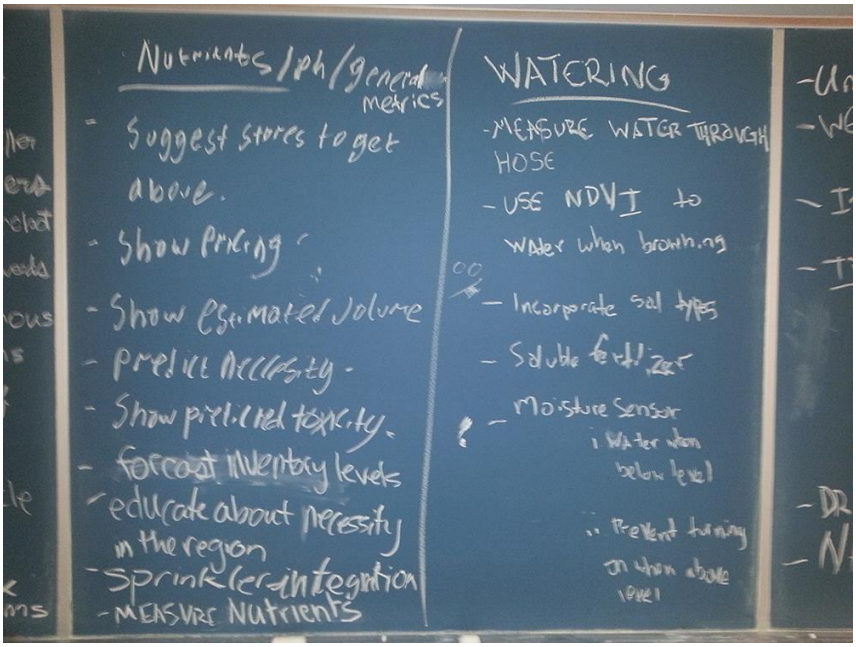

Figure 4: Example of a brainstorm session on the chalkboard

Concept Selection Process

For our concept selection process, each team member was assigned to a to a particular lawn specification category to research it. After the research was done, we came up with 10 ideas each for our respective categories by brainstorming. We then put the ideas into the table below and assigned them values individually (maximum of 5) in the following categories: cost, effectiveness, environmental impact, convenience, technological challenge and feasibility. The significance of each value for individual categories is detailed below:

a. Cost: An idea ranking based on the expenses and savings that may be realized with idea implementation
    1. Too expensive to possibly implement.
    2. Expensive to implement in first Groom iteration
    3. Does not cost anything relative to baseline.
    4. Costs nothing to implement and may save money
    5. Costs nothing to implement with considerable savings in the long run

b. Effectiveness: A ranking of how well a concept fulfills our persona's needs
    1. Does not affect persona's needs at all and would cause confusion
    2. Idea implementation may tantamount to pestering
    3. Benefit over non implementation is marginal
    4. Affects persona's needs to some degree
    5. Affects persona's needs significantly

c. Environmental Impact: A ranking of how significantly an idea contributes to lawn sustainability
    1. Significant adverse effects on lawn sustainability
    2. Adversely affects lawn sustainability
    3. Does not affect lawn sustainability
    4. Improves lawn sustainability
    5. Improves lawn sustainability significantly

d. Convenience: A ranking of the degree of convenience afforded to our persona if the idea is implemented
    1. Very inconvenient; burdensome
    2. Inconvenient
    3. Offers no convenience
    4. Convenient
    5. Very convenient

e. Technological challenge: A ranking of the technological feasibility of an idea
    1. Requires breakthrough in
    2. Requires significant research and studies
    3. Technology is available but requires research
    4. Requires basic technology
    5. Requires little to no technology

f. Feasibility: A ranking of how easy integration of idea will be in the alpha design
    1. Not feasible, will require a major shift to the system
    2. Less feasible to implement, will require some modifications to the system
    3. Equally feasible
    4. Easy to implement, doesn't require to many resources or changes to the system
    5. Seamless integration to the current system, will take little to no effort or resources to implement

The choice of a 5 point ordinal scale was to allow more flexibility with judging very subjective ideas or ideas that depended on multiple variables. Take, for example, the effectiveness of showing the predicted toxicity of applying soil chemicals. If the persona's use for the lawn is mainly for aesthetics, the predicted toxicity would do little to change or alter his behavior. If the persona however has children or pets that frequent the area, this idea would have a more significant impact on him, therefore for effectiveness, this particular concept scored a 4. A scale with 3 points however forces one to either praise or knock the idea and this can lead a concept to fall through the cracks with score misappropriation. In essence, a 5 point ordinal scale allowed us to assess each concept in a much more holistic way.

Our ideas and concepts generated were mostly centered on the "Reduce the dispersion of harmful substances through the product" aspect of TU Denmark's Approach to Sustainable Design eco-design principles. This is because of the most of the sustainability issues with lawns are due to the dispersion of harmful substances like water, fertilizer and carbon dioxide emissions. The reasons why these are harmful have already been detailed. Our top generated concepts are detailed in the table below:

Table 8: Top concepts after concept generation

Lawn Specification Category	Cost	Effectiveness	Environmental Impact	Convenience	Technological Challenge	Feasibility	TJ	SITA	SEAN	LEONARD
MOWING										
Calendar, alerts	3	4	3	5	5	5	25	26	22	24
PESTICIDES										
None Applicable										
NUTRENTS/pH/GENERAL METRICS										
Show estimated volume is needed	5	4	4	5	2	2	22	23	21	24
Predict necessity - CALENDAR	4	4	3	5	3	4	23	27	20	23
Show predicted toxicity	3	5	4	4	2	2	20	23	22	22
Measure nutrients and pH	2	5	3	5	1	1	17	23	25	23
WATER										
Incorporate soil types	3	4	3	4	4	4	22	19	23	23
Moister sensor - water below level	4	5	5	5	4	4	27	20	27	21
Weather API	4	4	4	5	4	4	25	22	30	24
Incorporate type of grass	4	4	3	4	4	4	23	21	23	23
iPhone App - turn water on, off; water usage	4	5	5	5	4	4	27	28	20	23

Everyone assigned values for each concept regardless of if it was under their research category or not. With 6 scoring categories to assign points to, the maximum an idea could possibly score was 30. The team unanimously decided that 20 was the cutoff mark in deciding what ideas would not make it into the final product. After all ideas were scored by all teammates, an idea that scored less than a 20 by all team members was automatically dropped and those which were all above 20 were likewise automatically kept. The ideas that had values above and under 20 across team members were then deliberated amongst the group and labeled either a “yes”, “no” or “Groom Pro”. The ideas displayed in the table are only those that had a “yes” value assigned to them. For the “no” and Groom Pro ideas, please refer to Appendix C.

Of these top concepts, our 5 favorite concepts are explained in detail below:

1. Mowing; calendar & alerts: Although the idea came up in the mowing category, calendar and alerts are broad and used system wide throughout Groom. Groom is supposed to make lawn care easier for our persona and a calendar and alert system that let our persona know ahead of time when next to mow, apply fertilizer, water and other miscellaneous things pertinent to lawn care would be indispensable. Also from a technological point of view, it would not be difficult to

implement. It would need a couple of "if" statements that when fulfilled would alert the user or carry out some other predetermined task.

The key thing to be wary of here is burdening the user with too many alerts or information that would make Groom less of a help and instead one more thing to worry about. Things like how often an alert should show up amongst other things need to be considered to truly make Groom usable and indispensable.

2. Nutrients, measure nutrients and pH: Nutrients are key to the performance of a lawn and therefore have to be measured to assess lawn health. The biggest obstacle to overcome here is how effectively we can actually measure these specifications using digital meters. Digital meters are amazing for the simplicity of how they portray information, but is also detrimental in that no digital meter currently exists that will tell you the exact concentration of NPK lawn soil may have. Instead it gives a general indicator of soil being okay, great or bad. This is a huge limitation, but given that our persona needs to only know if her soil is good enough to sustain her lawn, our method should suffice. We gave consideration to soil spectroscopy, but it is cutting edge technology still in its nascent stages and therefore will be impractical to try to deliver it in a consumer product at the moment. Similarly, lab soil tests are a bit of a hassle as users will need to actively source soil samples from their yard, send it in to a lab for analysis, wait on the results and manually enter it into Groom. This is exactly the kind of lawn care stress we created Groom to prevent and as such cannot be useful to Groom.

   We have also established that for the persona Groom is made for, granular information garnered from a lab soil test or other advanced methods are likely to be a waste as it is too much information. A digital meter integrated with Groom is sufficient for our persona as it will let her know when she needs to fertilize or carry out pH control without encumbering her with excessive details. There are plans to include more granular information and advanced testing equipment in a potential Groom Pro model to serve other personas that want detailed and granular information.

3. Chemicals: Show predicted toxicity: While fertilizer use is encouraged to maintain soil health, the danger of fertilizer, especially inorganic ones, leaching into the water is an ever present threat. In the same vein, fertilizer not absorbed by the soil can remain on the lawn surface creating a serious hazard for personas with children or pets that frequent the lawn. The key thing here is that we make they persona aware that by adding nutrients to your lawn, if done in excess it poses the risk of having serious consequences. The drawback here is that we may discourage fertilizer use completely. This by itself may be good for the environment, but it would be terrible for the lawn. We plan to mitigate this by adding sources of organic fertilizer to our alert system, and although it is feasible, implementation will be a challenge.

4. Water, weather API: Groom will have a weather API integrated in its software to help ease the strain lawns have on water supply systems on days where soil humidity is reasonably high such as after rainfall. This idea had no immediate disadvantages; in fact we think this is Groom's largest sustainability contribution. The idea should also be easy to implement, as a weather API will have access to information like the inches of rainfall expected and will adjust water-sprinkling patterns accordingly. We feel it is a huge boon for our product.

5. Water, moisture sensor: Working symbiotically with the weather API, the moisture sensor has the same advantages and disadvantages of the weather API.

Alpha Design

The Groom Alpha design is split into three separate and integrated devices. The three devices are the measuring instrument, the microcontroller, and the interface. The integration of the three devices allows the product to satisfy all of the product requirements.

The Groom measuring instrument will be responsible for gathering all of the vital metrics for the condition of the lawn. The base of the instrument will cover an area of approximately 6 inches by 6 inches, will be approximately 1 inch tall and will be covered in a weatherproof casing with various sensors attached at the bottom. During installation, the instrument will be pushed down until the sensors are not visible. They will serve to gather important data on the soil content as well as keep the product in place. The various sensors will be responsible for measuring the pH, nutrients including nitrogen, potassium and phosphorous and the moisture of the soil. These sensors are similar to commercially available soil sensors such as the Flexrake Moisture Meter and are read as digital information. On top of the device will be a solar panel. This will provide the device with a continuous source of energy. While the solar panel should provide sufficient energy during all conditions, a rechargeable battery will be available as a backup energy source. The instrument will also include a WIFI chip installed that sends the information in real-time to the microcontroller. Depending on the size of the lawn, additional complementary measuring specification units can be purchased to work in tandem with the main unit.

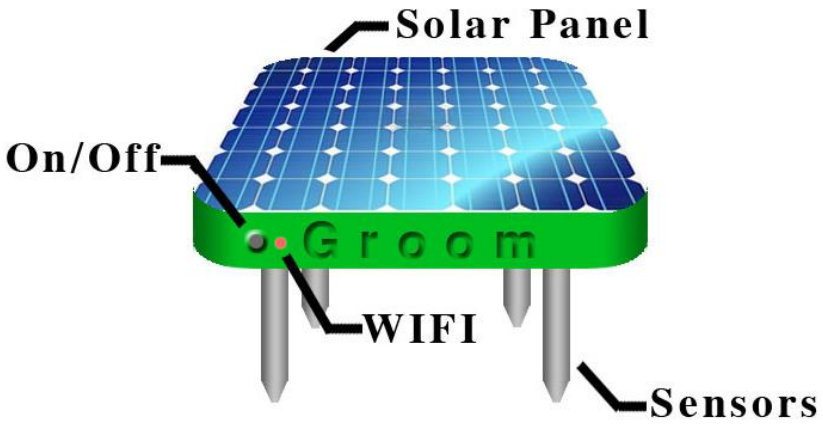

Figure 5: Groom measuring instrument alpha design

The microcontroller will serve as “the brain” of the Groom system and must be connected to the controller of the sprinkler system. Based on the moisture content it receives from the measuring instrument and a weather API, the microcontroller will determine optimal watering times, and therefore it will shut off the sprinklers if the soil has a sufficient moisture content or if the weather API is predicting rain. The microcontroller will determine the amount of water needed based on the moisture content as well as the type of grass and soil used on the lawn. In case the homeowner has a large lawn, the microcontroller will have the capacity to gather information from multiple groom measuring instruments. The microcontroller will have a cord attached that powers it by power outlet. Additionally, the microcontroller will be wirelessly connected to the router through Wi-Fi. This will allow all of the vital information gathered from the measuring instrument to be accessible anywhere via the internet.

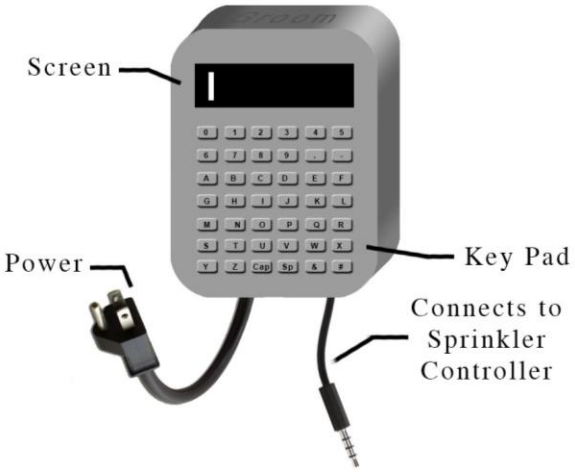

Figure 6: Microcontroller alpha design

The final component of Groom is the user interface. It will be available both through the web and as a mobile application. Each homeowner will create account which will be connected to the home's IP address. The user interface will provide the homeowner with all of the resources necessary to be an educated and informed lawn owner. The user interface will have a thorough database of tips that will improve the quality of the lawn while reducing homeowner's environmental impact and reduce the cost of lawn care. The tips will cover but not be limited to watering, fertilizer, pesticides, and mowing. Examples include recommendations for lawn height, information on the chemicals in weed killers and benefits of sharpening lawn mower blades. Additionally, the device will use the location of the IP address to generate information specific to the homeowner's location. This may include symptoms and recommendations for treating local pests, a list of indigenous grasses, and nearby stores that sell organic fertilizers. Additional information such as weather API will also depend on the location of IP address. A calendar and alert system will also be available to the homeowner on the user interface. Based on the metrics determined by the Groom measuring instrument, the calendar will let the homeowner know the status of the soil and alert him or her if the concentration of the nutrients are under the recommended levels or has reached toxic levels. When the lawn requires fertilizer, Groom will also let the homeowner know how much is needed. The user will also have the option to incorporate mowing into the predictive calendar. The user will be responsible for submitting when he or she has last mowed the lawn. By incorporating the season, type of grass, and grass height after last mowing the lawn, the calendar will use an algorithm that will notify the homeowner when next to mow the lawn. The user interface will also inform the homeowner on the lawn's current watering schedule. The user will have the option to make a custom schedule, preventing or making it mandatory to water during a particular time or day. In order for the user interface to properly work, information such as the type of grass, type of soil, and area of grass will be required when the homeowner first creates an account.

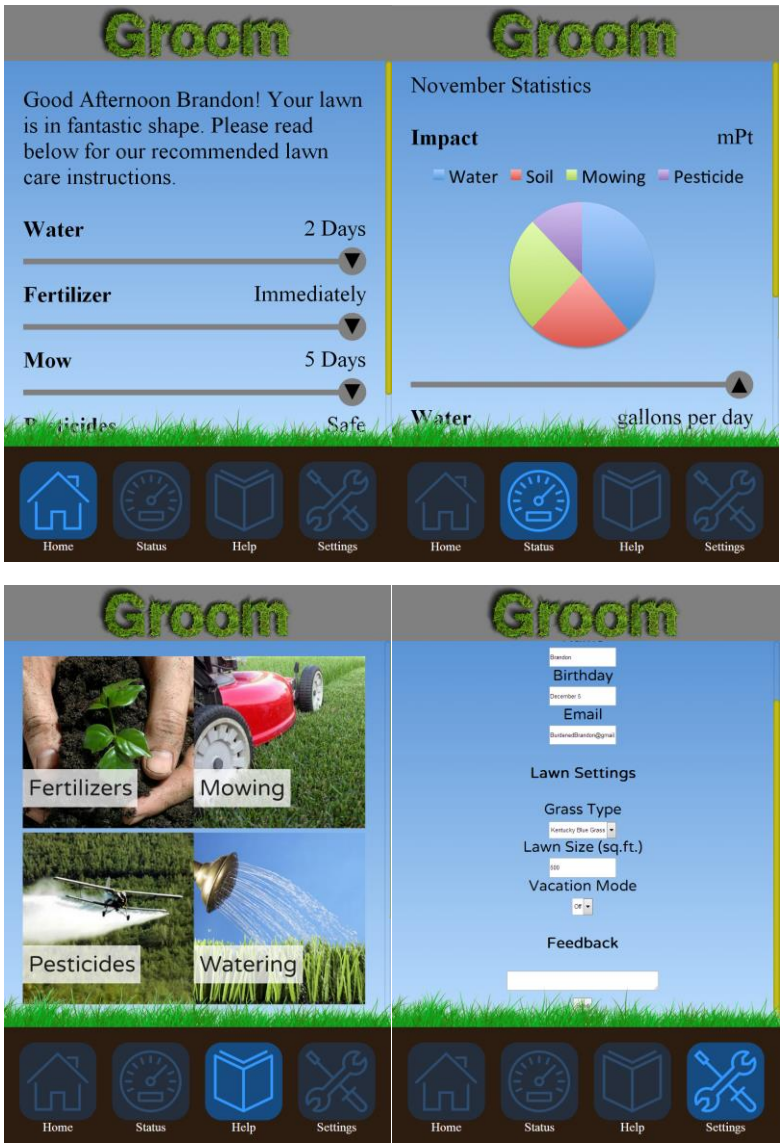

Figure 7: Groom user interface alpha design

Feedback on Alpha Design

After developing our alpha design, we made use of the Thanksgiving break and took the opportunity to pitch Groom our friends and family. Many of these people are close to our persona, thus the feedback we got was very valuable. People were generally positive towards Groom, however not everyone felt like they would invest in this type of product. The people who said they would not buy Groom thought it was a cool product, however they felt that it was not adding any value to their existing self-lawn care (a quote from one of the interviewees: "I'm in Michigan, so I don't have a water shortage. I would have more information about my lawn, but I still would have to do all the work by myself!").

The people that were most excited about this product were a couple who live in a suburban neighborhood home in Texas. Because of their homeowners association, they are required to maintain their lawn to a certain quality. They currently have a lawn care company (and spend about $125/month), however they said that they would be more interested in having a Groom understand the metrics of their lawn, then hire

people to come do specific jobs around the lawn (instead of one company with one large cost). Although they care about sustainability, this couple said their main motivation to buy a Groom would be the convenience and cost savings. This is aligned with our main value proposition. They also expressed frustration in watering their lawn, especially with the tight water regulations in Texas, and were especially interested in the sprinkler connection to the weather API. This made us realize that we should consider change our persona to a suburban father in a water-regulated state such as California or Texas to ensure Groom has the highest value. We also plan to market Groom more heavily in these states where the need is potentially higher.

One concern that our interviewees had about the Groom was the placement of the sensors of the microcontroller. People were worried that the device could possibly become a trip hazard if left on the ground and that both the device and the sensors would potentially get in the way of mowing the lawn. They also expressed concern about placing the solar panels such that enough solar energy could be generated to power the device. This suggests that we need to incorporate a stand-type apparatus for the microcontroller to ensure it is out of the way for the lawn users as well as in prime sun location. The interviewees also suggested we incorporate a battery system as a backup to the solar panels.

An interesting idea that we got from one of our interviewees was the possible integration of our product with a Home Area Network (HAN). This is a type of network that is being developed to connect all aspects of the home including gas, electric, and appliances. Adding the lawn care aspect to this network would make sense to integrate all the home functions and streamline the process for the homeowner. HAN is currently being tested at a pilot scale and is hoping to start permeating the market in the next five to ten years.

Final Concept Description

As detailed above, the most significant alpha design feedback we received was that for people whose approach to lawn care consisted only of watering and the occasional mowing, Groom generated to particular interest. In particular, these people so no benefit of having to spend money on Groom to help with the upkeep of a lawn they were not actively involved in taking care of anyway. Also, concerns were raised regarding the measurement instruments ability to generate enough energy from the solar panel on its back, the potential tripping hazard it poses when installed in a lawn, and the usefulness of what it measures on a large or sloped lawn where specification values would vary with position.

Having taken the above feedback into consideration, we made certain updates and improvements that seek to address shortcomings in the original alpha design. These are:

1. The inclusion of a rechargeable lithium ion cell within the measuring instrument. This helps mitigate any potential concerns regarding the ability of the solar cell to power the device.
2. The inclusion of a marker about 2 feet tall to indicate the general position of Groom on the lawn to help address tripping hazards the measurement device poses.
3. The option to purchase modular sensors to support the main measurement device on lawns that are large, have slopes or other characteristics that would render the main measuring instrument inaccurate.

Our final concept then, is our original alpha design with the updates and modifications detailed above.

Future Idea: Groom Pro

During the design ethnography, we kept receiving feedback about how a product like Groom would be good for lawn care services. We agree with this suggestion and wanted to expand on some of our

preliminary ideas. This iteration of Groom, called Groom Pro, will perform more in-depth analysis of the lawn for the user and contain advanced features with the target user now being the lawn care professionals. For instance, the Groom Pro will feature a grass height monitor so it can inform the lawn care service if the lawn needs to be mowed; sensed values of nutrients and composition of the soil will be more precise and fully transparent to the user; and the sensor system will be more widespread or mobile so that multiple samples can be taken. Other concepts that we generated for Groom Pro can be found in Appendix C.

Lawn care at your fingertips

Business Plan

Company Description

Groom addresses the pain points involved in lawn care as described in our design ethnography. The product aims to improve the convenience and peace of mind while guaranteeing improved quality and health and safety to the lawn.

Groom will primarily serve as a design and assembly company. The manufacturing of the components will be outsourced. The distribution and sales of the product will be performed by home improvement and hardware stores.

Market Analysis

Groom has a large target market. A national survey concluded that 88% of U.S. adults have a yard or landscape [7]. Among those with a yard or landscape, 81% rated upkeep and care as important [7] . With 240 million adults living in America, we believe the maximum possible market for Groom nationally equates to approximately 170 million people [32]. We project the market size will remain relatively constant in proportion to population.

Feedback conducted regarding our alpha design has indicated that the target customers will be members of upper middle class households. People in the upper middle class who have disposable income and lawn care service see significant value in the product. However, people with less money, who do not currently take care of their lawn, generally do not have the capacity and want to purchase it.

For this report, we define the upper middle class as households with an annual income over $100,000. They make up 20%, or nearly 24 million households [33]. We believe Groom will appeal to both homeowners who currently take care of their lawn themselves as well as homeowners who hire professional lawn care services.

According to the National Gardening Association, lawn care and landscape maintenance services account for 28 million households [34]. Through interviews, we determined typical lawn care services cost approximately $125 a month. Many people who get professional lawn care service have expressed interest in Groom as an alternative or as a supplement to professional lawn care services. We believe Groom satisfies the top five reasons homeowners hire professional lawn care services as referred in the table in Appendix E while being a more affordable option. It also guarantees to homeowners that they are performing the most sustainable and cost effective lawn care practices while maximizing the look and feel of their lawn. While Groom does provide increased convenience to the homeowners, they are still required to perform tasks such as mowing the lawn and laying new fertilizer, which would ordinarily be performed by professional lawn care services.

While professional lawn care services are considered the primary competitor, there are other lawn care products available to customers that implement technology in order to optimize lawn care. While they do not currently make up a significant portion of the market, they should be considered competitors as they may gain increased market share in the future. These products include the Toro's Soil Moisture Sensor [35], Greenbox's customized watering program [36], Lono's Sprinkler Controller [37], and Rachio's Iro (customized water program, similar to Greenbox) [38]. The Iro system will ship in spring 2014 for $199.

Groom provides a more holistic approach towards lawn care than its competitors. By having two devices, a sensor instrument and a microcontroller, it has increased functionality. Groom is able to interact with a smart device and also run independently based on the weather and moisture conditions. Additionally, Groom takes a more in depth approach by requiring the user input soil type, geography, grass type as well as other relevant information. Most importantly, Groom helps the homeowner with all lawn care tasks

including watering, mowing, fertilizer, and pesticides. However, due to the increased hardware required, Groom will be significantly more expensive.

The initial retail price for Groom will be $300 to $500 dollars. The price is based on the manufacturing, assembly, labor and transportation costs. The retail price of Groom will be approximately twice the cost of production in order to guarantee the company and distributers generate revenue. The price is expected to lower as production increases. Interviews conducted have shown there is significant interest in the product. While some people have expressed apprehension due the cost, overall there has been overwhelming evidence that customers in our persona are willing to pay for the product.

The most significant barrier to the market will be removing any possible skepticism from the homeowner. Traditional lawn care practices are deeply rooted into American culture. Implementing the technology to assist homeowners and recommend more sustainable lawn care practices may not appeal to traditionalists. Also, integrating the system may be deemed too much of a hassle for certain homeowners who are already pleased with their current lawn care strategy. Lastly, we currently have limited evidence verifying that Groom will generate improvement over its design requirements. In order to grab a significant piece of the lawn care market, Groom must have a strong advertising campaign, spread by word of mouth, and receive positive ratings by reviewers.

Product Description

As far as our customer is concerned, and well justified by our ethnography in the previous section, we designed Groom to address the following qualities of a lawn: look/aesthetic, feel, health/safety, convenience and cost. Out of these, the most immediate customer need satisfied is convenience with the following occurring in the long run. Specifically, the data that Groom gathers will optimize specification parameters to require the minimum upkeep for a healthy, good looking and safe lawn.

The specific benefit of Groom is its adaptable, preemptive and holistic nature. By keeping track of certain specifications and access to weather APIs, Groom effectively monitors the following: soil metrics (Nutrients & pH), added chemicals (Pesticides), lawn growth rate and water use. This gives us a unique advantage because we don't only make lawn care easier, we also ensure less hazardous lawn through Groom.

Groom is still in the development/idea stage as we work to finalize software and hardware choices for multiple aspects of the system. Regarding Groom's life cycle, the system is designed to undergo iterative updates about once every 4 years to update the microcontroller and the measuring device. Therefore, it is plausible that Groom doesn't exactly have an end of life as previous generation Grooms can be sold second hand or sent in for refurbishment like smartphones and other electronic devices. A point may be reached however where the microcontroller's processor or measuring instrument will be robust to incremental updates, at which point Groom will likely only have user interface updates. Also previous Generation Grooms will remain fully functional and the only drawback will possible be less features accessible to the owner due to hardware limitations.

Over Groom's developmental period, the team has received feedback from multiple potential customers who have shared their praise, enthusiasm and criticism for Groom:

- ExxonMobil Recruiter: "Wow, that's a great idea. My lawn is currently such a pain to manage."
- Design Expo Commenter: "Oh, I would definitely love to mow my lawn less often."

This positive feedback only serves to encourage us that there is a solid place in the market for Groom.

Marketing Sales Strategy

Market Penetration Strategy

As per our persona, we will target upper-middle class suburban American families. We will see if there is any interest by lawn-owning families outside of our target and if there is any way we can reasonably reach them with products. Otherwise, we will continue with our plan to create Groom Pro, which will be aimed towards lawn care services.

We will need a substantial amount of money just to produce the device. The cost sources for creating the product are 1) materials, manufacturing, labor, and transportation for manufacturing (we estimate $150 at most per unit), 2) assembly and preparation (completed in house with about two people at about $10/hour), and 3) shipping (dependent on the size of the order and will be charged to the purchaser).

For prototyping and validation, we estimate this product would take 2-3 years to fully develop. Based on other startups, we predict we will need set aside funds for the following areas: Patent Lawyer (about $10,000 fee for a minimally complex device) [39], two Design Engineers ($89,000 yearly) [40], and budget for running business, advertising, equipment, etc. (about $1,000,000)

The total costs for the development will be about $455,000 for the initial 2.5 years. The profit margin function of the product is

$$Profit\ Margin = (Price\ per\ unit - Cost\ per\ unit) * Units\ Sold - \ Other\ Costs$$

Assume distributors will sell the product for $400 and take $100 per unit. We would profit $150 per unit. Plugging in our values, the profit margin function is then

$$PM = \$300 * Units\ Sold - \$150 * Units\ Produced - \$1455{,}000 - 2 * \$89{,}000 * T - 2 * \$20{,}800 * T$$

Where T is the number of years since the manufacturing of the product. The salary for the design engineers is more significant than any other factor in this profit margin function, so lower initial salaries for the design engineers may need to be explored.

Communication Strategy

Groom will be advertised primarily through ads on television on channels that feature home improvement, such as the Home and Garden Television (HGTV) and through magazines such as Better Home and Garden. By targeting material that features lawn care, its audience should include people who are interested in lawn care and are also middle-upper class, which is close to our persona.

We are also considering doing cross-promotion with another product related to lawn care. We would raffle off a number of our units to people who bought the cross-promoted product. This is possibly less expensive but more time consuming than advertising. We also should choose a product that wouldn't be unsustainable if someone were to buy excess of due to our promotion.

Channels of Distribution Strategy

People who will be looking for a product like Groom will likely be looking in stores that focus on home improvement and maintenance, such as Lowe's and Home Depot, which have large sections in their stores for lawn care. These stores can sell the device at a markup of $100 to $150 above the wholesale price of Groom. Alternatively, we can pitch partnership with these stores, customizing Groom such that it advertises their store whenever Groom detects the user needs to get a product.

Groom will also be available for sale through our own website for those who prefer to do shopping online. We will match the in-store price to keep consistency between the two outlets. Later on, we will

expand distribution by utilizing other online stores, such as Amazon, as well as through specialty stores, such as Ace Hardware.

Growth Strategy
After the release of Groom, we plan to design add-on systems to Groom, additional online services, and updates to the Groom app. The add-on systems are physical devices that extend the functionality of Groom, offering additional convenience to the user. For instance, one device we are thinking about developing is an integrative system for the lawn mower to allow for automatic mowing that occurs on demand by the Groom. Additional online services are mostly features that require a large installed user base before it becomes useful. As such, we want to release those features after we get that user base.

After that, we plan to release the Groom Pro, which is a horizontal iteration of the Groom. As stated before, this is a similar device to the Groom that will service lawn care services by giving them more precise and informative tools. This would require a new design ethnography and design process.

Funds Needed to Start Company and Break Even

Based on the values in the Market Penetration Strategy, the product costs will be

$$Production\ Cost = (\$150 + Average\ Shipping) * Unit$$

The cost for personnel is

$$Personnel\ Cost = 2 * \$89{,}000 * (T + 2.5 years) + 2 * \$20{,}800 * T + \$10{,}000$$

Where T is the amount of time in years since the initial production of each unit of Groom. Assuming 20,000 units are produced in the first year, if we are able to sell 15,582 units during that month, we will break even and recuperate our sunk costs, and if we are able to sell only 10,732 units, we will have at least break even with our production costs. Worst case, we produce the first wave of 5,000 units and none of them sell. If this were to happen, we would have lost 2.4 million dollars. On the other hand, the product could be a runaway hit. Considering 28 million Americans pay for lawn care, best case all these Americans are interested in Groom. We would virtually be limited only with how quickly we can produce units to sell. The more realistic best case scenario would be if every person that fits our persona buys the Groom. Note, that since a lot of these numbers are estimated, results can differ.

To raise funding for Groom, we have considered a few strategies, one of which is to offer our company to be bought by another larger company. The company would pay for all of the costs of the development of production, but at the trade-off of controlling our salaries and influencing our design choices.

Another way to raise this much money is though Kickstarter. Kickstarter has been a way for companies to get crowd funding for their product and a way to get pre-sales for their product. It also serves as an advertisement platform as it will be available to browse to on the website. However, Kickstarter has a largely young adult male demographic of people who earn $0-50k a year [41]. This is a different economic class than our persona. If we do try this funding method, the product would be advertised in a different way, such as a holiday gift for their parents. We are currently not sure that a Kickstarter would succeed. The major positive of this method, however, is that there no cost in running a Kickstarter.

A third way to raise money is through striking deals with Home Depot or Lowe's. Groom has the capability to advertise products when the user needs a lawn care product. A partnership with one of those stores to push their product could earn us the money to begin production of the Groom. The downside with this option is distribution of this device could be limited to only the store which funds us, which limits our reach.

Lawn care at your fingertips

Additional Information

Eco-Efficiency vs. Sustainable Design

We believe Groom is an eco-efficient design. There are many benefits to the environment as well as to the user. Groom enables users to save resources and money. It also ensures that unnecessary chemicals are not put into the ground, the appropriate amount of water is used, and makes the lawn owner more aware of his/her actions and how he/she affect the environment. We do realize, however, that Groom could be used in unintended ways that would create negative impacts. One such way would be the addition of multiple features and the effect additional manufacturing may have on the environment. If additional sensors are incorporated in to the design (for a product like Groom Pro), this technology may contain special materials or require special manufacturing processes that hurt the environment and outweigh any benefits a potential Groom Pro device might offer.

While we feel Groom is an eco-efficient design, we do not believe it is a sustainable design. Although this product is helping the environment, is still encourages homeowners to have a lawn, an inherently unsustainable attribute of the residential sector. To move towards a sustainable design, we would need to modify Groom or create a new product that facilitated a shift towards replacing the traditional lawn with a more natural environment that included native species. This sounds far-fetched, especially given the fact that lawns are so ingrained into the US culture, however a true sustainable design would be able to modify a culture such as this one. While it is difficult to achieve, we have learned to always strive towards a sustainable design.

Design Critique

After reflecting on our semester, the Groom team identified some key aspects of our design and our process that we would have done differently. Starting from the very beginning of the design process when we were conducting "observations" to identify issues and problems, we would have kept our notes in a more organized way. Looking back, our observations were not documented well, which made it harder for us to identify issues and potential ideas for our design product. We should have kept an organized document of all the ideas, potential issues, and design ideas in a common document so we could reference them and potentially see patterns throughout the observations. Additionally for the design process, we would have like to incorporate observations into the design ethnography stage. We identified observations as being useful for our ethnography, however the timeframe of the semester and lack of response from the lawn care companies hindered our progress in that area. We were able to perform an adequate amount of interviews, however we believe that observations would have enhanced our design ethnography considerably. Finally, the last part of the design process that we would have done differently would have been the concept selection process. We came up with our own 5-point scale for evaluating the concepts, however we may have benefited from incorporating a different scale, such as the 3-point scale, or a hybrid of the two scales.

Looking back on our product, we feel the Groom has many strengths. Groom addresses the wide-spread issue of the sustainability of lawn care and can make a positive impact on both peoples' lives and the environment. This product targets a persona that is passionate about his lawn and always him to harness his motivation and use Groom to the fullest potential. From the feedback on our alpha design, we found that Groom also has a clear value to the homeowner, making it more attractive to buy. Finally, with the well-designed interface on mobile devices, Groom is not only effective, but convenient and fun to use.

As with all products, there are also many weaknesses of Groom that could be improved upon. We feel the largest area for improvement is cost. Currently, the technology that we have chosen for the Groom is expensive and we are unsure how the prices would change after talking with wholesalers or scaling up our product. Groom is also resource intensive in terms of the sensors, microcontroller, and packaging

required. To bring Groom to the next level, we see a few key areas that would be beneficial to improve upon. First, we would like to incorporate lawn care company information into the user interface. Currently, Groom provides an adequate amount of information about lawns, however still requires the homeowner to perform the lawn care themselves. If we could integrate lawn care company information that our persona could easily contact people to help them take care of their lawns, we feel that could strengthen the value proposition of the product. Second, we need to improve on the technology that we plan to incorporate into the product. We need to conduct more in-depth research on the costs of the desired sensors and contact manufacturers for wholesale prices to make a more appropriate price estimate for the alpha design. Finally, we would like to improve the way we incorporate sustainability education into Groom. Currently, we have an "education page" on our interface where users can look at to learn more about the native species in their area, mowing tips, and other lawn care information; however, we don't feel like this is especially engaging. We are not confident that users will look in the education section on their own time – we need to incorporate the education portion into the everyday uses of Groom to ensure we are disseminating the knowledge in a non-intrusive but engaging way.

Recommendations

For the next steps in developing Groom, we first recommend focusing on choosing specific technology that will be used in the product and creating a prototype. This will not only solidify the technical proof of concept, but will also help define the overall assembly, manufacturing, and packaging of the product. We also need to work on the predictive model that we have proposed for our system (similar to the Nest). We have not looked into this concept at any depth, but we realize this is one of our most technically challenging next steps. After creating a prototype, the next step would be to conduct in-house product testing and focus groups. We would test the technology to ensure quality, durability, and accuracy of every lawn care metric we claim to monitor. We also recommend conducting interviews, focus groups, surveys, and beta testing with people who represent our persona to gain feedback about our design and information to incorporate for the beta version of our product.

Simultaneously to technology development, we also recommend refining the Groom business. First, we would need to write a full business plan and conduct the research required to do so. This also could include reaching out to people who have product-based business to understand their successes and challenges. We also want to contact potential manufacturers, packaging, and distribution companies. This will give us a better idea of the cost, time, assembly, and materials that will be used to produce our product. It's important for our business to understand every part of our process and what impact it makes to ensure the sustainability and quality of the finished product (as discussed in the class videos this semester!). Following this effort, we will need to start looking at fundraising and possible investors to help launch our company. We see great potential in this product, thus we recommend making a big push for our company to enter the market. This may include advertising, commercials, and demo stands in stores.

Throughout the development of our company and product, we recognize how important it will be to continue to incorporate feedback into our design and iterate appropriately. This will include testing, interviews, focus groups, and surveys. Lawn care is a dynamic industry and we feel it will be important continue research and development efforts to keep up with the needs of the customers.

Finally, we recommend looking more into making an additional product in the Groom family, Groom Pro. As mentioned earlier in the report, Groom Pro is the "next generation" of Groom that is specially tailored for lawn care companies as the primary user. We would recommend going back to the design ethnography phase and conducting many interviews and observations, with lawn care companies in

particular, to redefine the persona for the product. We would also need to look at different technology and user interface to provide more detailed information to the user. We would also recommend incorporating grass height monitoring technology into this product. This was not included in the original Groom due to the complexity of the technology, however many interviewees were interested in these measurements and we feel it will be a great value added to the product for the future.

Project Reflections and Future Project Recommendations

This class was a great experience. We thought it was frustrating to go through the design process and go against what we were taught in most other engineering classes, but now we realize that this "struggle" is part of the learning process. We very much agree that encouraging students to take ME 499 before this class is a smart idea – we feel like we would have been more prepared for this class if we had taken an ME 499-type class before.

Having the lectures online through videos and having discussions/group work during the lecture time did not feel like it completely aligned. We were unsure of how to prioritize the information in the lectures and when the quizzes came around, we were not sure how the questions were chosen. The lecture period, while we expected it to be more discussion based, did not have many interactions between the students. Is it possible to incorporate more interaction into the classes? Some ideas we had was small-group discussions (with people not on your team) to talk about the lecture material. People are reluctant to ask questions in a big classroom, but we feel a small discussion group would be more meaningful. It would also help us meet others in class (we felt a bit siloed into our groups during the whole semester and didn't get to know anyone else).

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Works Cited

[1] K. McDade, "Greener grass? Factors relating to reducing environmental impacts of lawn care companies.," 2008. [Online]. Available: http://deepblue.lib.umich.edu/handle/2027.42/60652.

[2] R. Fulford, "The Lawn: North America's magnificent obsession," [Online]. Available: http://www.robertfulford.com/lawn.html.

[3] "The American Lawn," [Online]. Available: http://www2.cca.qc.ca/pages/Niveau3.asp?page=depliant&lang=eng.

[4] T. Hayden, "Could the Grass Be Greener," [Online]. Available: http://www.usnews.com/usnews/culture/articles/050516/16lawn.htm.

[5] G. Teyssot, The American Lawn, New York: Princeton Architecture Press, 1999.

[6] "The Joys of Mowing," [Online]. Available: http://webcache.googleusercontent.com/search?q=cache:aV4J2fk-

x8UJ:www.thedailybeast.com/newsweek/1991/04/29/the-joys-of-mowing.html+&cd=1&hl=en&ct=clnk&gl=us.

[7] "Research," LoveYourLandscape.com, 2012. [Online]. Available: http://www.loveyourlandscape.com/research/survey_report.cfm.

[8] I. Baldwin, "National gardening survey: Food gardening earns more than flowers," [Online]. Available: http://www.todaysgardencenter.com/business-management/state-of-the-industry/national-gardening-survey-food-gardening-earns-more-than-flowers.

[9] "Make Watering Easier," [Online]. Available: http://www.lowes.com/cd_Make+Watering+Easier_1311250380_.

[10] W. Lawson, "Study: Lawn Mowing Equals Car Trip," [Online]. Available: http://abcnews.go.com/Technology/story?id=98532&page=1.

[11] S. Littlefield, "Lawn Pesticide Facts and Figures," [Online]. Available: http://www.garden.org/subchannels/landscaping/ground?q=show&id=3440.

[12] "Chapter 4: Pesticides as water pollutants," [Online]. Available: http://www.fao.org/docrep/w2598e/w2598e07.htm.

[13] J. Morris and J. Bagby, "Measuring environmental value for natural lawn and garden care practices," *The International Journal of Life Cycle Assessment*, vol. 13, no. 3, pp. 226-234, 2008.

[14] S. Bender, "The Daily South: Don't Be a Lawn Watering Dummy," 12 July 2011. [Online]. Available: http://thedailysouth.southernliving.com/2011/07/12/dont-be-a-lawn-watering-dummy/. [Accessed 17 November 2013].

[15] "Nest Home," [Online]. Available: http://nest.com/.

[16] S. Brewster, "Smart lawn sprinklers cut down on water waste," [Online]. Available: http://gigaom.com/2013/10/10/smart-lawn-sprinklers-cut-down-on-water-waste/.

[17] K. Broekhuizen, "Improved irrigation system provides water and cost savings," [Online]. Available: http://sustainability.umich.edu/news/improved-irrigation-system-provides-water-and-cost-savings-0.

[18] S. Daly, Interviewee, *Design Ethnography, ME 589.* [Interview]. 26 September 2013.

[19] S. Skerlos, "SimaPro & Life Cycle Design Case Study," 6 August 2012. [Online]. Available: Life Cycle Design and Simapro. [Accessed 15 December 2013].

[20] P. B. Turkey, The organic lawn care manual: A natural, low-maintenance system for a beautiful, safe lawn, North Adams: Storey Publishers, 2007.

[21] "Turfgrass fertilization: A basic guide for professional turfgrass managers," 2003. [Online]. Available: http://plantscience.psu.edu/research/centers/turf/extension/factsheets/turfgrass-fertilization-professional#oth.

[22] "Herbicides," Environmental Protection Agency, 2012. [Online]. Available: http://www.epa.gov/caddis/ssr_herb_int.html.

[23] R. L. Duble, "Aggie Horticulture: Kentucky Bluegrass," University of Texas A&M Agrilife Extension, [Online]. Available: http://aggie-horticulture.tamu.edu/archives/parsons/turf/publications/bluegrass.html. [Accessed 17 11 2103].

[24] T. K. a. R. Cox, "Colorado State University: Buffalo Grass Lawns," 26 March 2013. [Online]. Available: http://www.ext.colostate.edu/pubs/garden/07224.html. [Accessed 17 November 2013].

[25] R. L. Duble, "Aggie Horticulture: Water Management on Turfgrasses," Texas A&M Agrilife Extension, [Online]. Available: http://aggie-horticulture.tamu.edu/archives/parsons/turf/publications/water.html. [Accessed 17 November 2013].

[26] N. W. Service, "Climate Prediction Center: Regional Climate Maps USA," 4 November 2004. [Online]. Available: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/us_12-month_precip.shtml. [Accessed 17 November 2013].

[27] A. Rodriguez, "Does cutting the grass promote growth?," SF Gate, [Online]. Available: http://homeguides.sfgate.com/cutting-grass-promote-growth-70036.html.

[28] B. Beckstrom, K. D. Cutler, K. Fisher, P. Giroux, J. Glattstein, M. MacCaskey, B. Marken, C. Nardozzi, S. Roth, M. Tatroe, L. Walheim and A. Whitman, "Mowing your lawn the right way," For Dummies, [Online]. Available: http://www.dummies.com/how-to/content/mowing-your-lawn-the-right-way.html.

[29] M. F. Quigley, "The American lawn: An unrequited love," 2000. [Online]. Available: http://ohioline.osu.edu/sc177/sc177_14.html.

[30] "Lawn and garden (small gasoline)," United States Environmetnal Protection Agency, [Online]. Available: http://www.epa.gov/otaq/smallsi.htm.

[31] M. Brian, "How Gasoline Works," How Stuff Works, [Online]. Available: http://science.howstuffworks.com/gasoline.htm. [Accessed 10 November 2013].

[32] "State & Country QuickFacts," United States Census Bureau, 2013. [Online]. Available: http://quickfacts.census.gov/qfd/states/00000.html.

[33] U. S. C. Bureau, "Income, Expenditures, Poverty, and Wealth," in *U.S. Census Bureau, Statistical Abstract of the United States: 2012*, 2012, p. 454.

[34] B. Butterfield, "Homeowners Spend a Record $45 Billion on Lawn and Landscape Services," The National Gardening Association, [Online]. Available: http://assoc.garden.org/press/press.php?q=show&id=2880&pr=pr_research.

[35] "Introducing the Toro XTRA SMART Precision Soil Moisture Sensor," Toro, 2013. [Online]. Available: http://www.toro.com/xtrasmart/?WT.ac=XtraSmart%20Internal%20Banner.

[36] D. Taylor, "Greenbox irrigation system waters your plants with help from your phone," Gizmag, 2013. [Online]. Available: http://www.gizmag.com/greenbox-ios-controlled-irrigation-system/26486/.

[37] "Lono Sprinkler Controller," Kickstarter, 2013. [Online]. Available: http://www.kickstarter.com/projects/173231925/lono-sprinkler-controller.

[38] "Smart lawn sprinklers cut down on water waste," GIGAOM, 2013. [Online]. Available: http://gigaom.com/2013/10/10/smart-lawn-sprinklers-cut-down-on-water-waste/.

[39] G. Quinn, "The Cost of Obtaining a Patent in the US," IPWatchdog, 2013 April 30. [Online]. Available: http://www.ipwatchdog.com/2011/01/28/the-cost-of-obtaining-patent/. [Accessed 15 December 2013].

[40] "Design Engineer Salary," indeed, [Online]. Available: http://www.indeed.com/salary/Design-Engineer.html. [Accessed 15 December 2013].

[41] "Kickstarter.com Traffic and Demographic Statistics by Quantcast," Quantcast, 14 December 2013. [Online]. Available: https://www.quantcast.com/kickstarter.com/demographics. [Accessed 15 December 2013].

[42] "Love Your Landscape," [Online]. Available: http://www.loveyourlandscape.com/images/WhyHireProHelp_lg.jpg.

[43] T. McAloone and N. Bey, "Environmental improvement through product development - guide," Technical University of Denmark, 2009.

[44] "Soil Nitrogen," [Online]. Available: http://www.ksre.ksu.edu/kswater/images/nitrogen.htm.

List of Appendices

Appendix A: Outline for Design Ethnography Guiding Questions

Appendix B: Link to Interview Summaries and Question/Answer Comparison Spreadsheet and Concept Generation Scoring Spreadsheet

Appendix C: Pictures of Concept Generation Chalkboard Sessions

Appendix D: Concept Generation List and Evaluation for Alpha Design

Appendix E: Table Showing Why People Higher Professional Help for their Lawn and Landscape

Appendix A: Outline for Design Ethnography Guiding Questions

Frame the guiding question
For our project, we went through many discussions and revisions to fully understand what the guiding questions were for our product. We first started out with very broad questions - how does lawn care work and what is the biggest annoyance? What parts of lawn care are harmful to the environment? Our initial idea was to find the intersection of lawn care annoyance and environmental impact, and innovate within that space. As we have moved through the first round of interviews, we have started to narrow the scope of our project focus on lawn care for homeowners.

Define the "who"
In brainstorming for this question, we found overlaps between different sections of the "who". Users include homeowners with lawns, lawn care companies, and large-scale lawn owners that own spaces such as golf courses, parks and sports fields. We also felt that these additional categories of people could also fall into the stakeholders: lawn users, homeowner associations, lawn care product suppliers (including fertilizer, water management, and mowers), and environmental quality regulators through the local government would fall into this category. Experts include representatives at the lawn care companies/suppliers and researchers in lawn soil, fertilizers/pesticides, water and mowing technology. Clients would include investors in our product.

Synthesize existing knowledge
In order to fully understand the area we intend to innovate in, it is important to be familiar with the current technology and research that already exists within lawn care. This includes an overview of lawns and lawn care, the environmental impacts of lawns, and current technology relating to controller systems. A full summary of our literature review can be found in section two, Product Functional Status.

Determine data collection methods
We plan to gather most of our ethnographic data from interviews with the people described above. Additionally, we plan to design a new set of questions for lawn care companies and large lawn-owners that are more pertinent to their fields. To complement the interviews, we would like to find situations where we can make observations; hopefully, this may include observing lawn care companies and homeowners going through their lawn care routine (possibly watching our parents). Finally, we plan to design a survey when we are farther along in the design process to gain a perspective on our product and receive feedback on the features and feasibility.

Develop the data collection structures
To design the questions for each interview, we plan to use the framework from the Stanford Design School, presented by Professor Skerlos and Professor Daly. This ensures that we will be taking the interviewee through a journey that builds trust and provides a chance to do a "deep dive" into the root of the issues; we want to work to avoid just skimming the surface. We also plan to design different questions for different people; homeowner questions will not be the same as those for lawn care companies or large lawn-owners. Most of the interviews will be conducted in beginning of our design process, but will continue throughout the semester. Simultaneously, we plan to reach out to the lawn care companies we talk with and try to set up opportunities to conduct observation. There is a possibility of making a Groom Pro – a device where the stakeholders are lawn care companies instead of the homeowners. This product would help streamline the business and provide immediate feedback for the lawn care conditions. We look to explore this throughout the report. The AEIOU approach will be useful with slight modifications for the specific situations.

We have begun the interview process in order to start gathering data from the first set of users and stakeholders, the homeowners. Currently, the interviews we have conducted are with the family members or close family friends of each team member. Using the framework described by Dr. Daly,

we designed a set of questions to explore the current practices and annoyances of lawn care while leaving room for the interview to focus on different aspects that the interviewee brings up. The questions are provided in the figure below:

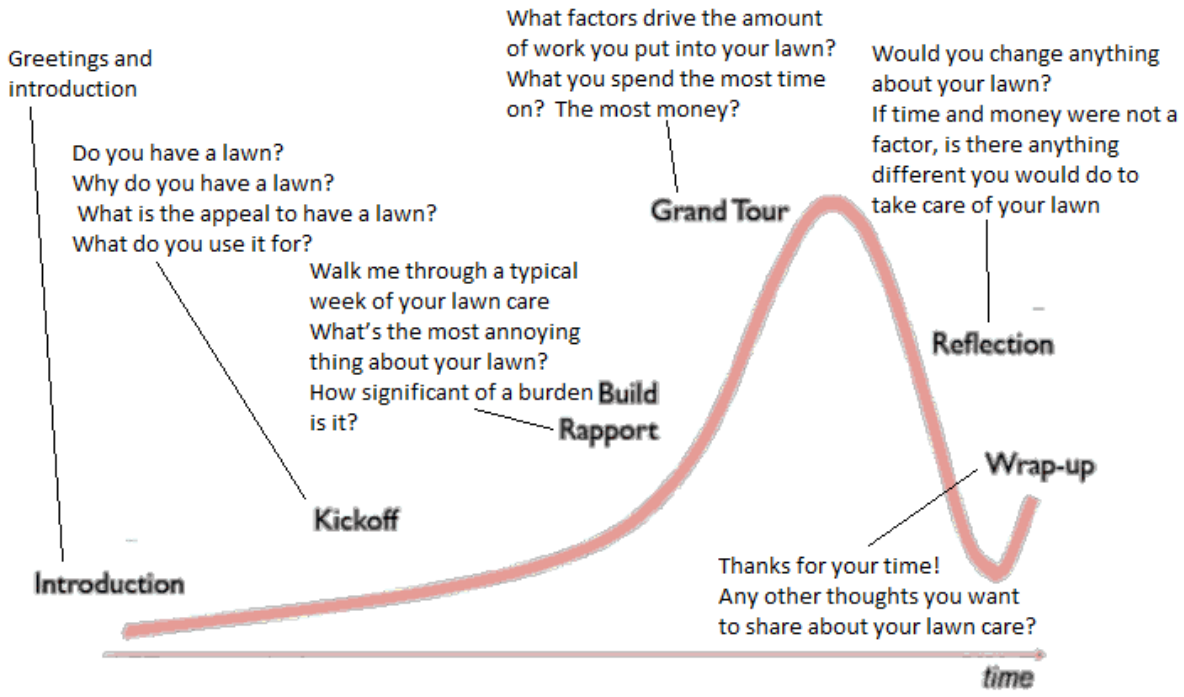


Figure A-1: Interview Framework and Questions

Appendix B: Link to Interview Summaries and Question/Answer Comparison Spreadsheet and Concept Generation Scoring Spreadsheet

1. https://docs.google.com/spreadsheet/ccc?key=0AklhP_M8RlnxdDBRNGl3VHJLVGVKaXlqV2VJUFRGM3c&usp=sharing
2. https://docs.google.com/spreadsheet/ccc?key=0AqivxF5SDEkOdGV2anFuaFJROHFmaVEzQ1E1cTZFZ3c&usp=sharing

Appendix C: Pictures of Concept Generation Chalkboard Sessions

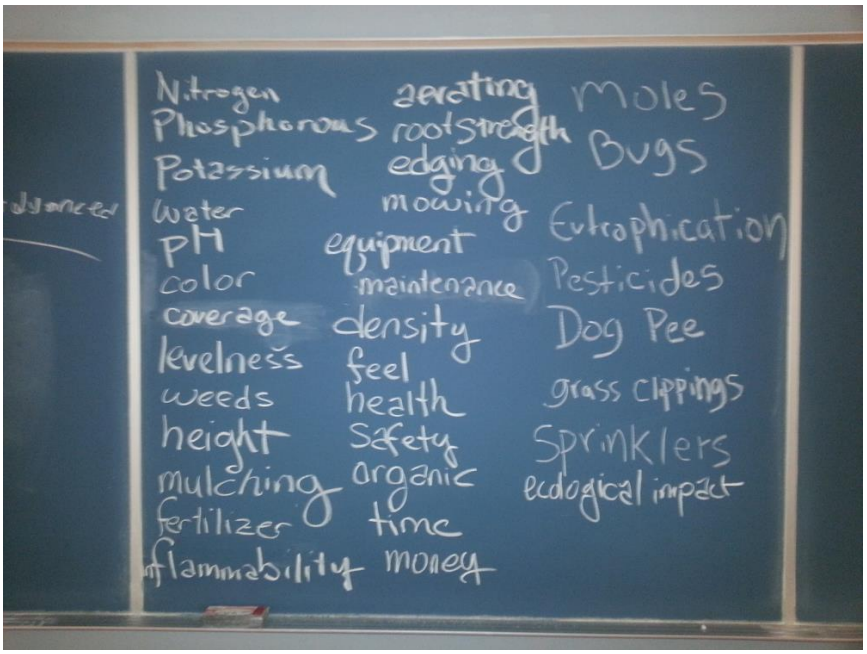


Figure C-1: Lawn care topics and problems

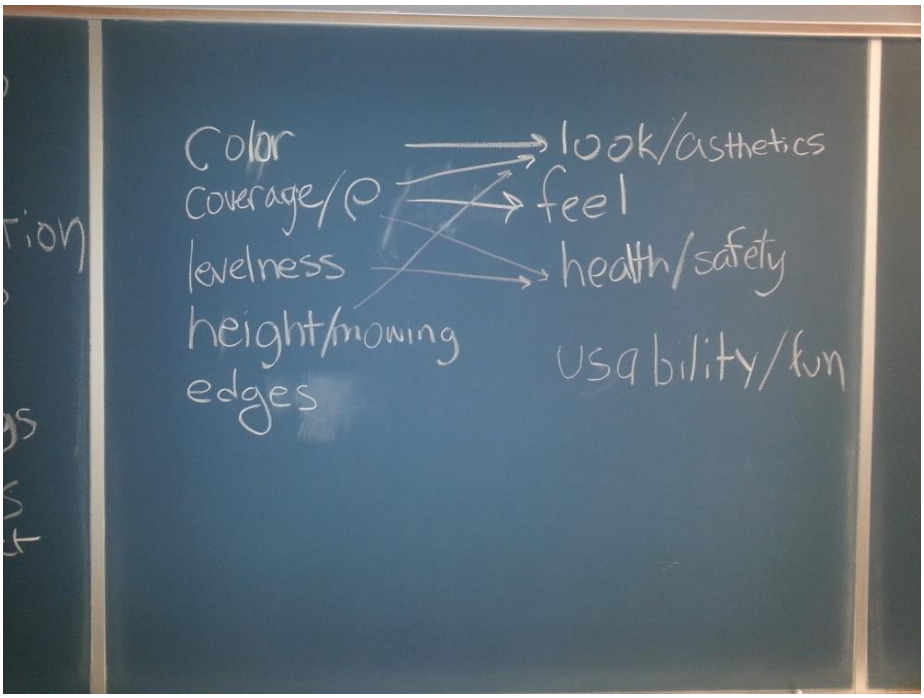


Figure C-2: Early classification of topics and problems

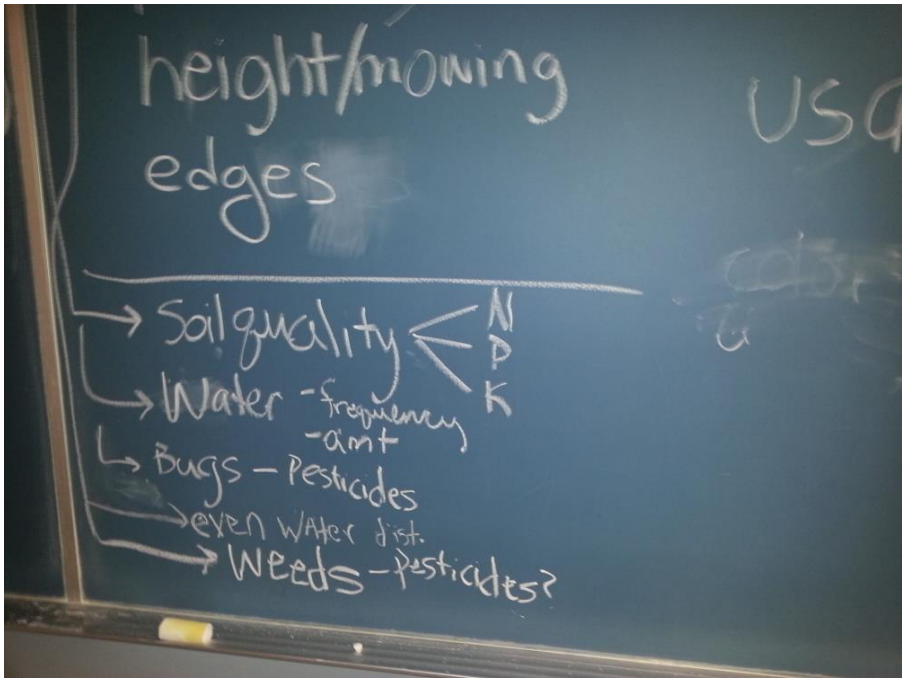


Figure C-3: Initial definition of measurable quantities

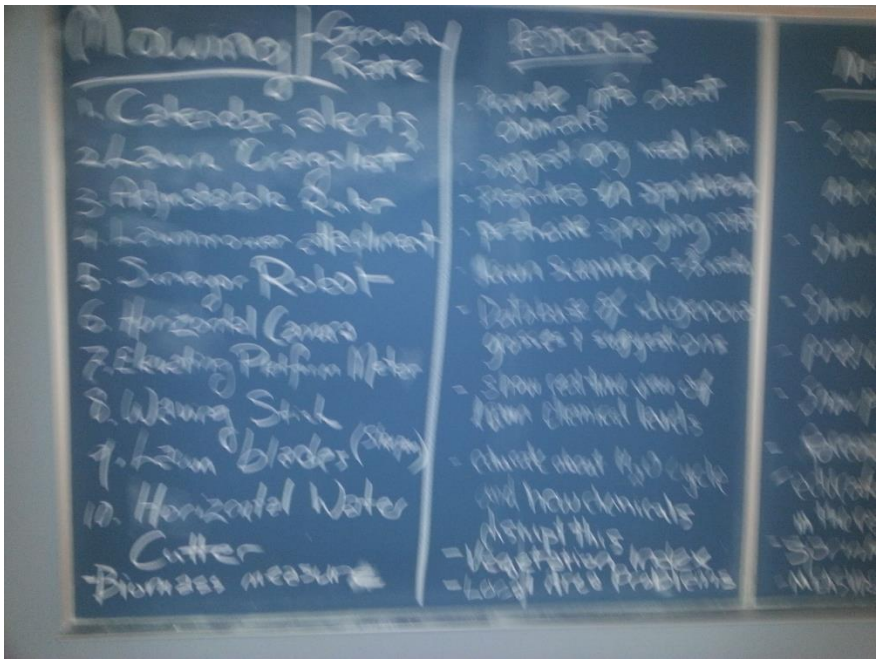


Figure C-4: Concept generation list part 1 (This photo is unfortunately blurry)

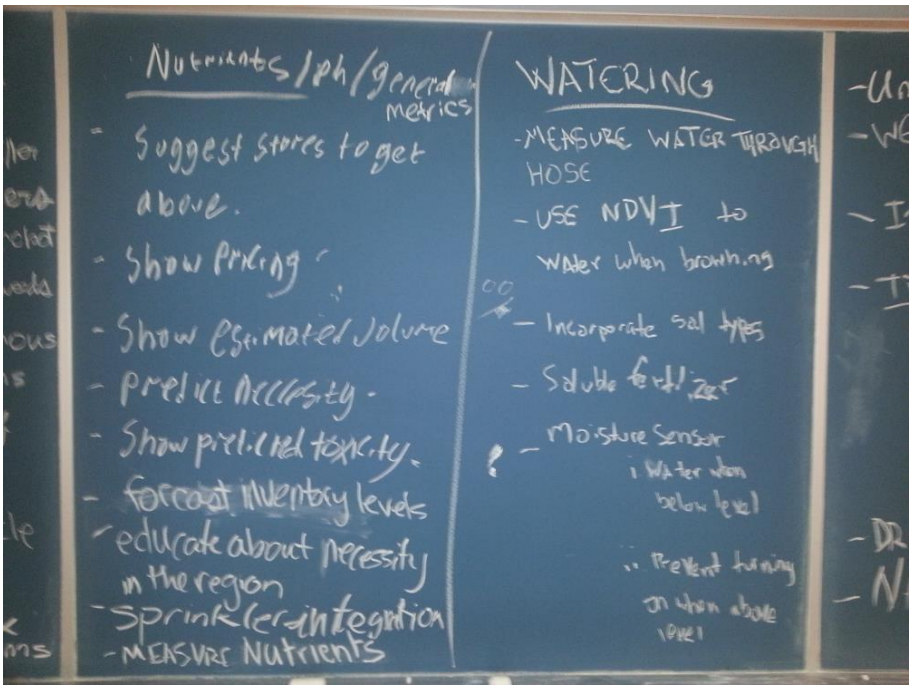


Figure C-5: Concept generation list part 2

Appendix D: Concept Generation List and Evaluation for Alpha Design

Guideline for the "Use?" column:

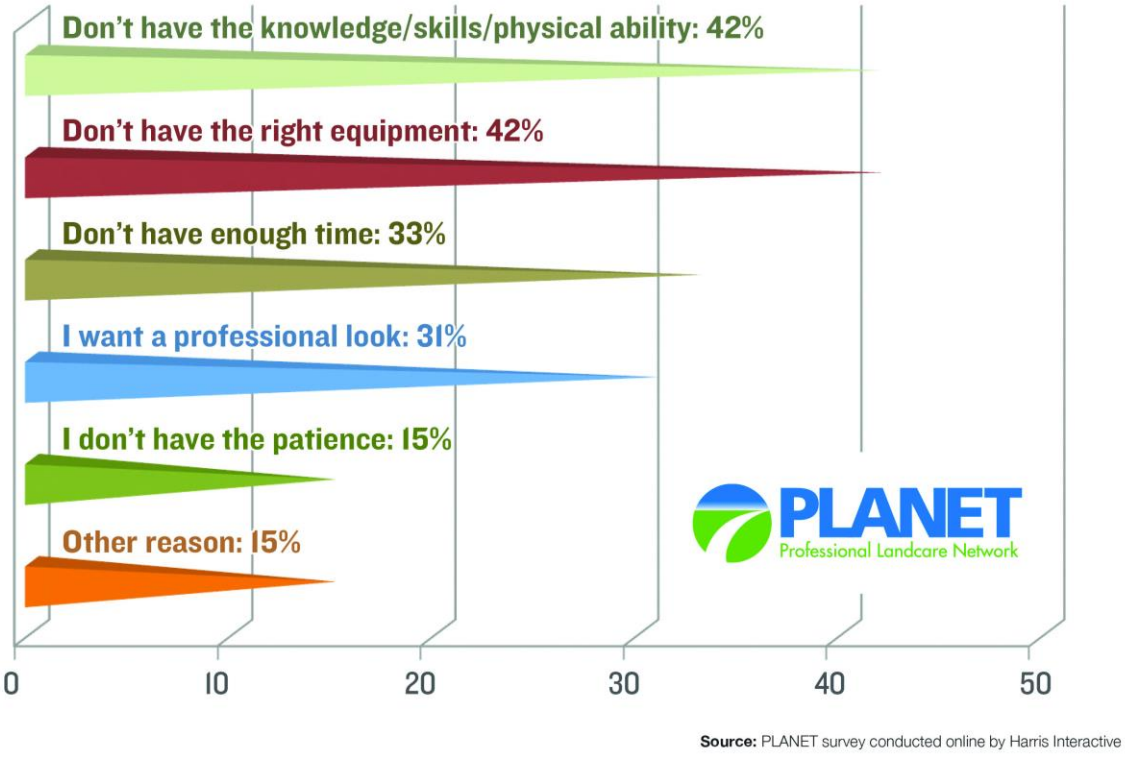
Yes – we will include this in the alpha design
Yes – we will include this in the alpha design in the database component*
No – we will discard this concept
Maybe – we are undecided about this concept
Pro – we will likely include this in the "Pro" iteration of the design

MOWING		Use?
Calendar, alerts	System to go on your phone. Uses predictive models to help scheduling tasks such as mowing. Sends alerts to email and other media if allowed to.	Yes
Lawn "craigslist"	Owners can advertise that their lawn needs to be mowed. People can then bid or accept the commission offer.	Pro
Adjustable Ruler	A stationary physical device place in the lawn that marks off the height which to mow the grass, depending on the type of grass.	No
Lawnmower attachment	Sensors on the lawn mower that measure grass height. Can also work in soil sampling unit.	No
Surveyor Robot	Same as above except separate, automated robot.	No
Horizontal Camera	Stationary physical device that looks at the grass or a light source at a distance. Measures height of grass.	No
Elevating Platform meter	Platform that lies on top of grass. Measures height of grass by how high it is elevated.	No
Waving Stick	Actuating device that measures if any grass is in the way of its swing. Measures if the grass is at its set height.	No
Lawn blades (sharpen!)	Remind users to sharpen their lawn blades.	Yes*
Horizontal Water Cutter	Uses lower-powered water cutting technology to cut grass automatically. Can also be sufficient for watering the grass.	No
PESTICIDES		**Use?**
Provide info about chemicals	List contents of pesticides and show their effects and side effects.	Yes*
Suggest organic weed killer	When the user is looking for pesticides, push organic ones.	Yes*

Pesticides/sprinkler integration	If needed, the water system can integrate pesticides into the watering system.	No
Pesticide spraying robot	Robot that automatically sprays pesticides on weeds.	No
Lawn scanner (%weeds)	Scans the lawn for the number of weeds.	No
Database of indigenous grasses and suggestions	When user is looking for grasses, push indigenous grasses.	Yes*
Show real time view of lawn chemical levels	Show the measure levels of pesticides in the soil.	No
Educate about water cycle and how chemicals disrupt this	Information for the database	No
Vegatation Index	Implement vegetation index	No
Local area problems	Show local area problems and pest to hopefully allow better treatment of these pests.	Yes*
NUTRENTS/pH/GENERAL METRICS		**Use?**
Suggest stores to obtain materials	List stores that have the materials required.	Yes*
Show pricing	List pricing of materials required.	Yes*
Show estimated volume is needed	Estimates how much materials are needed to be added.	Yes
Predict necessity	Estimates how necessary the materials to be added are.	Yes
Show predicted toxicity	Estimates the environmental impact of the materials added.	Yes
Forcast inventory levels	Estimates the supply of materials currently in the household	No
Educate about necessity of chemicals in the region	Provide information about how necessary certain nutrients are in the region to prevent overabundance of the nutrient	Yes*
Sprinkler integration	Put fertilizer nutrients in the sprinkler system when needed.	Pro
Measure nutrients	Measure nutrient levels in the soil with a sensor	Yes
WATER		**Use?**
Measure water through hose	Measures volumetric flow rate to estimate total water used to water the yard.	Pro
Use NDVI to water when browning	NDVI is a camera device that sees certain wavelengths	No

	of light. Would trigger if a set amount of yellow/brown is detected in the color of the lawn	
Incorporate soil types	Adjusts ideal levels based on the soil type inputted.	Yes
Soluble fertilizer	Water soluble fertilizer to allow for easier application and absorption.	Pro
Moisture sensor - water below level	Moisture sensor that triggers watering when water level is below healthy levels	Yes
Moisture sensor - prevent turning on when above leve	Moisture sensor that triggers watering when water level is above necessary levels.	Yes
Weather API	Estimates water needed based on weather.	Yes
Incorporate type of grass	Adjust ideal levels based on the grass type inputted.	Yes
iPhone App - turn water on, off; water usage	Allows for controlling the water sprinklers through the iPhone	Yes
Drip water system	Drips water onto the grass to lower evaporation rate.	Pro
Native system	Recommend grass that is native to reduce the water requirements of the grass.	No

Appendix E: Table Showing Why People Higher Professional Help for their Lawn and Landscape



Source: Planet Professional Landcare Network [42]