Gamified App to Increase the Quantity and Quality of Household Recycling

Grant Proposal

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Executive Summary

Despite recycling being one of the simplest and most impactful ways for citizens to protect the environment, less than 1/3 of American households recycle. This lack of involvement leads to valuable resources being landfilled and harmful greenhouse gasses being produced. This project aims to increase the quality and quantity of recycling produced on a household level by increasing individuals' motivation to practice positive recycling habits. In addition to a general increase in the consistency of one's recycling, the specific habits targeted in this study are cleaning and sorting recyclables. Increasing these habits will be accomplished using a novel gamified app. The app will be developed using the Flutter framework. The final product of this project will be a recycling app that has several gamified components which will be based on the results of a survey on gamification preferences and previous research. The app will be considered a success if it meets two conditions. Firstly, users must produce more, higher quality recycling while using the app than when not using it. Secondly, users must report increased motivation and a more positive recycling experience. If the app is successful, individuals will send a higher quantity of quality recyclables to material recovery facilities. As a result, more resources will be recycled which promotes a circular economy.

This project is being conducted by Lindsey Paradise, a junior at the Mass Academy of Math and Science. This project was inspired by the Green Knights, an environmentalist group.

Keywords: household recycling, gamification, motivation, app development

Gamified App to Increase the Quantity and Quality of Household Recycling

The need for improved recycling habits across the globe is emphasized in the United Nation's 12th sustainable development goal (Helmefalk & Rosenlund, 2020). In 2018, the US alone produced over 292 million tons of municipal solid waste (MSW) (United States Environmental Protection Agency, 2022). However, only 69 million tons of waste were recycled in the US that year (United States Environmental Protection Agency, 2022). While 25 million tons were composted and 35 million were combusted with energy recovery, 50% of the waste produced by the nation, some 146 million tons, were still landfilled (United States Environmental Protection Agency, 2022). Figure 1 shows how the United States' waste management has trended over the past 58 year. Looking at this figure, it is evident that there is significant potential to improve our recycling habits. As climate change has progressed, in part due to the increasing waste production, recycling has been recognized as a tool worth investing in since it supports a circular economy (Nixon & Saphores, 2009; United States Environmental Protection Agency, 2019) and has been shown to lower greenhouse gas emissions (Klaiman et al., 2017). Recycling is the tool that the world needs to limit, and eventually eliminate, MSW.

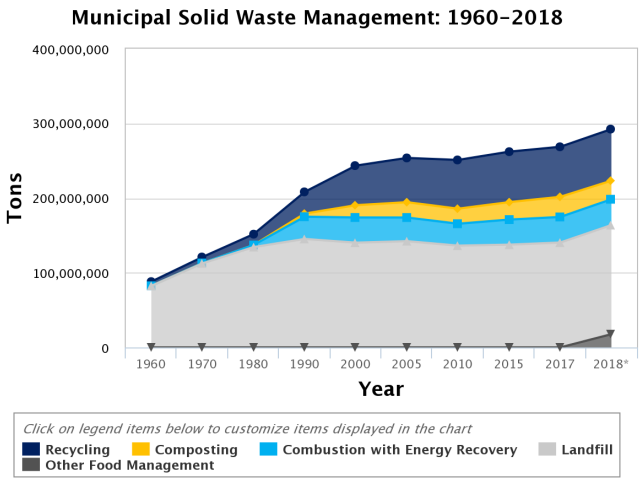

Figure 1: Graph depicting municipal solid waste production and management strategies in the US in the years 1960-2018. Although other management styles exist, landfilling remains the most prominent method. Reprinted from the United States Environmental Protection Agency, 2023, https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials.

Household Recycling

Positive recycling habits on a household level are crucial to the success of a waste management system. On the simplest level, these habits include actively participating, and effectively cleaning and sorting the recyclables. However, in the United States, only 32% of households recycle (United States Census Bureau, 2021), which is significantly less than the recycling rates in other countries (Klaiman et al., 2017). Previous studies have concluded that those with lower income and less education were less likely to recycle (Klaiman et al., 2017), although other studies have produced opposite results (Nixon & Saphores, 2009).

Household recycling habits are crucial to the recycling process, because if households produce better quality recycling, then material recovery facilities (MRFs) can be more efficient and process more recyclables. A 2022 study by Dr. Carlos Correa and colleagues found that only 50% of the recyclables collected by Sao Paulo's waste collection system were processed by the MRFs (Correa et al., 2022). Additionally, because the quality of recyclables was low, meaning that the products were missorted and/or contaminated, over 35% of the recycling batch was rejected even though only 7.4% of the batch was rejectable material (Correa et al., 2022). Thus, improving household recycling habits, by increasing citizen participation and the quality of the recyclables produced, is greatly needed.

Barriers to Effective Household Recycling

Currently, there are many barriers which dissuade households from recycling. In a 2009 study, Nixon and Saphores determined that space, time, and safety were the population's main obstacles to recycling. Additional barriers include not knowing the consequences of poor sorting on the recovery process (Helmefalk & Rosenlund, 2020) and not knowing the significance of one's actions on the environment (Klaiman et al., 2017). Lastly, needing to hand clean recyclables before sorting them is seen as a major barrier to effective recycling since it necessitates time and effort (Klaiman et al., 2017). If these barriers cannot be overcome, then a household will either choose not to recycle or will produce low quality recycling.

This project aims to address the barriers of cleaning recyclables, lacking knowledge of significance, and sorting properly. These barriers were chosen, because if they are relieved, the user will be able to produce high quality recycling, even if another barrier causes them to do so at a lower volume.

Existing Solutions

There are many existing solutions to encourage citizen recycling. On the App Store, there are many apps such as SortIt, by Victor Salamanca, and Catch the Trash, by John Palevich, that teach users to recycle through a sorting game. Although these apps teach users how to sort effectively, they do not encourage any real-world recycling habits. Similarly, apps such as Recycle Coach by Municipal Media help users to determine if a product is recyclable and where they can recycle it. These apps act as educational resources but rely on users being self-motivated to use them.

Apps like ZeLoop, by ZeloopTech, and the smart bin system created by Briones and collogues in their 2018 study have successfully increased citizen recycling participation by offering a monetary reward for reaching defined goals (Briones et al., 2018). However, both systems require users to use specific collection bins. There is currently no solution that motivates and supports users in actively and accurately recycling within their own homes.

Gamification

Gamification is the process of implementing a motivational affordance that triggers a psychological outcome that further produces a behavioral outcome (Figure 2). This process has been shown to successfully intrinsically motivate users in many studies (Hamari et al., 2014). Gamification takes game mechanics such as competition, collaboration, points, badges, and leaderboards, and applies them to nongame contexts. This intrinsic motivation makes users want to complete tasks that were once viewed as unfavorable. Often, gamification is successfully used in

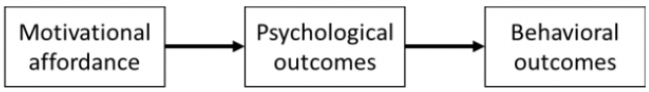

Figure 2: Flow chart depicting the defining effects of gamification. Reprinted from "Does gamification work? -- A literature review of empirical studies on gamification" by Hamari, Koivisto, and Sarsa, 2014*, 47th Hawaii International Conference on System Sciences, p. 3025–3034.*

education and work settings (Hamari et al., 2014).

Gamification in Recycling

Overcoming one's barriers to recycling necessitates intrinsic motivation, and gamification is a tool that is recognized for its ability to intrinsically motivate its users (Helmefalk & Rosenlund, 2020). When gamification is applied to recycling it can help the users overcome their own barriers to recycling and to produce a higher quality and quantity of recyclables.

In their 2020 study, Helmefalk and Rosenlund conducted a series of focus groups which discussed the features they would like to see in a gamified recycling app. The participants highlighted that a digital solution was preferred to a material one and that while the recycling process should feel like a game, it should not literally be turned into a game or interfere with the physical recycling process (Helmefalk & Rosenlund, 2020). The focus groups also stated that they would like to have a solution that gives them immediate feedback and praise for their positive environmental actions (Helmefalk & Rosenlund, 2020). Users would also like to receive frequent reminders to recycle and be able to compete against other neighborhoods and zip codes to see who could produce the most recyclables (Helmefalk & Rosenlund, 2020). Leaderboards, badges/awards, and social interactions were also suggested. Monetary motivators have also been shown to be effective in increasing both user participation and mass of recyclables (Briones et al., 2018). Lastly, a gamified recycling solution should be adaptable to diverse home recycling processes (Helmefalk & Rosenlund, 2020).

Impact and Success

If the proposed app increases the quality and quantity of the recyclables of the households that use it, it will be deemed successful. As previously stated, this increase in recycling will work to decrease the amount of greenhouse gas emissions (Klaiman et al., 2017). The improved quality of the recyclables will also improve the efficiency of MRFs (Correa et al., 2022). Additionally, if recyclables are removed from compost and landfill streams, the compost and ash produced after processing will be of higher quality since they do not include plastics (Nixon & Saphores, 2009). Combined, these attributes work to support the United Nation's 12th sustainable development goal, and combat climate change.

Section II: Specific Aims

Presently, several barriers prevent American households from participating in recycling programs and recycling properly (Klaiman et al., 2017; Nixon & Saphores, 2009). This lack of proper recycling negatively impacts both the environment, through an increase in greenhouse gas emissions and increased use of natural resources, and the economy, because resources must be sourced internationally instead of domestically (United States Environmental Protection Agency, 2019). Thus, a product that encourages households to participate in recycling programs correctly and actively is greatly needed.

The long-term goal of this project is to develop an app for Apple and Android devices that will use gamification strategies to motivate users to overcome the three most crucial barriers to proper recycling. These barriers are cleaning recyclables, lacking knowledge of significance, and sorting properly. The rationale is that if these barriers to recycling are alleviated, then households will produce high quality recyclables. Although other barriers may affect the quantity

of recyclables produced, it is more important to encourage high quality recyclables so that material recovery facilities can efficiently recover recyclables (Correa et al., 2022). The testing will gauge the ability of specific gamification strategies, as determined by the gamification survey, to increase the quantity and quality of household's recycling. It is hypothesized that the selected strategies (monetary incentive, carbon counter, and analytics) will positively impact the households' recycling output as these strategies were supported by 81%, 77%, and 73% of survey respondents respectively. To support a strategy, a participant must have selected "agreed" or "strongly agreed" when asked if the strategy would positively impact their recycling behaviors. See Appendix 3 for a description of each of these strategies.

Specific Aim 1: Determine which gamification strategies users believe will most impact their motivation to improve their recycling habits.

Specific Aim 2: Determine whether a monetary incentive, carbon counter, and analytics affect the quality and quantity of recyclables produced by an American hold. It is hypothesized that these gamification strategies will increase the quality and quantity of recyclables produced by an American household.

Accomplishing the first specific aim will enable the determination of which gamification strategies are most likely to motivate users to participate is positive recycling habits. From there, I will be able to determine how the selected strategies impact the quality and quantity of recycling produced.

Section III: Project Goals and Methodology

Significance

This engineering project is significant because it will provide and test a novel approach to increasing recycling habits in a demographic that has been understudied in previous research.

Additionally, the study will increase understanding of how gamification strategies can be used to motivate users to complete undesirable tasks, which can be extrapolated to other fields.

Innovation

The product of this project will be a novel app that motivates households to practice positive recycling habits without altering their manner of recycling (curbside, drop-off, etc.). Although there are apps which use gamification strategies to actively motivate households to practice positive recycling habits (Briones et al., 2018), none do so without altering users' current recycling system. Since the app adapts to users' unique recycling routines rather than requiring the user to conform to the system's requirements, the proposed solution can be more easily integrated into diverse households and serve a broader target audience (Helmefalk & Rosenlund, 2020).

Methodology

Specific Aim #1: Determine which gamification strategies users believe will most impact their motivation to improve their recycling habits.

To fulfill Specific Aim #1, teenagers and adults with connections to the Massachusetts Academy of Math and Science or Marianapolis Preparatory School were anonymously surveyed on their recycling habits and gamification preferences. The survey was constructed using Google Forms and was emailed to potential participants. See Appendix 2 for a list of survey questions. The participants were given at least 1 week to complete the survey. Over 500 individuals were contacted and asked to share the survey with additional friends and family members. When the survey closed on 11/27/23 there were 98 responses. This Specific Aim will be complete when the

survey has closed, and the data is analyzed to determine which gamification strategies to implement.

Justification and Feasibility. A survey was an appropriate method to address Specific Aim #1 because it allowed the researcher to observe the recycling habits and gamification preferences of a diverse group of people in a short period of time. This strategy is similar to the series of focus groups Helmefalk and Rosenlund conducted in 2020 to propose a gamified solution to recycling. Additionally, participants were able to complete the survey at a time and place that was convenient for them. This flexibility likely increased the number of responses.

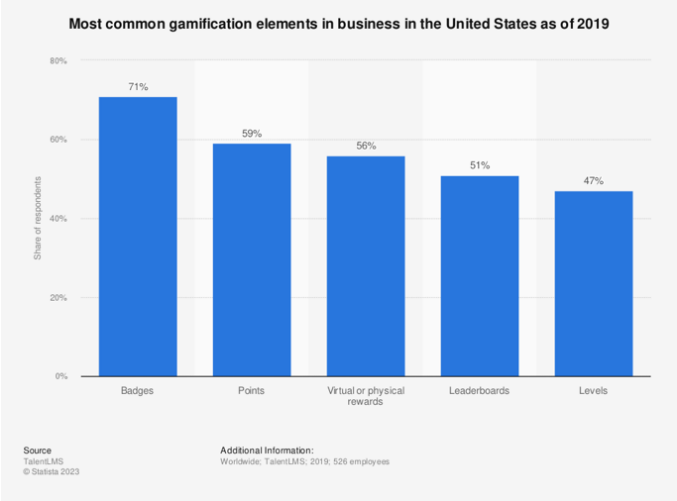

Figure 3: Bar graph depicting the most common gamification elements in business in the United States as of 2019. TalentLMS. (August 19, 2019). Most common gamification elements in business in the United States as of 2019 [Graph]. In *Statista*. Retrieved November 30, 2023, from https://www.statista.com/statistics/1100506/gamification-elements-business/

The last question of the survey, see Appendix 2, asked users to rank how strongly they agreed that each of the listed gamification strategies would increase their motivation to recycle and improve their recycling habits. Successful studies from Briones (2018) and Helmefalk (2020) involving gamified recycling and the statistics outlined in Figure 3 were used to formulate the proposed gamification strategies. Figure 3, which depicts the most common gamification elements in business in the United States as of 2019, supported this Specific Aim as it helped to justify the inclusion of strategies such as badges, eco points, monetary reward, and leaderboards.

Summary of Preliminary Data. The preliminary data from the recycling and gamification survey shows that participants viewed monetary rewards, carbon counters, and

analytics as the most impactful gamification strategies in a recycling context. Figure 4 shows that these three were the most desired, while teams and personal goal setting were the least popular. It was surprising to see neither points, badges, nor leaderboards were among the top 3 strategies since these are often regarded as the most popular gamification strategies (Figure 3). The top 3 gamification strategies determined in Figure 4 will be used to execute Specific Aim #2.

Figure 4: Scores of Proposed Gamification Strategies

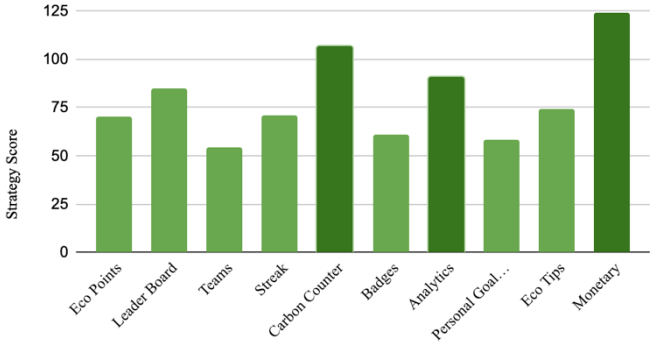

Figure 4: Bar graph depicting the strategy score for each gamification strategy included in the survey. Scores were calculated by assigning a value to each of the survey response options. The response options and their corresponding values are as follows: Strongly Disagree (-2), Disagree (-1), No Impact (0), Agree (1), Agree Strongly (2). Scores were summed for all respondents. The 3 highest scoring strategies are marked in dark green.

Expected Outcomes. The outcome of Specific Aim #1 is data regarding the recycling habits and gamification preferences of a diverse population. The knowledge gleaned from this survey will be used for selecting which gamification strategies to implement in the gamified recycling app. Since respondents found teams and personal goal setting to be the least motivating strategies, they would not be the most impactful to include in the app. Similarly, because monetary incentive, carbon counter, and analytics were viewed as the most impactful, these will be the first strategies to be implemented. It is worth noting that the monetary incentive strategy was considered the most motivating solution (Figure 4). Thus, it is important for the team to secure funding for the project so a monetary incentive can be provided to users to encourage positive recycling habits.

Potential Pitfalls and Alternative Strategies. One major pitfall of the methods outlined above is that the survey was optional for participants, which means that the data collected represents only those who were willing to participate in the survey. If those who struggle the

most to practice positive recycling habits were disinclined to complete the survey, the data cannot be used to decide which gamification strategies will encourage them the most to recycle. Instead, the data may represent the gamification preferences of who already care about the protection of the environment. If that is the case, the target audience of the app may need to be adjusted to focus on those who are already partially environmentally conscious rather than those who are starting on a blank slate.

Another pitfall of this survey is that the majority of potential participants contacted, and respondents, were high school students in the 13-19 age range. In fact, when the survey closed, 65.3% of participants were teenagers. This large demographic of youth means that the older populations were underrepresented in the data. If significant conclusions can only be made regarding the gamification preferences of teenagers, then the target audience of the app must be altered to only include teenagers.

Specific Aim #2: Determine whether a monetary incentive, carbon counter, and analytics affect the quality and quantity of recyclables produced by an American household.

To fulfill Specific Aim #2, an app for Apple and Android products will be coded in Dart using the Flutter framework. The app will allow users to make an account and store data regarding their recycling habits. Additionally, the top three gamification strategies as determined in the survey will be implemented. After the app is developed, testing will begin in several households across Massachusetts. For 1 week, each household will recycle as normal. After the week has passed, participants will be given a questionnaire to evaluate their knowledge of recycling and motivation to recycle. Their recycling will be collected and given a score based on its quality and quantity. Then, the members of the household will download the gamified recycling app to their devices. The participants will be instructed to allow the app to aid in their

recycling throughout the week. At the end of the week, participant's recycling will be collected and scored on the same scale and participants will fill out the same questionnaire. This Specific Aim will be complete when the in-house testing is completed, and the data is analyzed to determine how the gamified app impacted participants' recycling habits.

Justification and Feasibility. The methods stated above directly work to fulfill Specific Aim #2. Flutter is the most appropriate tool to use for this project, because when using its framework, an app can easily be programed to work on both iOS and Android products (Payne, 2019). It is important that the app works on both iOS and Android products, since each has continuously held roughly half of the market (Figure 5). The testing will produce data that quantitatively and qualitatively describes participants' recycling habits before and after the use of the app. These can be compared to draw conclusions about the effect of the selected gamification strategies on household recycling.

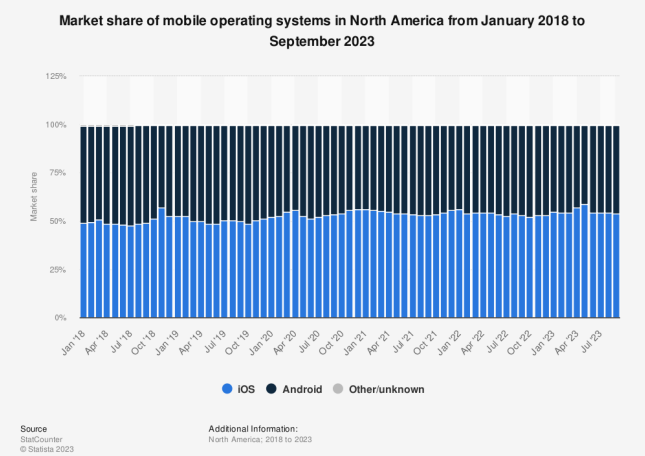

Figure 5: Graph comparing the market share of iOS and Android mobile operating systems in North America from January 2018 to September 2023. *StatCounter. (October 20, 2023). Market share of mobile operating systems in North America from January 2018 to September 2023 [Graph]. In* Statista*. Retrieved December 01, 2023, from https://www-statista-com.ezpv7-web-p-u01.wpi.edu/statistics/1045192/share-of-mobile-operating-systems-in-north-america-by-month/*

The proposed testing strategy is similar to that used by Briones in his 2018 publication: *Use of Gamification Techniques to Encourage Garbage Recycling, A Smart City Approach*.

Summary of Preliminary Data. The app is not yet developed. There is not presently any preliminary data.

Expected Outcomes. The outcome of Specific Aim #2 will be a collection of data quantitatively and qualitatively describing participants' recycling habits before and after the use

of the app. This knowledge will be used to determine if the gamification strategies implemented in the app successfully motivated users to overcome common barriers to recycling. If the users report increased motivation in the post testing survey and their recycling scores increase, then the app will be a success. If the opposite is true, then different strategies may need to be used to encourage households to participate in proper recycling habits.

Potential Pitfalls and Alternative Strategies. The short testing window for this phase of the project poses a potential pitfall for Specific Aim #2. Originally, testing was scheduled to take place over the course of 4 weeks, where 2 weeks would be allocated for the recording or normal recycling behavior and the other 2 weeks for measuring the changed behavior while using the gamified recycling app. However, because there were delays in the development of the app, this timeframe no longer seems feasible. The decreased timeframe may weaken the data, since recycling amounts can naturally fluctuate week to week.

Another pitfall for Specific Aim #2 is that the demographic of people who agree to test the app may be those who already practice positive recycling habits and have little room for improvement. If so, the effect of the gamification strategies may be less obvious than with those with more room for improvement.

Section III: Resources/Equipment

The 2 resources which are necessary for the success of this project are:

1. Human Participants: In order to gather data to support the effect of the selected gamification strategies on recycling output, there must be households which agree to participate in the 2-week test. At least one member of each participating household must

have a smartphone or tablet on which to use the app. Ideally, the app will be tested in at least 10 households with participants of varying ages.

2. Monetary Incentive: Survey participants determined that a monetary incentive would motivate them to practice positive recycling habits more than any other strategy. Thus, a monetary incentive will be incorporated into the app. It is proposed that this incentive will take the form of a voucher or gift card to a "green" company or service.

Section V: Ethical Considerations

1. **Danger in evaluating recycling:** When evaluating the participants' recycling before and after the use the app, it will be necessary to examine their waste by hand. This process is potentially dangerous because waste may contain products with sharp edges. To alleviate this danger, gloves will be worn while handling the participants' recycling.
2. **Potential to decrease recycling:** Although the gamified recycling app is intended to positively impact household recycling by increasing the quality and quantity of household recyclables, it is possible that the app unintentionally has a negative effect. This outcome may be the case if users negatively respond to the increased time it takes to recycle while using the app. If the app is determined to have a negative effect on participants, they will be asked to delete it from their devices after the testing period ends so that it does not continue to negatively impact their recycling habits.
3. **Participants' Data:** The initial survey was conducted anonymously so data regarding recycling habits and gamification preferences cannot be traced back to an individual. When testing in conducted in households, participant's data will not be attached to their name or any other identifying information. When participants make an account on the

app, they will be able to choose their username, so they can decide if they wish to reveal their identity or not.

Section VI: Timeline

Task / Subtask	Due Date	Completion Status
1. Gamification Survey	11/28/23	Completed
1.1 Survey is Built	11/15/23	Completed
1.2 Survey is reviewed and sent out to adults (through Facebook) and teenagers (through MAMS, Green Knights, and personal contacts)	11/17/23	Completed
1.3 Survey is Closed	11/27/23	Completed
1.4 Results of the Survey are Analyzed	11/28/23	Completed
2. App Development	12/10/23	Completed
2.1 All Pages, including sketches for the selected gamification strategies are completed.	11/30/23	Completed
2.2 Metric for measuring environmental impact is determined and color scheme is finalized.	12/1/23	Completed
2.3 Framework of the app is completed.	12/3/23	Completed
2.4 Ability to create a log in is implemented.	12/3/23	Removed
2.5 Gamification strategies, chosen according to the survey, are implemented.	12/10/23* This is an MVP; additional improvements will be made between this date and the opening of the testing window.	Completed
3. Household and School Testing	1/31/23	Completed

3.3 Email asking for participants.	12/14/23	Completed
3.4 Email participants with details, send out a form to determine which testing period works for them.	12/16/23 – 1/1/24	Completed
3.5 Perform Testing	1/1/24-1/31/24	Completed
4. Analyze Data	2/4/24	
4.1 All Data from household testing is analyzed.	2/4/24	

Section VII: References

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Section VIII: Appendix

Appendix 1: Granting Agency

The target audience of this grant proposal is Too Good To Go, a company that aims to decrease food waste by offering discounts on food products that restaurants and stores would otherwise be required to throw away. This reduction of thrown away food helps to decrease the amount of food waste that is produced and therefore decrease the amount of greenhouse gas emissions. Although Too Good To Go is not a granting agency, I have selected it as the subject of my grant proposal because I am potentially partnering with them for my STEM 1 project. In this partnership, app users may be able to earn a voucher to Too Good To Go by completing specified recycling tasks.

Appendix 2: Survey Questions

Over 500 teenagers and adults were sent a Google Form with the following Survey Questions:

- What is your age?
- How frequently do you recycle?
- Does your household recycle?
- How much do you know about proper recycling habits? (scale 1-4)
- How motivated are you to recycle? (scale 1-6)
- Rank how strongly you agree that the following gamification strategies will increase your motivation to recycle and improve recycling habits such as cleaning and sorting.
    - Eco Points
    - Leaser Board

- Teams
- Streak
- Carbon Counter
- Badges
- Analytics
- Personal Goal Setting
- Eco Tips
- Monetary Incentive

Appendix 3: Descriptions of Selected Gamification Strategies

1. Monetary Incentive: A voucher to an eco-friendly company, such as Too Good To Go, that is earned by completing defined challenges.
2. Carbon Counter: Helps users to see their individual effect on the environment by relating the amount of carbon they've prevented from entering the atmosphere to relatable measurements.
3. Analytics: A weekly report that gives the user an overview of how they performed during the week. It shows if their habits are becoming more positive or negative and highlights their achievements.