

Background

Recycling:

- Municipal solid waste production has increased in the United States since 1960 (US EPA, 2023)
 - Causes more greenhouse gasses to be produced (Lee et al., 2016)
- Recycling produces a net savings of carbon emissions
 - Reduces use of energy and raw materials (Turner et al., 2015)
- Necessary Improvement In Household Recycling
 - Only 32% of American households recycle (United States Census Bureau, 2021)
 - Higher quality recyclables allow material recovery facilities to process more recyclables (Correa et al., 2022)
- Many barriers dissuade households from recycling
 - Space, time, and safety (Nixon & Saphores, 2009)
 - Time required to clean and sort recyclables (Helme Falk & Rosenlund, 2020; Klaiman et al., 2017)
 - Lack of knowledge of environmental impact (Klaiman et al., 2017)

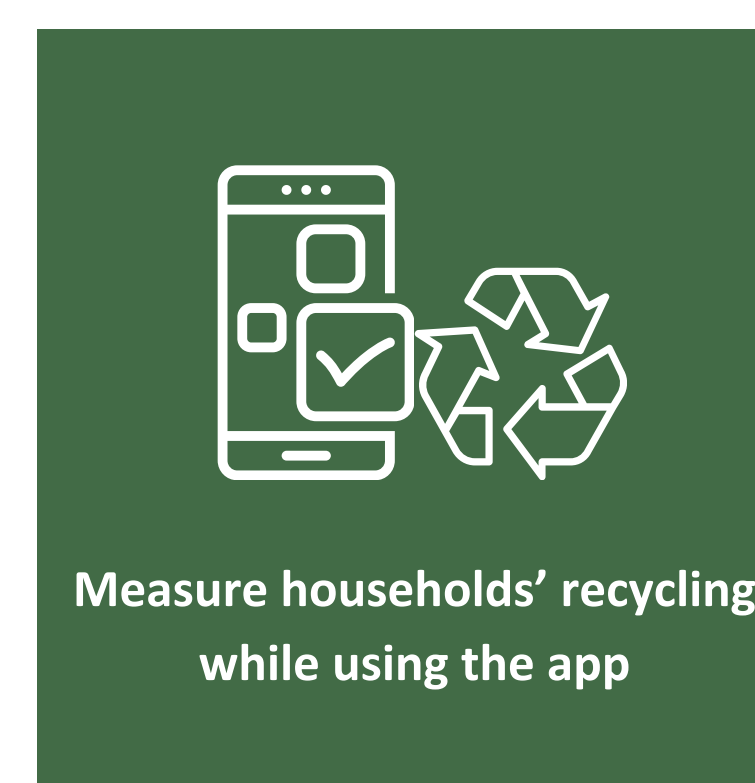
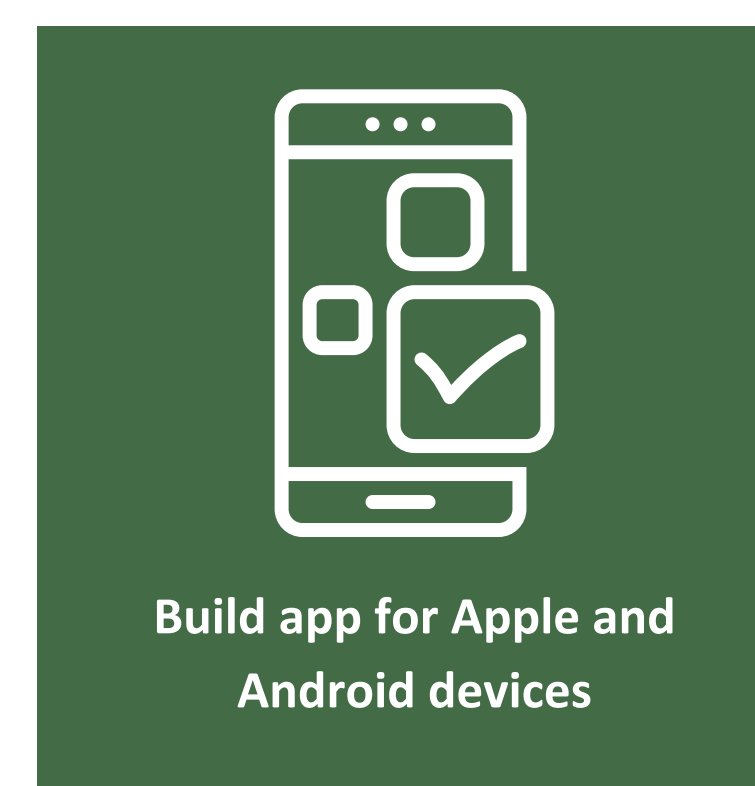
Gamification:

- Gamification is the application of game mechanics in a non-game context (Alsawaier, 2018)
 - Commonly used in work or education studies (Hamari et al., 2014)
 - Primarily used to increase intrinsic motivation (Hamari et al., 2014)

App Competitor Analysis

- Teach, but do not incentivise recycling:
 - SortIt, Catch the Trash, Recycle Coach
- Incentivise recycling, but change methods
 - ZeLoop
 - Smart city approach (Briones et al., 2018)

Methods



Designing and Testing a Gamified App to Increase the Volume and Accuracy of Household Recycling

Lindsey Paradise

Engineering Need

There is a lack of motivation to practice good recycling habits such as cleaning, separating, and sorting products, especially among those that do not understand the positive effects of recycling on the environment.

Engineering Goal

Design a gamified app for Apple and Android devices that increases the volume and accuracy of household recycling while allowing the user to maintain their current recycling system.

Results

Figure 1: Average Change in Participants' Recycling Knowledge, Motivation, and Impact Belief

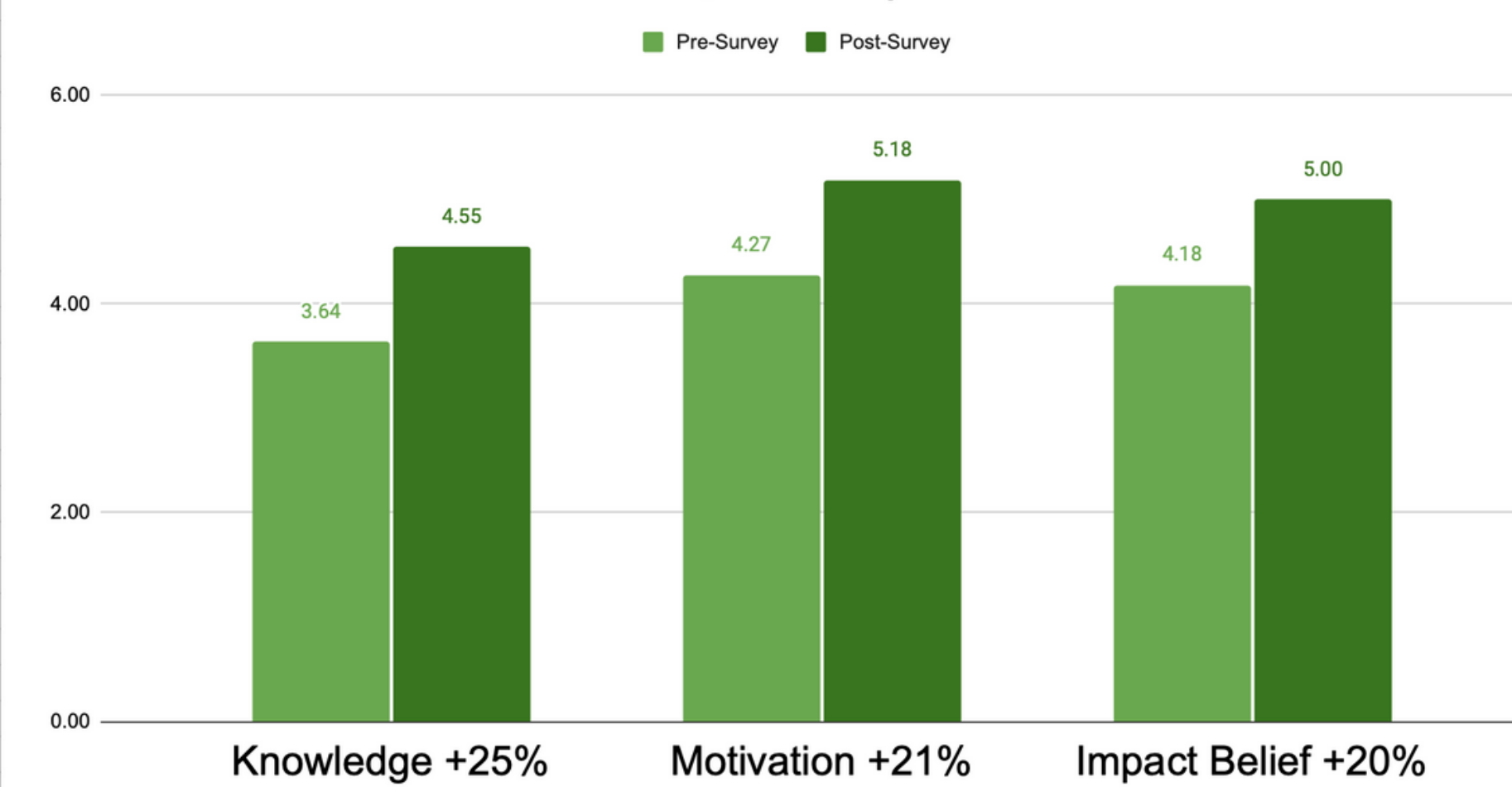


Figure 2: Comparison of Local Quantity Scores Before and After the Use of Carbon Crush

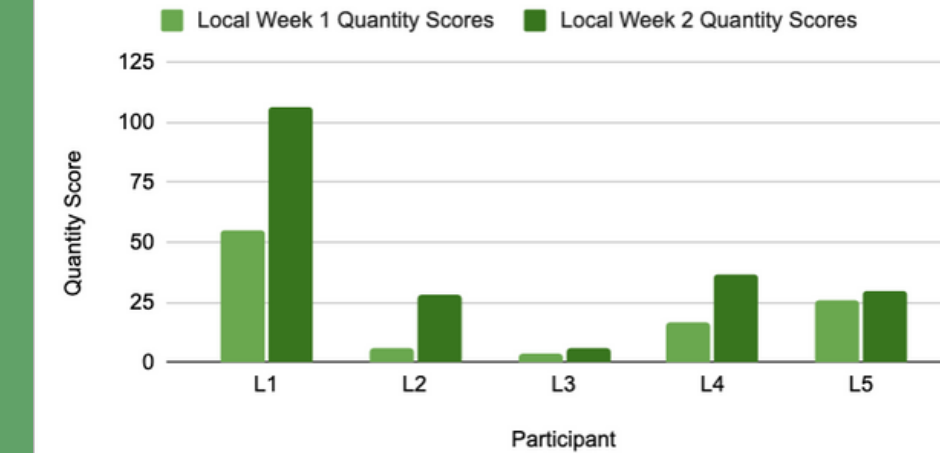


Figure 3: Comparison of Local Quality Scores Before and After the Use of Carbon Crush

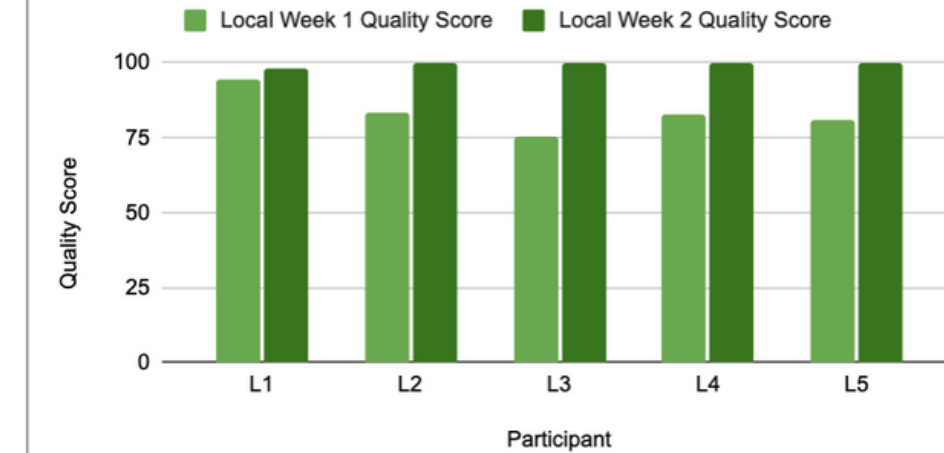


Figure 4: Comparison of Remote Quantity Scores before and After the Use of Carbon Crush

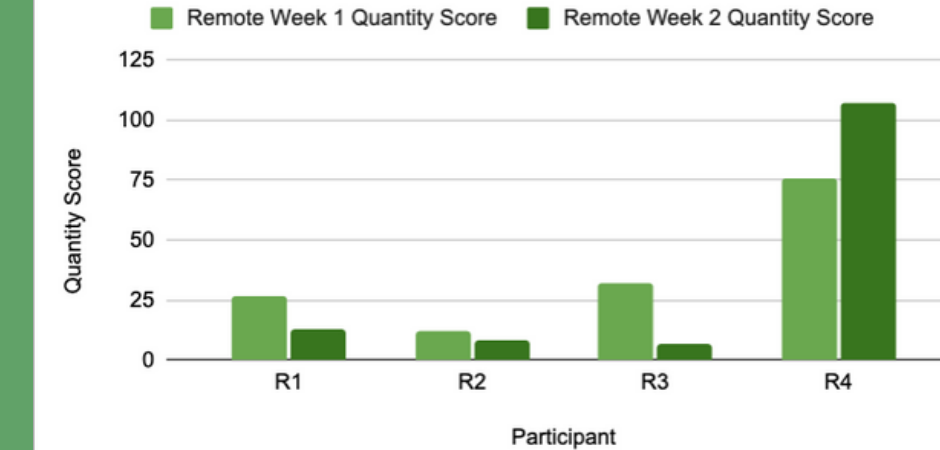


Figure 5: Comparison of Remote Quality Scores before and After the Use of Carbon Crush

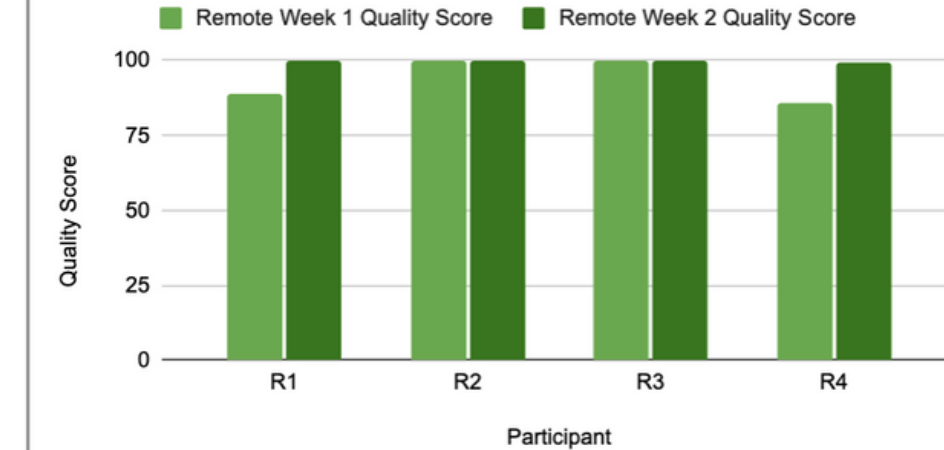
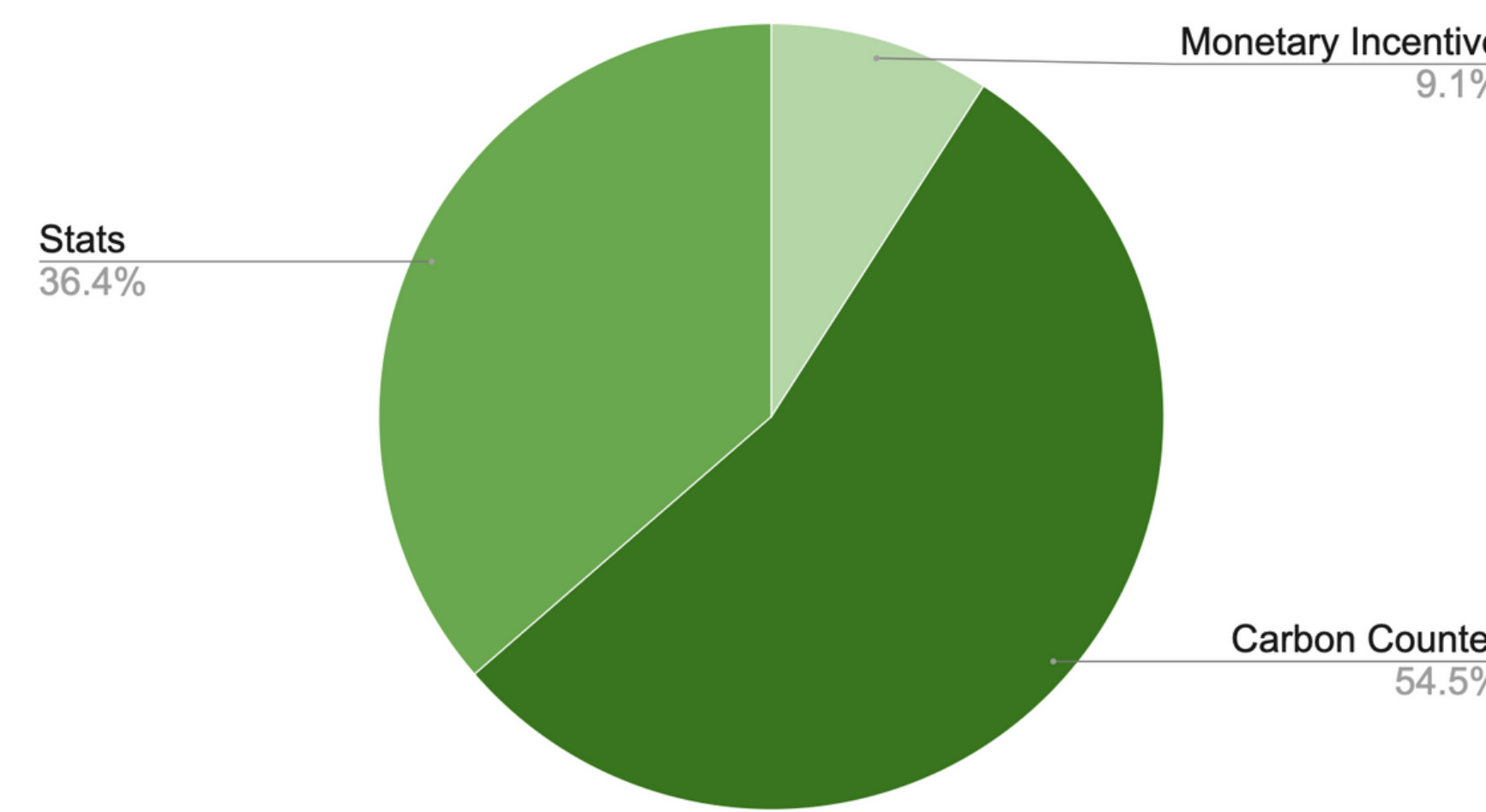


Figure 6: Participant Reported Most Impactful Gamification Feature



Level	Criteria	Score 0-1
1	App causes an increase in the percentage of a user's batch of recycling that is correctly cleaned, separated, and sorted	1
1	App causes an increase in the number of items a user recycles in a 1 week period	0.5
1	App allows user to maintain their current recycling system	1
1	App works on iOS and Android devices	1
2	App increases users' knowledge of proper recycling habits	1
2	App increases users' motivation to recycle	1
2	App increases users' knowledge of their impact on their impact on the environment	1
2	App allows users to create an account and store data	0.5

Analysis

Local

- Highest increase in quality score (16.4%)
 - ***p<0.005

Remote

- Quantity score decreased by 3 points on average
 - Suggests that the extra step of taking a photo of recyclables interferes with the recycling process

Non-Recycling Senior Citizens

- Highest average increase in quality score (91)
 - Demonstrates that greater change can be made amongst a non-recycling population
- Continuation of recycling habits after app use

Conclusion

This project has produced a **novel app** that motivates individuals to practice the positive recycling habits of cleaning, separating, and sorting recyclables **without altering their manner of recycling** (curbside, drop-off, etc.) using a monetary incentive, carbon counter, and statistics as **gamification strategies**. The app successfully increased the users' **knowledge** of proper recycling habits, **motivation** to recycle, and **belief in the impact** of their recycling. This project has also revealed that if the process of recycling is made too inconvenient, the quantity of users' recyclables may decrease.

The increase in the quantity and quality of products as seen in the Local and Senior Citizen groups produced a **net reduction in greenhouse gas emissions** and worked to promote a circular economy (Nixon & Saphores, 2009; Turner et al., 2015).

Future Improvements

1. Verification of Recycling Inputs
 - a. Image recognition model or attachment to recycling bins
 - b. Replace count metrics with mass
2. Additional Gamification Features
 - a. Eco Points, Leaderboards, Teams, Competitions, Analytics Report
3. Item Logging
 - a. More material options
 - b. Ability to delete mistakes, snackbar for confirmation
4. Quests and Monetary Incentives
 - a. Simpler quests, greater variety
 - b. Form a partnership with eco-friendly companies

Graphical Abstract

