Analyzing and Improving Recycling Performance at WPI

Major Qualifying Project Submitted to the Faculty of

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Abstract:

The amount of waste generated on campus at WPI has steadily increased over the past 10 years, but the recycling efficiency has lacked in response to this increase. With this project, we aimed to identify opportunities to implement improvements to the current recycling process at WPI through surveying, data analysis, and experimental testing. The goal of this project was to improve the recycling performance of the campus population to optimize recycling efficiency.

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Introduction

Project Motivation

The motivation for this project stems from the growing threat of global warming and climate change, as well as finding ways to improve how we protect the environment. Across the globe, waste generation has increased exponentially and it is believed that failing to address this issue could prove to be catastrophic in the future. It was clear that changes need to be made in how we live our daily lives, and time was running out to take action. Our team was motivated by the opportunity to make a difference and inspire others to do the same. We hope that with this project we will be able to make a positive impact on the WPI community and environment, and start a movement towards environmental sustainability throughout the region.

Background

Environmental awareness is a growing issue in today's world and companies are searching for ways to adapt the way they operate to be more environmentally sustainable and efficient. They also analyze the situation from a business perspective, looking for areas of improvement where costs can be minimized and profits increased.

A frequent target area for companies is their recycling and waste management process. Analyzing a waste management process, specifically the recycling portion, is an effective method for determining how efficiently and properly waste is being dealt with to protect the environment. We decided to analyze the recycling on campus because we believe, along with the Office of Sustainability at WPI, that improving recycling efficiency and behavior on campus will help minimize the amount of waste generated. It is important to consider all factors of the process, from knowledge of proper guidelines and behaviors to physical or logistical barriers limiting production. There is a common misconception that most people recycle efficiently. Recycling requires a certain level of attention and commitment that many people do not have, or they are not willing to do the extra effort to recycle properly. Across the globe, issues from the trash in the oceans to wildfires are growing more prevalent and detrimental to the environment.

Since 2018, China has established a new standard for recycled materials that require reduced contamination from 3% to 0.5%. This new standard has impacted the recycling industry throughout Massachusetts, as the state has decided to implement this standard and require the contamination rate to be 0.5% (WPI Office of Sustainability, 2018).

The Office of Sustainability at WPI provides leadership and direction for sustainability programs at WPI. Ranging from recycling and waste management to community engagement, the Office of Sustainability works to spread environmental awareness throughout campus. Each year since its establishment, the Office submits a Sustainability Report, documenting sustainability data, initiatives, and achievements from the past year. They have made it clear that a reduction of waste and improvement in recycling will require realistic goals, concrete action plans, and communication with the community (WPI Office of Sustainability, 2018). Along with a few other clubs and organizations on campus, the Office of Sustainability has worked to establish a culture centered around environmental awareness that is reinforced through continued education on campus.

The WPI recycling program handles paper, cardboard, plastics #1-#7 (nearly all), glass, batteries, used electronics and components, lights, ballasts, books, and surplus. Recyclable materials include paper and cardboard, newspaper, and clean and empty containers (glass, plastic, metal). Single stream non-recyclable materials include styrofoam and paper cups, plastic bags, containers with food residue, plastic wrappers, disposable utensils, and straws.

Figure 1: Pictured above are the different recyclable materials collected throughout the campus at WPI.

The amount of waste generated throughout the campus at WPI has consistently increased over the past decade, with about 800 tons of waste generated this past year. The areas on campus with the highest concentration of waste generated are residence halls and recreational/community areas (rec center and campus center). From July 2018 to June 2019, waste generation data gathered by WPI showed that 162.38 tons of waste was produced in the Campus Center, and over 200 tons of waste produced among the numerous residential halls on campus. These two areas of concentration represent almost half of the 800+ tons of waste generated total on the WPI campus. It is very important to target areas of highest concentration in order to yield the highest results. The datasheet provided to us separated waste into two categories: trash (non-recyclable material) and recycling (recyclable material). Combining the two values together represents the total waste generated, and the recycling rate is derived from dividing the waste total by the amount recycled.

Year	Total Waste	Trash	Recycling	Recycling Rate
2006	**331.67**	269.87	61.8	18.63
2007	**636.67**	518.25	118.42	18.60
2008	**573.81**	473.53	100.28	17.48
2009	**610.88**	464.59	146.29	23.95
2010	**664.15**	484.39	179.76	27.07
2011	**665.32**	494.73	170.59	25.64
2012	**579.81**	465.95	113.86	19.64
2013	**709.25**	555.84	153.41	21.63
2014	**835.7**	577.62	258.08	30.88
2015	**816.57**	600.04	216.53	26.52
2016	**744.395**	553.845	190.55	25.60
2017	**718.83**	554.18	164.65	22.91
2018	**735.085**	519.04	216.045	29.39
2019	**811.08**	545.57	265.51	32.74

Increase in total waste	10%
Increase in trash	5%
Increase in recycling	23%
Increase in recycling rate	3.34%

Figure 2: Pictured above is data regarding waste production on campus at WPI from the years 2006-2019.

There is a basic flow of production to disposal of waste on campus at WPI that is important to be aware of when analyzing the waste management process. Trash is disposed of by students and staff into the trash and recycling bins in each building. At the end of the day, custodians collect it and dispose of it in one of two ways. In buildings that have trash compactors, custodians empty the collected trash into the compactors to be picked up later. In the buildings that do not have trash compactors, the custodians bring the trash to the exterior of the building for pickup. Next, staff driving the trash and recycling truck pick up trash from some buildings and recycling from all buildings and bring it to the designated trash and recycling compactors. The custodian then reports the number of materials collected to the Head of Facilities. From there, Waste Management picks up trash and recycling and brings it to a landfill or recycling center (See Appendix A).

On the WPI campus, there are trash/recycling bins located in buildings and classrooms where students, faculty, and others have the opportunity to recycle properly. Each bin is labeled whether you should put recyclable materials in it or if it's for non-recyclable materials. A number of the bins have pictures or descriptions above them describing what types of materials can be disposed of in the respective bins. We identified potential areas where improvements could be made and will discuss how we addressed them with this project.

Even with the numerous bins and descriptions of how to properly dispose of items, there is a human error factor in this situation. One of the biggest misconceptions regarding recycling in waste management is that 'it doesn't matter if something belongs in recycling the hauler will sort everything anyway.' Non-recyclable items are removed from recycling streams but recyclable items are not removed from the garbage, as they are directly hauled to the landfill (WPI Office of Sustainability, 2018). Garbage placed in recycling increases the cost of the recycling process and will increase the cost of garbage and recycling service.

The recycling rate on campus, which is currently about 32%, has not mirrored the results campus leaders have hoped in order to match the continued increase in waste generation. This is an area of particular concern among members of the WPI community, and we wanted to increase the recycling rate through improving recycling performance on campus. To do so, we researched various different factors and behaviors that affected recycling performance, like previous experience, knowledge, accessibility of facilities, and clarity of signage explaining how to properly recycle. We gathered data on these factors from upper-class students at WPI to identify potential explanations for the lack of recycling on campus. Conclusions could then be made for why recycling was lacking on campus, and we tested potential improvements based on this data which we will discuss further later in this paper.

Problem Statement

The problem we were looking to address with this project was the need to improve recycling performance and efficiency on campus. The amount of waste generated on-campus at WPI has increased steadily since 2006, likely due to the growth of the student population among other factors. In 2006, about 330 tons of waste was generated on the WPI campus, and that value reached over 800 tons in 2019. From 2006 to 2019, the amount of waste generated has increased by over 10% each year. WPI officials and campus leaders are actively looking for ways to minimize waste generation on campus (WPI Office of Sustainability, 2018). Looking at the recycling rate over the years, improvement has lacked in response to the steady increase in waste generation. In 2006, approximately 61 tons of waste was recycled, with a recycling rate of 18.63%. In other words, 18.63% of the total waste generated was effectively recycled. In 2019, about 265 tons of waste was recycled, with a recycling rate of about 32.74%. From 2006 to 2019, the recycling rate on campus increased by 3.34% (see Figure B). Compared to the increase in the trash (non-recycled material), which was 5%, this was something that needed to be improved.

WPI recently switched from sorting commodities to single-stream recycling. With single-stream recycling, all types of recyclable materials like plastics, paper, metal, glass, etc. are put into a single bin by consumers. This differs from sorting commodities in that each type of recyclable material is not separated into specific bins. The WPI Office of Sustainability believed this could be a possible reason for the lack of recycling on campus, as they thought it would increase the recycling rate, but it did not and it resulted in commodity contamination. It was vital to gather data on the knowledge, attitudes, and behaviors related to recycling on-campus of a sample of the student population in order to get a better understanding of the effectiveness of the current system.

In today's society, efficient recycling methods are needed now more than ever. Waste generation is increasing at an alarming rate and we are running out of ways to dispose of it properly. As a result, we need to find a way to properly and efficiently minimize waste and increase the rate of recycling. Without doing so, the environment will be subject to further damage from waste generation.

Previous Project Work

There have been a few projects completed in the past at WPI with similar motivations, goals, and methods of this project and the goal of improving overall recycling performance on campus. A common thread amongst these IQPs and MQPs was the need to address the level of knowledge of recycling, recycling habits, and people's perception of the recycling processes and whether improvements were needed. A few of the methods used included interviewing students and staff, surveying, and visiting recycling redemption centers to learn more about recycling and apply observations on to recycling at WPI. There were a few interesting attempted goals that didn't end up working out like a recycling redemption station on campus (DiMestico et al., 2017) and adding bins of different styles, colors, and sizes (Le & Nhan, 2018). A few of the reasons these failed included negative feedback from campus members (students/staff), economic feasibility, and time constraints. One common conclusion between these projects was that improving recycling performance on campus is a continuous project and requires consistent attention to adapt to the changing campus population year to year. Reading through previous IQPs and MQPs helped steer our project in the right direction and we focused on the recycling knowledge, attitudes, habits and perceptions of the campus population at WPI and how to improve it based on what we learned from that data.

Goals and Objectives

The ultimate goal of this project was to improve recycling performance and efficiency on campus. In order to accomplish our goal for this project, we completed the following objectives. We researched factors and behaviors that influenced recycling performance on college campuses and developed hypotheses that could explain recycling habits and behaviors at WPI. These hypotheses addressed demographics, knowledge of recycling, accessibility of recycling facilities (bins, etc.), and clarity of proper recycling guidelines displayed by WPI. We constructed a survey to gather data for our developed hypotheses. Using contingency tables, we concluded whether or not the hypothesized factors had any influence on recycling behavior at WPI based on the data gathered from the survey. We then tested the effect of adding bins to a building on campus and how that affected recycling performance. We hope that the results of this project will influence the campus population to improve their recycling habits and behaviors and help improve the recycling rate on campus in the future.

Literature Review

Waste Generation

Human activities have always generated waste. This was not a major issue in the past but has become a serious problem (Giusti, 2009). All over the world, countries are experiencing a large increase in population, prosperity, and urbanization. Such growth has led to issues in the collection, recycling, treatment and disposal of the increasing amounts of solid waste (Cherubini, Bargigli & Ulgiati, 2009). Proper waste management techniques and methods are vital to protecting the environment and the safety of those living in it. An example of this issue arose in Malaysia, where rapid modernization, following an excellent record of economic growth, coupled with a steadily increasing population, exposed Malaysia to threatening environmental problems, particularly in regards to the increasing volume and variety of waste generated (Tih & Zainol, 2012). This problem is common across the globe, and there are various different ways it has been approached. When proposing waste management strategies, they must be based on the reality of the generating source, thus, it is important to know both the characteristics of the waste and recyclables local market (de Vega, Benítez & Barreto, 2008). Therefore, direct waste analyses or waste characterization studies offer the most effective process for examining the various wastes generated and identifying opportunities for waste reduction, reuse, recycling, and composting (Smyth, Fredeen & Booth, 2010).

Another issue arising from waste generation is how to effectively dispose of waste while protecting the environment. The increasing amount of solid wastes generated has resulted in a reduction in landfill capacity (Malakahmad et al., 2010). Landfilling is one of the most widely used waste disposal methods across the globe. A recent study was conducted in Brazil where the life cycle of basic food items was studied in order to discover the reasons for low landfill diversion rates of this material. It was concluded that there were a few different factors contributing to the increased waste generation and low diversion rate in landfills. These included: inadequate purchasing schedules and poor practices of manipulating produce in the stores, street market traders needed to exercise control over cost structure and optimize purchasing schedule, and acquisitions and sales of every fruit and vegetable item needed to be documented and compared in order to discover and quantify losses. The research team also discovered that management issues contributed to waste generation, and they developed a model of management methods and tested their chances of success. The model addressed the issues above and was accepted and implemented by the farmers, local markets, and supermarkets in the study (Fehr, Calcado & Romao, 2002).

When dealing with waste generation, special attention should be paid to the waste generation sources since the characteristics and composition of the waste differ according to their source (de Vega, Benítez & Barreto, 2008). Waste characterization studies have been effective at addressing this specific facet of waste generation. A recent study in Malaysia utilized waste characterization to identify different types and sources of waste on a college campus in order to suggest improvements for waste segregation and disposal. From this study, the research team concluded that almost 80% of generated solid waste in academic buildings of the campus was found to be recyclable, and a system that contains three separate bins for food waste, paper and the rest of generated waste was suggested for initial waste separation in the campus (Malakahmad et al.,2010).

Waste Management Methods

Across the globe, waste is disposed of in many different ways using various techniques and methods. Nowadays, management and recycling of waste materials is one of the important economic and environmental issues that must be considered by policymakers to attain sustainable development of a society (Taghizadeh et al., 2012). A hierarchy in waste management can be used to rank actions to be implemented in programs within the community. The US Environmental Protection Agency (EPA) has defined this hierarchy as source reduction, recycling, waste combustion and landfilling (Malakahmad et al., 2010).

The U.S. EPA defines Integrated Solid Waste Management (ISWM) as a complete waste reduction, collection, composting, recycling, and disposal system. An efficient ISWM system considers how to reduce, reuse, recycle, and manage waste to protect human health and the natural environment (Adeniran, Nubi & Adelopo, 2007). A few of the available and well-seasoned technologies for treating biodegradable waste components are composting, accelerated anaerobic digestion, landfilling with methane capture for power generation, landfilling without methane collection, and mixed waste incineration. The first two of these technologies produce compost and therefore, may be considered a means of closing the material balance and the life cycle. (Fehr, Calcado & Romao, 2002). Each form of waste management has certain pros and cons that make its use beneficial and costly fiscally and environmentally.

Waste Source Separation

Waste source separation has been widely accepted as a key method for minimizing waste and enhancing recycling efficiency. While often successful, there is evidence of obstacles faced when trying to implement waste source separation. A study in China found that insufficient publicity, lack of waste separation standards and knowledge, lack of comprehensive coordination between different management departments, and infrastructure mismatch (i.e., wastes were source-separated, but were then mixed again when transported and disposed of) are some of the key reasons for the failure of waste source separation. This observation was made prior to the study, and one of the main conclusions drawn from implementing waste source separation centered around education and awareness. The study observed that waste separation publicity in China should do more on displaying the current environmental pollution caused by municipal solid waste. Also, more on-field waste separation campaigns need to be launched, so that people can have more real experience of waste separation and will have a better understanding of the achievements of their actual efforts (Zhang et al, 2017).

Landfilling

Landfills are accepted to be permanent depositories of mixed waste, carefully isolated from their environment by appropriate impermeable layers at the bottom and methane scavenging vegetation at the top (Fehr, Calcado & Romao, 2002). In Europe, landfilling is the most used method of waste management. In 1999, 57% of waste was landfilled in western Europe, and 83.7% in central and eastern Europe. About 18% of waste was incinerated and 25% recycled in western Europe, while western Europe saw 6% incineration and 9% recycling. In 2006 the United States landfilled 54% of waste, incinerated 14%, and recovered, recycled or composted the remaining 32%. The type of waste management practices adopted in each country are mostly functions of economic considerations, but are also a reflection of technical aspects due to the type of waste to be handled (Giusti, 2009). Landfill diversion remains low simply because it has never been a specific management priority at regional or national levels (Fehr, Calcado & Romao, 2002)

Recycling

Traditionally, recycling was separated into multiple streams, meaning that different types of recyclable materials like cardboard, paper, glass, plastic, and metal were disposed of in different bins. The latest trend in recycling is the movement towards single-stream recycling, where all recyclable materials are disposed of in the same container. With single-stream recycling, residents throw everything in the same container for pickup, where it is sorted at a materials recovery facility (MRF).

Single-stream recycling has been adopted and utilized at an increasing rate across the country since the early 2000s, and the communities, companies, etc. that experiment with it have found positives and negatives associated with the process. The most important benefit of single-stream recycling is its positive effect on waste generation. Separating waste by source and type targets recyclable material which significantly lowers waste production (Smyth, Fredeen & Booth, 2010).

The city of Madison, WI was one of the leading communities making the switch to an automated collection system with single-stream recycling in 2003. This decision was made on the basis of a cost-benefit analysis comparing the single stream to the current system even without any test or trial runs in the city. Their analysis relied on estimated costs and benefits comparing the initial system to the new system of an automated collection with single container recycling prior to the program change. The study found that a majority of the cost savings resided in the collection process, specifically the use of fewer vehicles and man-hours, leading to lower costs for fuel, maintenance, and labor. With single-stream, the City of Madison purchased recycling carts whereas in the initial system, households had to purchase plastic recycling bags separately, and eliminating that part of the process saved money for consumers (Jamelske & Kipperberg, 2006).

Waste Management at Higher Educational Institutions

Because of their large size, population, and vast amounts of waste generated, colleges and universities have become a point of focus for sustainability efforts. Often referred to as Higher Educational Institutions (HEIs) throughout the literature, college campuses can play a key role in the promotion and use of sustainable practices due to the inherent expertise amongst staff and students, their role as facilitators for future leaders and their wide-ranging engagement with a range of stakeholders in the community (Bailey, Pena & Tudor, 2015). In the United States, it is mandatory that colleges and universities implement waste reduction and recycling strategies (de Vega, Benítez & Barreto, 2008). Colleges and universities, like small municipalities, often encompass large areas of land and diverse populations who must change their behavior in order to achieve natural resource management and environmental protection goals. Furthermore, colleges and universities are typically engaged in complex scientific, social, and educational activities with considerable material consumption and energy usage. As a result, universities may be viewed as communities with significant direct and indirect impacts on the environment (Kaplowitz et al., 2009).

There are a number of benefits associated with participation in waste management at HEIs. Appropriate waste management would bring benefits to the institution such as a reduction of the financial resources destined to waste management, but, above all, it would set an example to the students and the community (de Vega, Benítez & Barreto, 2008). It was found that college students will influence future society and their waste source separation behavior will have great impacts on both their parents' generation and children's generation (Zhang et al., 2017).

Due to the integrated nature of their activities, institutions can easily fashion out their own mini solid waste management systems within the large municipal solid waste management system framework. With such systems in place in institutions, resource recovery and waste recycling can more easily and effectively be incorporated, reducing the pressure on solid waste disposal sites (Mbuligwe, 2002). Students are a useful resource in waste management studies because they are intelligent, motivated to make a difference, and they are generally aware of campus operations because they are present on campus every day. Given such a widely-held belief in the crucial role of students in recycling program success, many previous studies of campus recycling programs have focused on the effect of short-term interventions such as rewards, goal setting, feedback, information and education on promoting recycling behavior among students (Kaplowitz et al., 2009). For instance, student concern for a lack of on-campus recycling facilities led to the implementation of a zero-waste program at Massey University, New Zealand (Mason et al., 2003). The research team was successful in establishing this zero-waste program, and they were able to gain support from all administrations and departments on campus to continue its use in the future.

Waste characterization studies are a common approach in recent studies completed on waste minimization on college campuses. Analysis of waste flows within universities and institutions is the first step in designing a successful and comprehensive management system towards environmental protection (Taghizadeh et al., 2012). In a recent study conducted at the University of Lagos, Nigeria, a waste characterization study was conducted to determine the trends in the volume of waste generated and examine possible integrated solid waste management strategies. It was found that the recycling potential on campus was very high, constituting about 75% of the total waste generated, and organic waste generated could be managed via composite formation or integration with the sewage management system. The team determined that strategic policy and community participation would be needed for the source reduction and improved recycling of waste (Adeniran, Nubi & Adelopo, 2017). A similar study was conducted recently on the campus of the University of Baja California (UABC) to set the basis for the implementation of recovery, reduction and recycling waste management programs at the campus. Similar to the Nigerian study, the waste characterization in this study showed that the waste on campus presents a high recovery potential both in the case of waste generated in buildings and waste from gardens and the community center. The team concluded that more attention must be paid to solid waste characterization studies and solid waste management (SWM) on campuses in the area (de Vega, Benítez & Barreto, 2008). It is clear that different factors and methods can be utilized and implemented when trying to employ waste management strategies and practices on college campuses.

In recent years, sustainable waste initiatives on college campuses have not been as successful as anticipated. In previous studies assessing why students don’t actively participate in recycling efforts, it was found that inconvenience and a lack of promotion and education were the main barriers to recycling (Bailey, Pena & Tudor, 2015).

The inconvenience issue stems from inadequate infrastructure and the fact that there is generally more effort involved in recycling than disposing of an item as waste (Rada et al., 2016). In a 1998 study, it was found that students were almost twice as likely to recycle if there are recycling bins in each classroom, compared to when they are only in central areas. This is due to the fact that students don’t want to have to make an effort to seek out places to recycle. Instead, they would rather know exactly where to go and have easy access to recycling infrastructure (Ludwig, Gray & Rowell, 1998).

On a college campus, communication and advertising play key roles in developing successful waste management and recycling programs. Several approaches (media or modes) have been used on campuses to communicate recycling program information to individuals. These communication modes include newsletters, television advertisements, stickers on bins, radio commercials/public service announcements and personal contacts (Kaplowitz et al., 2009). Recycling education programs should communicate time and space needs for recycling, inform people about where to go for assistance, and explain what materials can be recycled as well as how they should be prepared (Kaplowitz et al., 2009).

Methodology

<u>*Experimental Analysis*</u>

Surveys/Questionnaires

Surveys and questionnaires are used world-wide to collect large amounts of data efficiently and economically within relatively short time frames (Lefever, Dal & Matthiasdottir, 2007). Both surveys and questionnaires have shown promise in building awareness of recycling initiatives, as well as gaining an insight into the perceptions of recycling and waste management from students and faculty. Often, surveys are administered in an attempt to test predetermined hypotheses of the data being collected, and this is useful to make conclusions about the current state of a recycling program of an institution (Tih & Zainol, 2012).

One of the advantages of surveying is that there are a variety of different ways and techniques a survey can be utilized to obtain the information you are looking for. There are advantages to collecting data using online surveys and questionnaires. These methods guarantee a rather short time frame for the collection of responses and are time and cost-saving and online data collection protects against the loss of data and simplifies the transfer of data into a database for analysis. Some researchers even argue that using a web survey guarantees a potentially better response rate. Some disadvantages that are common are the unreliability of the email address lists and the lack of willingness, particularly among students, to participate(Lefever, Dal & Matthiasdottir, 2007). This was particularly important for our project, and we constructed our survey in a way that was easy to operate and gathered the data we needed to proceed with our methodology.

For this project, we needed to consider what data we wanted to obtain from our survey/questionnaire, how we could analyze that data, and how we could use it to make conclusions. We used the survey software Qualtrics to complete and send out the survey and gather the data. We used contingency tables and Chi-Square tests of independence to make conclusions on our predetermined hypotheses, which we will discuss further in the next section.

Hypothesis Testing

Hypothesis testing is a method of statistical analysis where assumptions or theories made about a population are tested for significance to make conclusions about the population. Hypothesis tests are usually performed by measuring and examining a random sample of the population being analyzed. The four steps of a hypothesis test are stating the two hypotheses so that only one can be right, formulate an analysis plan, which outlines how the data will be evaluated, carry out the plan and physically analyze the sample data, and analyze the results and either accept or reject the null hypothesis (Majaski, 2019).

Predetermined Hypotheses

We predetermined four sets of hypotheses. The motive behind testing these hypotheses was to assess whether recycling behavior is dependent on specific factors and behaviors of the student population. We determined that the testing following four sets of hypotheses would allow us to identify potential areas of improvement and explanations for lack of recycling on campus at WPI.

Set 1

Ho: Demographics and recycling behavior are independent

Ha: Demographics and recycling behavior are dependent

Though the relationship between them is inconclusive, most researchers have found that women, elder people, high-educated people, and high-income people are likely to be more involved in waste management activities (Zhang et al., 2017). We wanted to see if a person’s recycling behavior depended on their gender (male, female, other) or their role on campus (student, staff, undergrad v. graduate). We tested this hypothesis to see whether recycling behavior is dependent upon the demographics of the people on campus responding to the survey.

Set 2

Ho: Past behavioral experience/exposure to recycling and recycling behavior are independent

Ha: Past behavioral experience/exposure to recycling and recycling behavior are dependent

Behavioral experience works both ways and research has shown that the recurrence of old habits can contribute to new recyclers gradually discontinuing with recycling (Clay, 2005). Early research into conservation behavior indicated that for activities that were highly repetitive, such as recycling, adoption was best predicted by past experience with that behavior (Clay, 2005). Therefore, we determined that an important factor in recycling performance on campus is whether people have exhibited proper recycling behavior at home or prior to coming to WPI. We tested this hypothesis to exhibit whether a person's recycling performance on campus is dependent upon their previous exposure/experience (or lack thereof) with recycling at home.

Set 3

Ho: Knowledge and familiarity of recycling policies and recycling behavior are independent

Ha: Knowledge and familiarity of recycling policies and recycling behavior are dependent

Researchers have found that recyclers, in general, are more knowledgeable about recycling issues than non-recyclers, leading to more efficient recycling results (Zhang et al., 2017). Recycling behavior at university campuses may be increased by adding recycling options, raising community members' knowledge of recycling, and improving the convenience of recycling. Empirical evidence suggests individuals' participation in recycling programs is correlated with their knowledge of how, where and what to recycle as well as their knowledge of how recycling benefits the environment (Kaplowitz et al., 2009). Past research clearly shows that knowledge, or lack thereof, of recycling guidelines, is one of the biggest reasons a person does not participate in a recycling program. We tested this hypothesis to determine whether a person at WPI's recycling performance is dependent upon their knowledge and familiarity of recycling guidelines on campus. This allowed us to determine whether actions needed to be taken to improve the knowledge of recycling policies on campus in order to improve overall recycling performance.

Set 4

Ho: Clarity of recycling procedures and opinion of whether to add more bins are independent

Ha: Clarity of recycling procedures and opinion of whether to add more bins are dependent

Past research has shown that providing suitable and enough recycling bins would encourage more people to participate in recycling activities (Malakahmad et al., 2010). Also, we found that the more confident a person is to perform a behavior, the more likely he/she will engage in the behavior. If a person is uncertain of where to put an item, for example, if the signage or directions are unclear, they are less likely to recycle correctly (Tih & Zainol, 2012). There are a few different ways to address improving the ease of recycling. Past studies have experimented with increasing the number of bins and locations, changing the color of existing bins to a brighter color to increase visibility, larger signs with instructions on how to recycle, and monetary incentives - because of large campus population monetary rewards could not be given to each student, random awards given out by undercover recycling advocates (Moldofsky, Boudeman & Foley-DeFiore, 2012). Overall, it is clear that in today's society sometimes people fail to do something because it is either complex, difficult, or time-consuming, so it is important to make sure that recycling on campus is as simple and easy as possible in order to ensure more students participate. Testing this hypothesis was important for determining whether a person's recycling performance was dependent upon the clarity and accessibility of recycling bins.

Contingency Tables

Our hypotheses dealt with determining dependence between two different variables, and the best way to do this was by using contingency tables to perform Chi-Square Tests for Independence. A row (r) x column (c) contingency table shows the observed frequencies for two variables (Larson & Farber, 2006). The main purpose that a contingency table serves is to organize categorical data of observed values to perform tests of independence. Contingency tables are useful for analyzing categorical data, and for our project testing for independence between categorical variables was our main form of analysis, making contingency tables very useful for this project.

Variable x Variable y

Example	Answer A	Answer B	Answer C
Answer A			
Answer B			

Table 1: Pictured above is an example format of a contingency table.

Chi-Square Test for Independence

A chi-square independence test is used to test the independence of two variables. Using a chi-square test, you can determine whether the occurrence of one variable affects the probability of the occurrence of the other variable (Larson & Farber, 2006). When performing a chi-square independence test, we executed the following steps.

1. State the null and alternative hypotheses.

2. Specify the level of significance, also known as confidence level, that we want to test at, typically either 90%, 95%, 97.5% or 99%.
3. Identify degrees of freedom with the formula (r-1)*(c-1).
4. Determine the critical value.
5. Determine the rejection region (range of values which reject Ho).
6. Calculate the test statistic. The test statistic takes your data from an experiment or survey and compares your results to the results you would expect from the null hypothesis.
7. Make a decision to reject or fail to reject the null hypothesis (reject if the test statistic is greater than the critical value for the chosen confidence level in the Chi-Square distribution table) (See Appendix A).
8. Interpret the decision in the context of the original claim ("We can conclude with x% confidence that….") (Larson & Farber, 2006).

Using chi-square independence tests was instrumental in our analysis of survey data, and allowed our team to make conclusions on the dependence of variables of recycling behavior that we believed influenced recycling performance on campus. The conclusions we made from this analysis led our team to conclude that running an experimental test on one of the buildings on campus was the next step to take for this project.

Experimental Testing

Gathering data and analyzing it to test our hypotheses enabled our team to identify potential methods of running a test for implementing improvements to current recycling procedures on campus in order to improve recycling performance. We realized that we needed a physical representation of applying improvements in areas revealed from our survey data and analysis. We concluded that running an observational test for one week in one of the buildings on campus would allow us to illustrate the effects of our proposed improvements.

With this test, we chose a building, performed a walkthrough to observe the current state of recycling facilities, from the number of bins on each floor to whether they were placed in areas of maximum foot traffic, and noted areas of methods that we felt could be improved. We then added or relocated bins to satisfy the areas of improvement we observed, and totaled the weight of recyclables collected (in lbs.) from the bins for a total of one week. Next, we removed the bins after the one-week time period expired, and collected data for the weight of recyclables collected with the original number of bins and set up in the building. We compared the data between the two different setups, our improved design versus the original layout, and made a conclusion on whether our improvements were successful. We discuss this process further in the Findings chapter.

Findings

Survey Distribution

Requirements

Chi-square independence tests have a few conditions that need to be met in order to use them to analyze categorical data. It is a non-parametric test, also called a distribution-free test. Non-parametric tests like the chi-square independence test should be used when any of the following conditions pertain to the data:

1. The level of measurement of all the variables is nominal or ordinal.
2. The sample sizes of the study groups are unequal; for the $\chi 2$ the groups may be of equal size or unequal size whereas some parametric tests require groups of equal or approximately equal size.
3. The original data were measured at an interval or ratio level, but violate one of the following assumptions of a parametric test:
    a. The distribution of the data was seriously skewed or kurtotic (parametric tests assume a normal distribution of the dependent variable), and thus the researcher must use a distribution-free statistic rather than a parametric statistic.
    b. The data violate the assumptions of equal variance or homoscedasticity.
    c. For any of a number of reasons (1), the continuous data were collapsed into a small number of categories, and thus the data are no longer interval or ratio. (McHugh, 2013).

The data we planned to gather from this survey satisfies conditions 1 and 2 of this list, as our data would be ordinal and as we will discuss further in the next section our sample sizes are different because we surveyed undergrad students, graduate students, and staff. There was no specific population requirement since we were operating with ordinal data, so we were attempting to survey as many people as possible, but were not as concerned with fulfilling a specific number of responses. Due to our survey satisfying these conditions, we were able to confidently send out our survey knowing that we would be able to perform statistical analysis to make conclusions about our predetermined hypotheses.

Survey Development

The purpose of using a survey for this project was to gather data from the campus population at WPI that would allow us to test our predetermined hypotheses about the relationship of certain factors and behaviors that impact recycling performance. After a few weeks of deliberation, we narrowed the survey down to 15 questions.

1. What is your gender?
2. What is your role on campus? (Student, Staff, Other)
3. What year are you? (if Student is selected)
4. What country are you from?
5. Where do you live? (On-campus or off-campus)
6. How often do you recycle? (Daily, 2-3 times/wk, once/wk, never)
7. Do you recycle at home? (Y/N)
8. Do you recycle on campus? (Y/N)
9. Why do you recycle? (lists multiple reasons why people recycle according to research)
10. Why don’t you recycle more often? (if once or never is selected on #6)
11. Did your High School (HS) have a recycling program?

12. How familiar are you with recycling guidelines? (extremely, very, moderately, slightly, not familiar at all)
13. How effectively does WPI display proper recycling guidelines and behaviors? (extremely, very, moderately, slightly, not at all effective)
14. Do you find recycling on campus confusing? (extremely, very, moderately, slightly, not confusing at all)
15. Is there a need for more recycling facilities (bins, containers, etc.)? (Y/N)

We made sure to organize our questions based on our predetermined hypotheses concerning Demographics, Recycling Behavior/Experience, Knowledge/Familiarity of Recycling, and Clarity/Ease of Recycling. Questions 1-5 were tailored to gather data for the demographics of respondents. Questions 6-11 were developed to gather data to show the recycling behaviors and experiences of the respondents. Questions 12 and 13 served the purpose of illustrating the respondents' knowledge and familiarity with recycling behaviors and policies on campus. Finally, questions 14 and 15 were responsible for assessing the respondents' opinions on the clarity and ease of recycling on campus.

The entire process of constructing the survey was completed using the survey software Qualtrics. Qualtrics is a very efficient web-based software that allows users to create surveys and generate reports, enabling them to do surveys, feedback, and polls using a variety of distribution methods. Using Qualtrics allowed our team to construct our survey in a very organized and efficient manner, simplifying the process of distribution, data collection, and analysis.

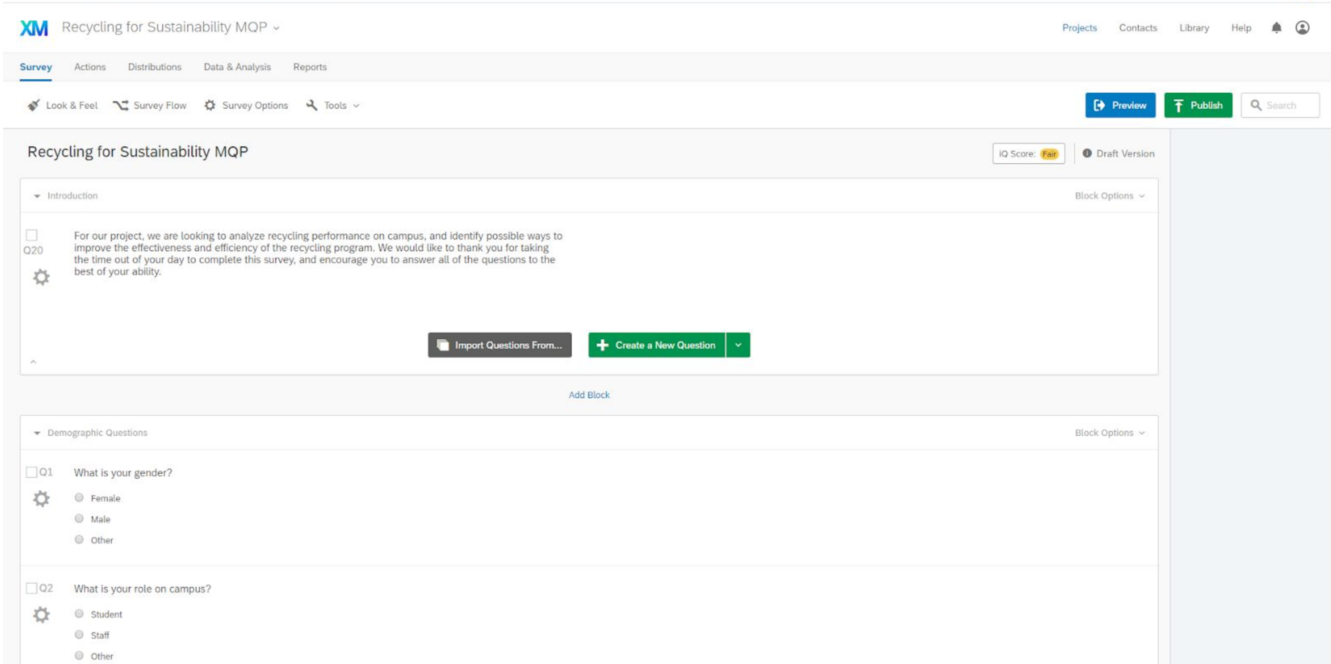

Figure 3: Pictured above is the survey development platform we used for this project, Qualtrics, and its many functions.

Distribution Method

Based on our predetermined hypotheses, we decided to distribute the survey to undergrad students, graduate students, and staff. This would allow us to make conclusions about the significance of different factors of recycling among the three different groups. Within the Qualtrics software, there is a distribution option via an anonymous email link, with a few distribution lists in the system from previous projects in the WPI Qualtrics system. We found distribution lists for undergrads, graduate students, and staff, and distributed our survey to each group. The survey was accessible via phone or computer and was compatible and easy to navigate on both platforms (See Appendix D for visual layout). Recipients of this email responded on a voluntary basis, in other words, it was required to complete our survey, each recipient had the choice of whether to participate.

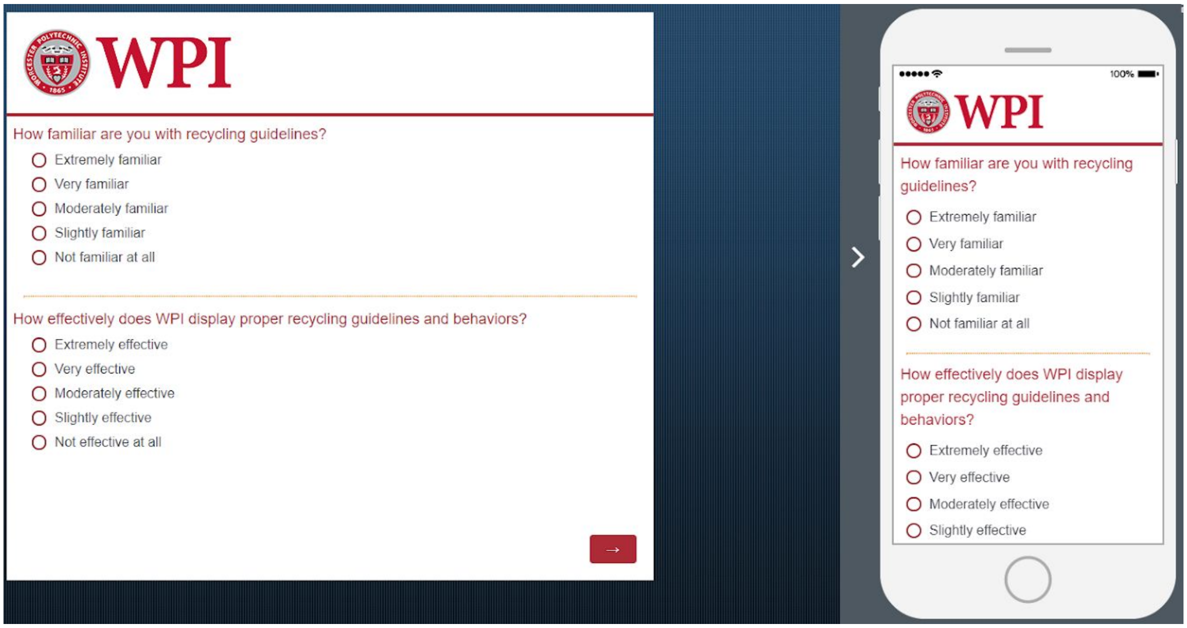

Figure 4. Pictured above is the display of the survey from the respondent's view. On the left side is the computer view and on the right side is the smartphone view.

This impacted our collected data because there was a potential presence of response bias among the respondents. This is an assumption that perhaps the people who are most passionate about recycling and waste management will be more likely to want to fill out our survey, and conversely, those who may not be as passionate about recycling may not want to fill out the survey. This was important to consider because we may have unintentionally missed out on a sample of people's recycling behaviors and expertise could provide more suitable feedback for needed areas of improvement for recycling on campus. However, we were still able to analyze the data we collected and made conclusions on this data, so we considered the distribution of our survey a successful process.

Survey Results

We received a total of 212 responses to our survey for this project. Using Qualtrics, we were able to organize the collected data for each question based on the hypothesis it was meant to assess. The results of the Demographics questions are as follows:

- What is your gender?

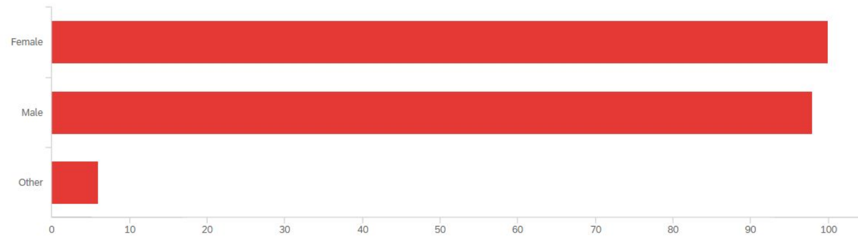

Table 2: Collected responses from our survey regarding the gender of respondents.Female-100, Male-98, Other-6.

- Undergrad v. Grad?

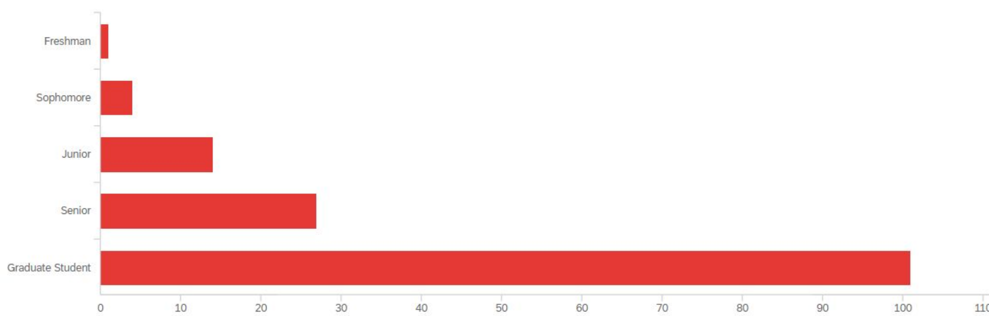

Table 3: Collected responses from the survey regarding the YOG of student respondents.Undergrad-101, Graduate-46.

- Student v. Staff?

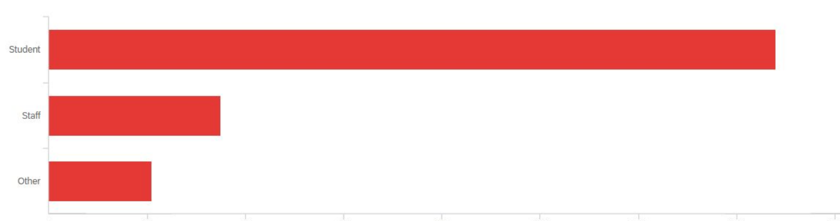

Table 4: Collected responses from the survey regarding role on campus (student or staff member). Student-148, Staff-56.

For the questions regarding recycling behavior and experience the results were as follows:

- How often do you recycle?

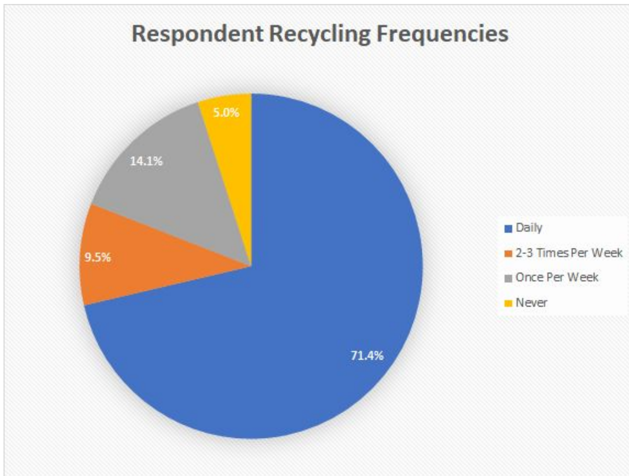

Figure 5: Collected responses from the survey regarding recycling behavior on campus.

- Did your HS have a recycling program?

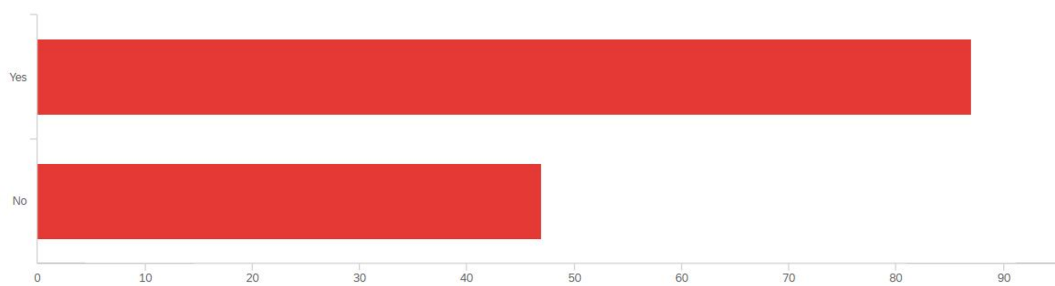

Table 5: Collected responses from the survey regarding HS recycling programs. Yes-87, No-47.

For the questions tailored to discuss knowledge of recycling policies the results were as follows:

- How familiar are you with recycling guidelines?

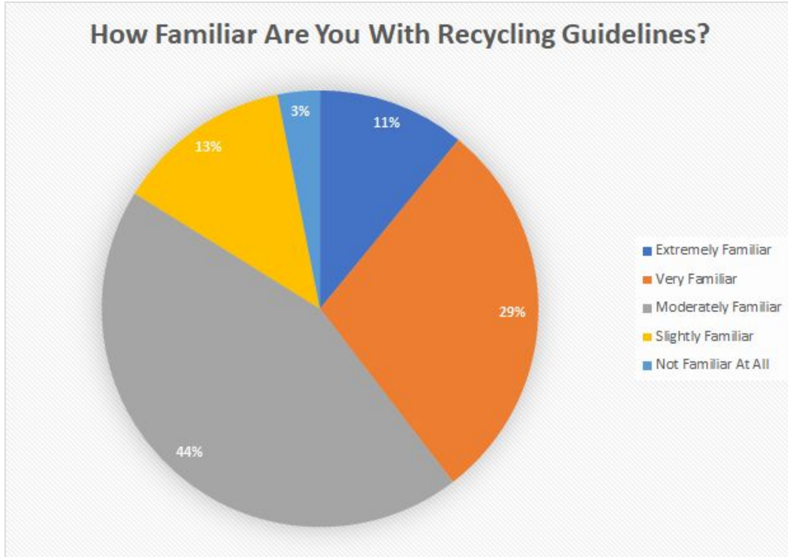

Figure 6. Collected responses from survey for knowledge of recycling guidelines.

- How effectively does WPI display proper recycling guidelines and behaviors?

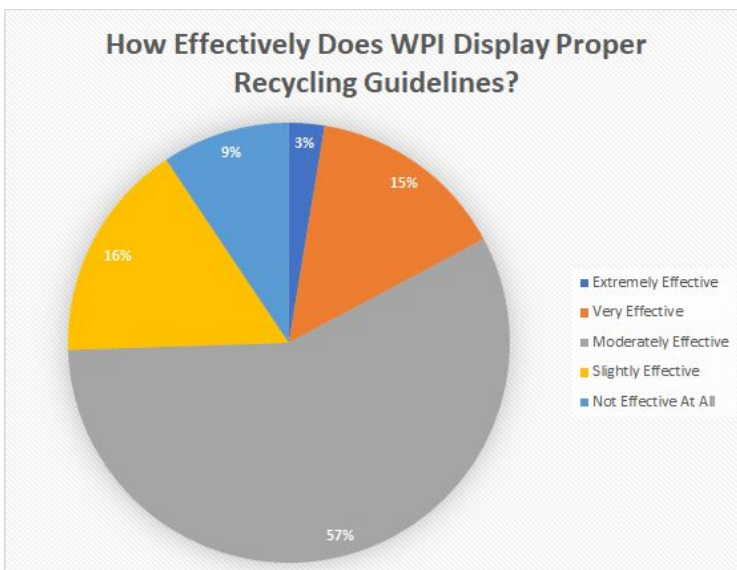

Figure 7. Collected responses from the survey regarding WPI's display of proper recycling guidelines.

For the questions regarding clarity and ease of recycling on campus the results were as follows:

- Do you find recycling on campus confusing?

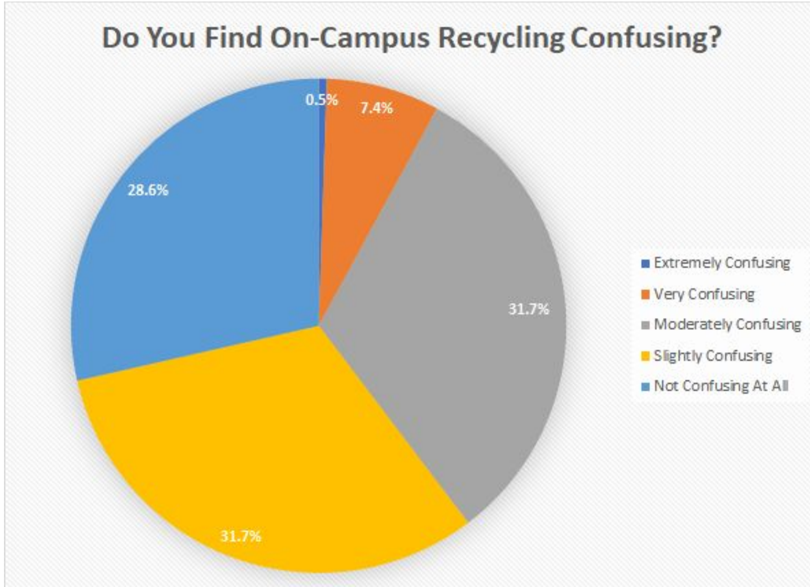

Figure 8. Collected responses from the survey regarding the clarity of recycling on campus.

- Is there a need for more recycling facilities (bins, containers, etc.)?

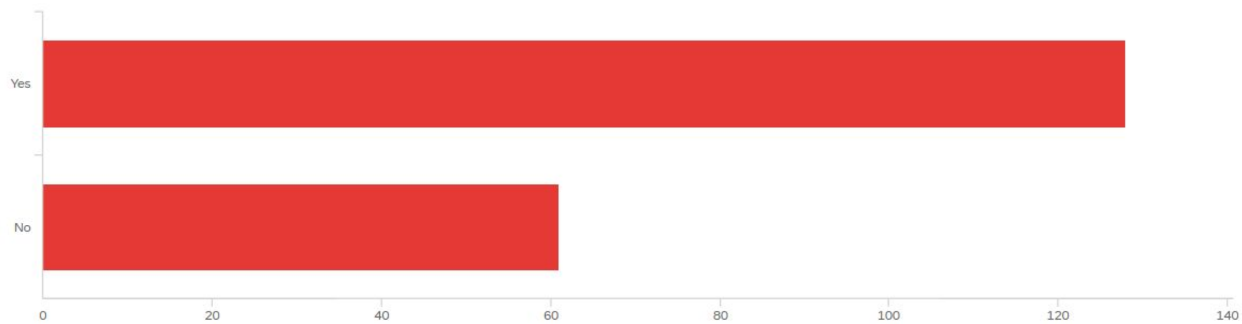

Table 6: Collected responses from the survey regarding the need for more recycling facilities on campus. Yes-128, No-61.

Any difference between the total respondents for each question and the total surveys completed (212) can be explained by human error. Our survey was entirely voluntary, leaving opportunities for questions to be skipped over or not answered. None of the questions were mandatory or required to be answered because there was no way to enforce this using the Qualtrics software. As a result, there were a few instances where respondents chose to skip a question, leaving a few gaps between the total collected answers to a question and the total surveys completed. This did not affect our analysis, however, as we still had sufficient data to make conclusions based on our predetermined hypotheses, and reveal what steps were next to implement improvements to the current recycling performance on campus.

Analysis

For the first hypothesis regarding demographics, we did three analyses based on three different criteria. We used contingency tables to assess differences in gender, age, and education level and their willingness to recycle. In our analysis, we found that we had a close to even split between male and female respondents. Once we put the results into a contingency table with the observed data, we were able to calculate the expected data and the chi-square data. The result of the chi-square test was that there is less than 90% confidence that gender plays a role in someone's willingness to recycle. Meaning that gender and willingness to recycle are independent. (See Appendix D)

When comparing students and staff, we found that students had almost three times more responses than staff, this could have led to some discrepancies in the data, but this was not the case. There was a fair distribution of responses to how often students recycle. The trouble in this analysis resulted from the response bias amongst the staff. Response bias is the tendency of a person to answer questions on a survey untruthfully because they may feel pressure to give answers that are socially acceptable. This is evident in the 89.1% of staff that responded that they recycle daily, leaving only 6 respondents that recycle less frequently. In our analysis of students and staff, we were able to find that with more than 99.5% confidence, age and education play a role in someone's willingness to recycle. Meaning that age, education, and willingness to recycle are dependent. (See Appendix E)

In addition to the previous test between staff and students, we wanted to see how the willingness to recycle differed between undergraduate and graduate students in terms of education level. There were a little more than twice the amount of responses from graduate students than there were from undergrad students. There may be some slight response bias in this question as well because 72.7% of undergrads said that they recycle daily. If this were the case, there would be no need for this project. In our analysis of undergraduate and graduate students, we were able to find that with more than 97.5% confidence, education plays a role in someone's willingness to recycle. Meaning that education and willingness to recycle are dependent. (See Appendix F)

For the second hypothesis regarding recycling behavior and experience, we used contingency tables to assess differences in exposure to recycling practices before coming to WPI. We achieved this by asking the students if their secondary school had a recycling program and how often they recycled. Using contingency tables and the chi-square test, we were able to find that, with 95% confidence that previous experience with high school recycling programs makes someone more willing to recycle. Meaning that previous experience with recycling and willingness to recycle are dependent. (See Appendix G)

For the third hypothesis regarding knowledge and understanding of recycling practices, we used contingency tables to assess whether familiarity of recycling practices on-campus has an effect on whether a person will recycle or not. We asked people how familiar they were with recycling practices and guidelines on a scale from extremely familiar to not at all familiar and placed this into a contingency table with how frequently those respondents recycled and ran a chi-square test. In the analysis of this data, we found that, with 99.5% confidence, someone's familiarity with recycling practices has an influence on if they will recycle or not. Meaning that familiarity with recycling guidelines and willingness to recycle are dependent. (See Appendix H)

For the fourth hypothesis regarding the accessibility and understanding of on-campus recycling practices, we used contingency tables to assess a person's willingness to recycle, as well as if having prior experience with recycling contributes to the opinion of needing more bins on campus. For the first test to find whether someone will recycle or not based on how clear they find WPI's on-campus recycling guidelines, we asked people to rate how confusing they thought WPI's recycling guidelines were and then we placed that data into a contingency table with how often those respondents recycle and ran a chi-square test. In the analysis of this data, we found that an understanding of WPI's on-campus recycling guidelines and practices has no influence on their willingness to recycle or not. Meaning that understanding of recycling guidelines and willingness to recycle are independent. (See Appendix I)

We wanted to see if people thought that having more bins would be necessary for this project. So we put the responses to if people think that there is a need for more recycling facilities on campus into a contingency table with whether or not the respondents had prior experience with recycling programs. In addition to the overwhelming 106 to 21 response in favor of adding more bins, we found that, with 95% confidence, that people who thought we need more recycling bins have had prior experience with recycling initiatives. We believed that whether a person had past experience with recycling in a HS program would support their opinion of the need to add more bins and facilities on campus. In other words, we thought that their opinions of whether we should add more bins would have strong support because they have previous experience with recycling in a school environment and would, therefore, know how effective certain methods of improving performance are. As a result, we tested to see if a person's opinion on the need for more bins was dependent upon whether they had previous experience in a recycling program. (See Appendix J)

Conclusions

The results from the analysis allow us to conclude that age, education level, previous experience with recycling, and familiarity of recycling guidelines all play a major part in someone's willingness to recycle. This analysis also showed us the importance of adding more bins. Gender and an understanding of recycling guidelines do not affect someone's willingness to recycle. With this knowledge, we can accept the last null hypothesis that states that the clarity of recycling procedures and the opinion of whether to add more bins are independent.

Testing Improvements

Requirements, Process, Parameters

We were able to successfully run this experimental test with assistance from the WPI facilities department. Due to the time constraints of the project, we only had the luxury of running this test for one week. We reached out to our sponsor, Liz Tomaszewski, with our plans for testing the effect of adding bins to a building, and she emailed the head of facilities, Terry Pellerin, to see which building the facilities department would like to run the test on. It was decided for the Atwater Kent building to be the location of our experiment. Prior to meeting up with a facilities employee, we walked through Atwater to assess the current state of recycling facilities in the building. We walked throughout the hallways and study areas on each of the three floors of the building, looking at the number of bins present, location, visibility, and accessibility of bins, and identified areas that lacked bins and could benefit from adding more bins. We compiled our observations into a Word document (See Appendix K) and notified our sponsor of our observations and how many bins we planned to add.

The next step in the process was to meet with a facility maintenance employee and gather the bins we needed. On the morning of the first day of the week-long test, we picked up the bins in a garage at the Rec Center and loaded them into a facility maintenance truck, where they were transported to Atwater. There, we unloaded the bins and placed them throughout the building in the predetermined areas of need that we identified in the walkthrough.

Figure 9: Recycling bins used for distribution throughout Atwater Kent Laboratories during experimental testing.

Due to a miscommunication on our part, we were only able to collect measurements of the total recyclable material collected for the final day of the test and the day after we removed the bins that were added. When we agreed upon the one-week timeframe that we would be running this test, we assumed that the facilities workers would be able to collect data throughout the week. Midway through the week, it was revealed that we needed to collect the data manually, as the employees were busy and unable to document the total amount of recyclable materials collected. We reached out to our sponsor and informed them of our mistake and were able to arrange a way to collect data at the end of the one-week time frame. This miscommunication affected the results of the test only in the quantity of data accounted for and recyclable material collected. Instead of having measurements for each day of the seven-day test, we only had two days/sets of measurements. One set was collected on the final day of the test, representing recycling performance with bins added. The other set was collected a day after we removed the bins that we added, representing recycling performance with the original setup and layout of bins in the building.

Recyclable materials were left aside in a room by where we were able to access it and collect measurements. This was done by the morning custodian and the night custodian, allowing our team to measure the recyclable materials collected in the morning and at night. After our last measurement at night, we removed all of the bins that we added, resetting the recycling facilities back to its original state prior to the test. Finally, on the day after we removed the bins that we added, we weighed the recyclable materials collected to compare the data of our test to when the test ended. This allowed our team to conclude whether the test was successful and if it could be beneficial to perform similar tests on other buildings on campus. Collecting measurements every day of the test would have allowed us to make a conclusion with stronger data to back it up but our results still showed a clear effect of adding bins, as the recyclable material collected after we removed the bins was significantly less than when extra bins were present throughout the building. This is discussed further in the results section.

Figures 10-11: Process of weighing one of the individual bins of recyclable materials collected during our experimental test at Atwater Kent Laboratories.

The process of weighing the recyclable material collected was simple and effective. We first weighed an empty recycling bin, so that we could subtract that weight from a bin with recyclables in it in order to calculate the weight of the recyclables alone. Using a step-on scale, we weighed each bin in the room and collected the weight of recyclables, organizing them in an excel file (See Table 7).

Figure 12: Step-on scale used to weigh each bin of collected recyclables for experimental testing.

Results/Analysis

The data collected on the final morning and night of the test were as follows:

Empty Bin	23

2/27/2020	Bin #	Weight(lbs.)	Weight of Recyclables(lbs.)	Total Recyclables(lbs.)	
AM	1	51.2	28.2	131.8	Test in progress
	2	47.9	24.9		
	3	59.3	36.3		
	4	65.4	42.4		
PM	3	65.8	42.8	96.7	
	4	76.9	53.9		
2/29/2020	1	29.5	6.5	6.5	Original facilities

Table 7: Collected data for recyclable materials in Atwater Kent Laboratories during and after experimental testing of adding extra bins.

The total amount of recyclables collected with the extra bins was 228.5 lbs. We only measured two of the bins at night because materials were only added to these two bins and the others were the same as we measured in the morning. We removed the bins after the last measurement on 2/27, waited for a day and measured again on 2/29. There was only one bin with recyclable material in it and the total amount of recyclables collected dropped to 6.5 pounds. This data clearly shows a difference of over 200 pounds in recycling performance when we added bins versus after removal of the bins.

Conclusions

The data we collected provides strong evidence that the test was successful in improving recycling performance. There was a significant difference in the amount of recyclable material collected when we added bins versus when we removed the bins and reset the facilities back to the original layout. We also believe that performing similar tests on other buildings, either periodically or all at once, will yield similar results and lead to improving recycling performance on campus as a whole. There were definitely areas of improvement in the process of the test itself which will be useful for potential tests in the future. Our team believes that running the test for longer than one week and collecting data every day will only strengthen the amount of data to back up conclusions made from the test. Due to time constraints and miscommunication on our part, our test lacked in these areas, but we were confident in our conclusion and the impacts of the test as a whole.

Conclusions and Recommendations

Conclusions

The goal of this project was to identify ways to improve recycling performance on campus. We were successful in analyzing different factors and behaviors that influence recycling among the campus population. Testing potential improvements based on this analysis was instrumental in our conclusion for improving the recycling performance on campus. Our team was able to make the following conclusions as a result of this project.

Recycling performance is dependent upon a person's age, education level, previous experience with recycling, and familiarity of recycling guidelines. There are some topics addressed in this study that WPI cannot control, such as age education level, and previous experience with recycling, but WPI can control how familiar its population is with recycling guidelines. This study shows that someone is more willing to recycle if they are familiar with recycling guidelines. The fact that there are people on WPI's campus that aren't familiar at all with recycling guidelines shows that there is a need for improvement in this area. WPI's Office of Sustainability has attempted to satisfy this need by starting a "Green Team". The "Green Team" is a group of like-minded students whose goal is to educate other students on the importance of recycling, why they should recycle, and proper recycling guidelines.

Spreading more bins, a.k.a. recycling facilities throughout campus is a successful method for improving recycling performance. This study showed that adding bins greatly increased the amount of recyclables placed into recycling bins. Following this knowledge, if this were to be replicated across campus, the recycling rate will greatly increase as people have more access to recycling bins and won't have to go out of their way to recycle. With more opportunities to recycle for people on campus, there will be a higher amount of recyclable material collected, leading to increased recycling performance.

Increasing recycling efficiency and minimizing waste is a continuous process, requiring consistent research, experimentation, and project work. As we have previously stated, increasing the recycling rate at WPI will take time and will be a group effort. Students, professors, and other staff need to work together to address the current lack of recycling.

Recommendations

Previous project work on improving recycling performance has concluded that this is a continuous project and issue that needs to be acknowledged and addressed on campus for years to come. Past IQPs and MQPs have suggested that more project work be completed to attempt to identify and implement improvements to boost recycling performance on campus. To build off of these past projects, this project will serve to be a benchmark for future improvements that can be made to the current recycling program at WPI. We recommend for our sponsors do the following:

- Implement more experimental tests like the one performed in this project on other buildings on campus, whether it's adding more bins or rearranging the setup and display of the layout. Other tests could assess how and where bins are displayed affect a person’s willingness to recycle. Regardless, it will be important to gather opinions from as many sources as possible.
- Continue to gather data on recycling performance on campus to keep track of knowledge, experience and recycling behavior of students and staff on campus.
- Seek assistance from another MQP team in the future when conducting further research into recycling on campus.

The above recommendations allow our sponsor to expand on the results of our project, and apply our procedures and methods to improve recycling performance in other areas on campus at WPI. Past WPI project teams have suggested the following: “Future teams working toward initiatives on campus that affect community recycling behavior or infrastructure should consider and understand student, staff, and faculty motivation and awareness regarding recycling. Having a better understanding of the effectiveness of their initiative and how it will change community behavior will allow the team to structure their program to produce the changes that they desire.” (DiMestico et al., 2017). The more projects that are completed by teams in the future will only increase the overall knowledge of recycling habits, familiarity, and attitudes towards recycling of campus inhabitants. This in turn will expand the interaction of campus inhabitants with recycling on campus and improve overall recycling performance. Improving recycling performance is not a one time project, and we hope our sponsor actively pursues methods to identify and implement improvements to stay up to date with the shifts and changes in society as time progresses into the future.

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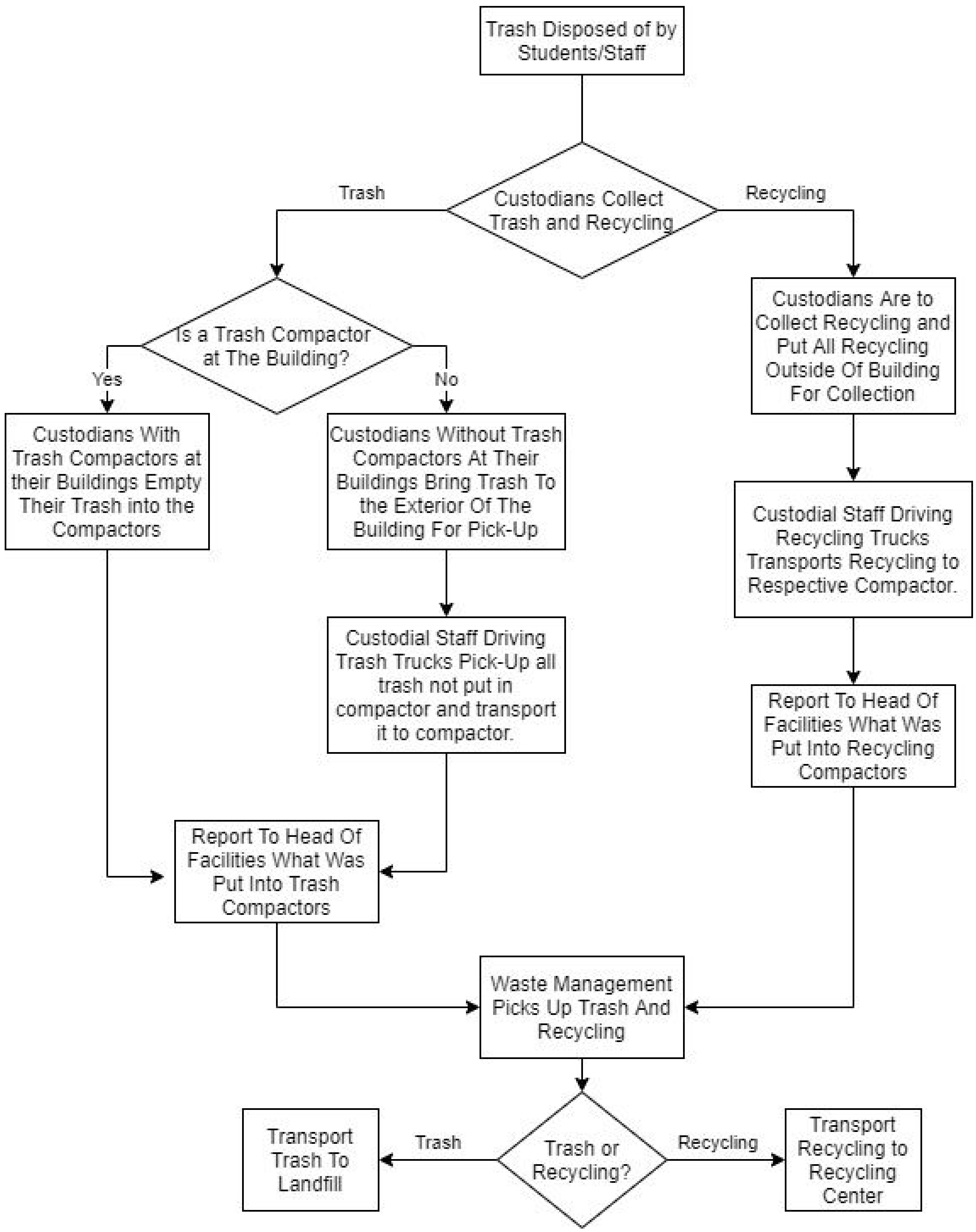
Appendices

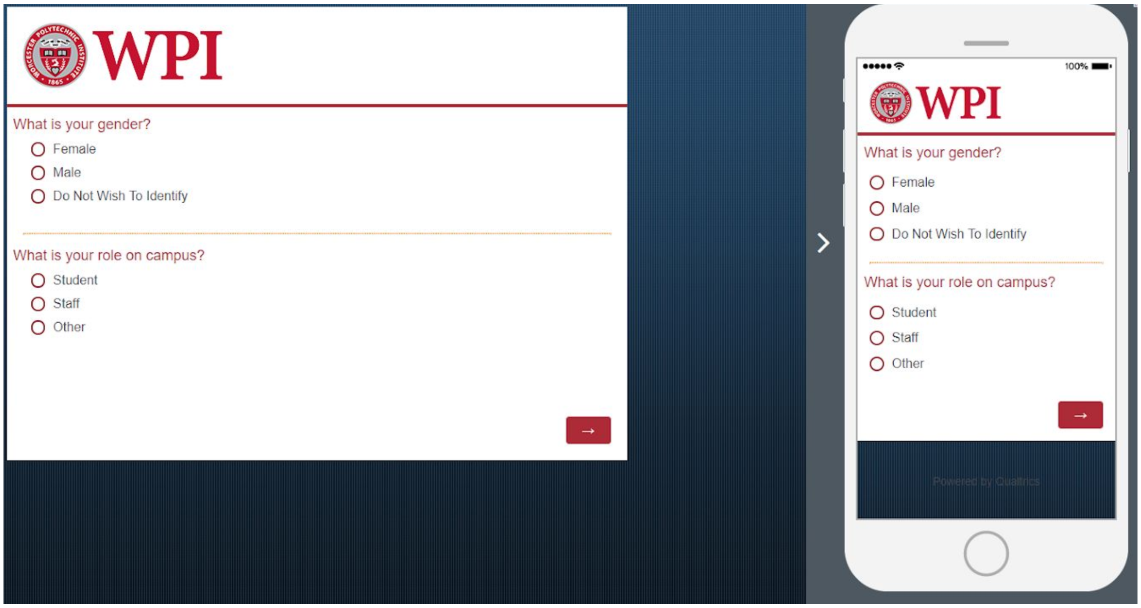
A. Chi-Square Distribution Table

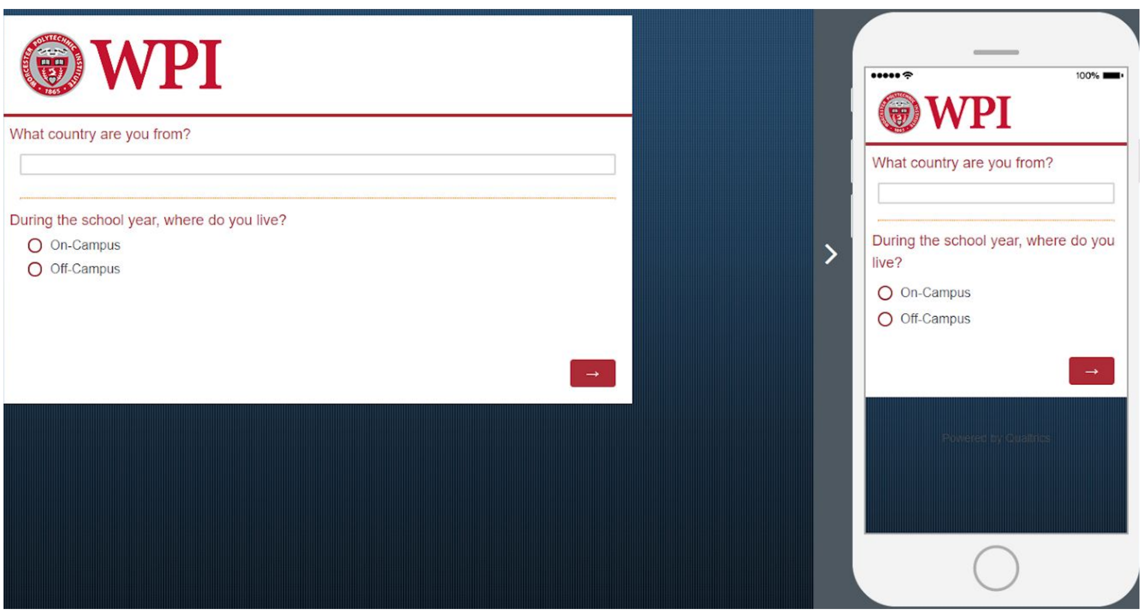
	P										
DF	0.995	0.975	0.2	0.1	0.05	0.025	0.02	0.01	0.005	0.002	0.001
1	.0004	.00016	1.642	2.706	3.841	5.024	5.412	6.635	7.879	9.55	10.828
2	0.01	0.0506	3.219	4.605	5.991	7.378	7.824	9.21	10.597	12.429	13.816
3	0.0717	0.216	4.642	6.251	7.815	9.348	9.837	11.345	12.838	14.796	16.266
4	0.207	0.484	5.989	7.779	9.488	11.143	11.668	13.277	14.86	16.924	18.467
5	0.412	0.831	7.289	9.236	11.07	12.833	13.388	15.086	16.75	18.907	20.515
6	0.676	1.237	8.558	10.645	12.592	14.449	15.033	16.812	18.548	20.791	22.458
7	0.989	1.69	9.803	12.017	14.067	16.013	16.622	18.475	20.278	22.601	24.322
8	1.344	2.18	11.03	13.362	15.507	17.535	18.168	20.09	21.955	24.352	26.124
9	1.735	2.7	12.242	14.684	16.919	19.023	19.679	21.666	23.589	26.056	27.877
10	2.156	3.247	13.442	15.987	18.307	20.483	21.161	23.209	25.188	27.722	29.588
11	2.603	3.816	14.631	17.275	19.675	21.92	22.618	24.725	26.757	29.354	31.264
12	3.074	4.404	15.812	18.549	21.026	23.337	24.054	26.217	28.3	30.957	32.909
13	3.565	5.009	16.985	19.812	22.362	24.736	25.472	27.688	29.819	32.535	34.528
14	4.075	5.629	18.151	21.064	23.685	26.119	26.873	29.141	31.319	34.091	36.123
15	4.601	6.262	19.311	22.307	24.996	27.488	28.259	30.578	32.801	35.628	37.697
16	5.142	6.908	20.465	23.542	26.296	28.845	29.633	32	34.267	37.146	39.252
17	5.697	7.564	21.615	24.769	27.587	30.191	30.995	33.409	35.718	38.648	40.79
18	6.265	8.231	22.76	25.989	28.869	31.526	32.346	34.805	37.156	40.136	42.312
19	6.844	8.907	23.9	27.204	30.144	32.852	33.687	36.191	38.582	41.61	43.82
20	7.434	9.591	25.038	28.412	31.41	34.17	35.02	37.566	39.997	43.072	45.315

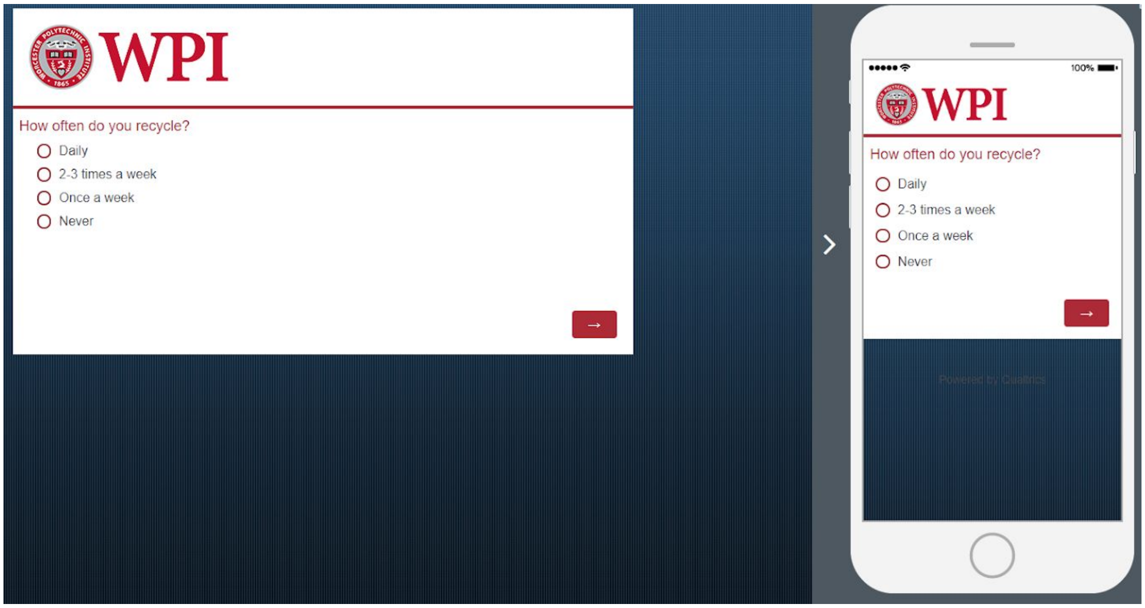
B. Waste Disposal/Recycling Flow Chart

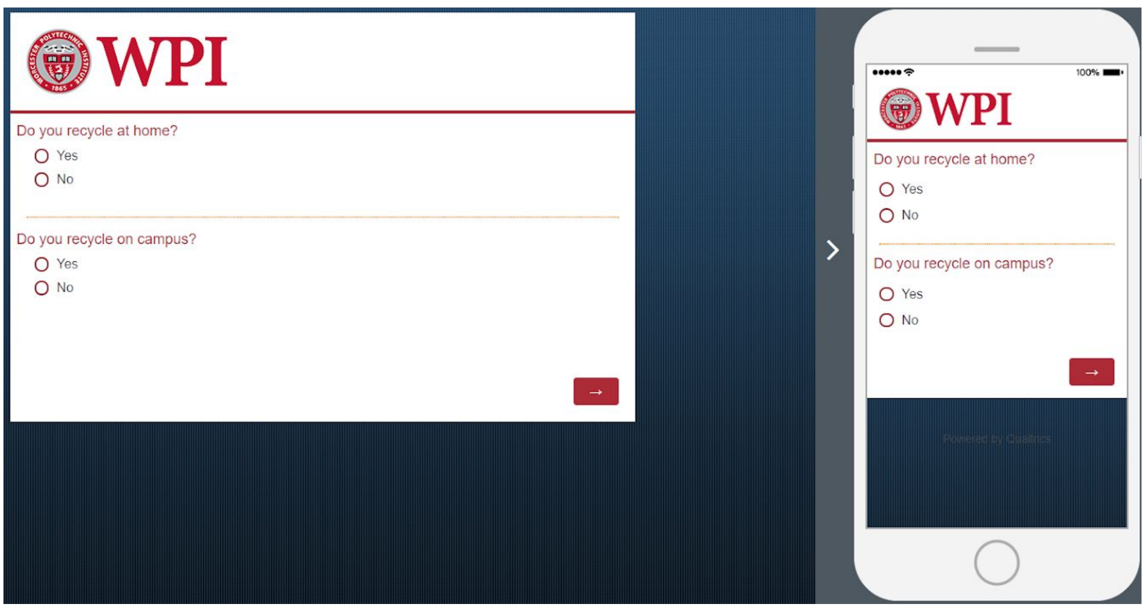


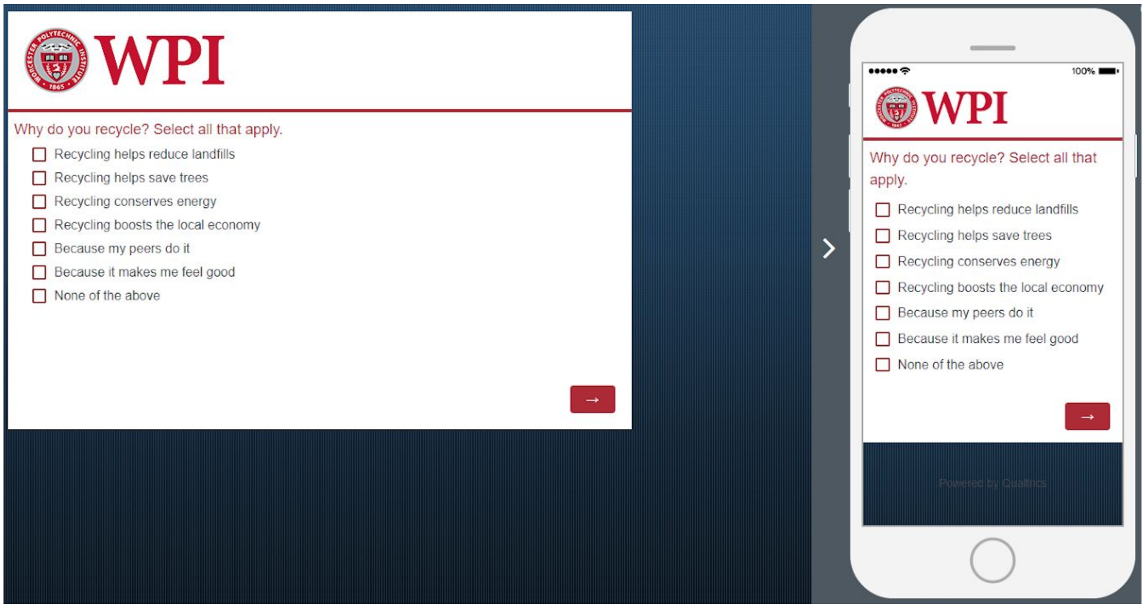
C. Qualtrics Survey

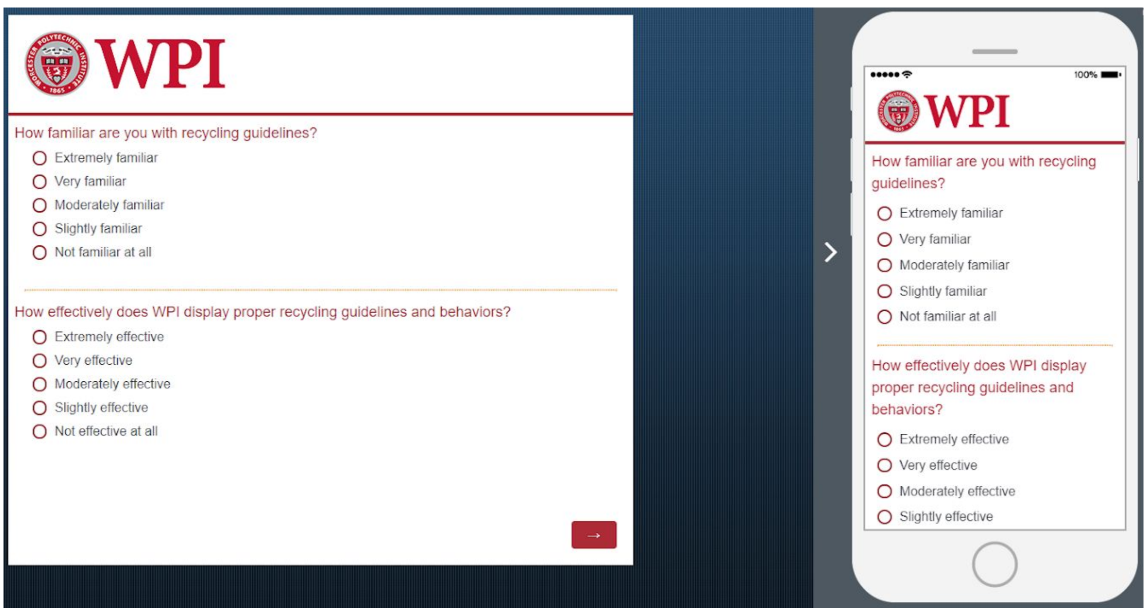


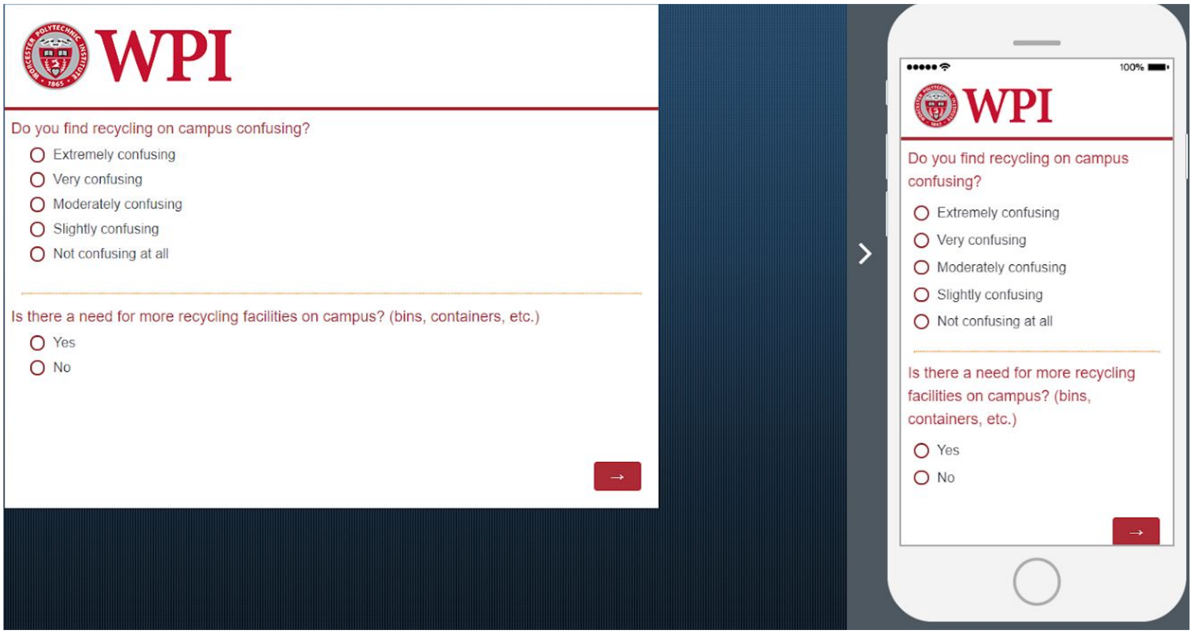



WPI
How often do you recycle?
Daily
2-3 times a week
Once a week
Never
→


WPI
Do you recycle at home?
Yes
No
Do you recycle on campus?
Yes
No
→


WPI
Why do you recycle? Select all that apply.
Recycling helps reduce landfills
Recycling helps save trees
Recycling conserves energy
Recycling boosts the local economy
Because my peers do it
Because it makes me feel good
None of the above
→
100%
WPI
Why do you recycle? Select all that apply.
Recycling helps reduce landfills
Recycling helps save trees
Recycling conserves energy
Recycling boosts the local economy
Because my peers do it
Because it makes me feel good
None of the above
→


WPI
How familiar are you with recycling guidelines?
Extremely familiar
Very familiar
Moderately familiar
Slightly familiar
Not familiar at all
How effectively does WPI display proper recycling guidelines and behaviors?
Extremely effective
Very effective
Moderately effective
Slightly effective
Not effective at all
→
100%
WPI
How familiar are you with recycling guidelines?
Extremely familiar
Very familiar
Moderately familiar
Slightly familiar
Not familiar at all
How effectively does WPI display proper recycling guidelines and behaviors?
Extremely effective
Very effective
Moderately effective
Slightly effective


WPI
Do you find recycling on campus confusing?
Extremely confusing
Very confusing
Moderately confusing
Slightly confusing
Not confusing at all
Is there a need for more recycling facilities on campus? (bins, containers, etc.)
Yes
No
WPI
Do you find recycling on campus confusing?
Extremely confusing
Very confusing
Moderately confusing
Slightly confusing
Not confusing at all
Is there a need for more recycling facilities on campus? (bins, containers, etc.)
Yes
No

D. Chi-Square Independence Test: *Recycling Performance vs Gender*

Observed	Male	Female	Total
Daily	64	73	137
2-3 Times Per Week	11	8	19
Once a week	15	13	28
Never	5	5	10
Total	95	99	194

Expected	Male	Female
Daily	67.1	69.9
2-3 Times Per Week	9.3	9.7
Once a week	13.7	14.3
Never	4.9	5.1

Chi Squared	Male	Female
Daily	0.14896	0.13060
2-3 Times Per Week	0.26145	0.35950
Once a week	0.11071	0.12774
Never	0.00213	0.00213
Result	1.14321189	
	3 degrees freedom	
	Insignificant	

% of responses	Male	Female
Daily	33.0%	37.6%
2-3 Times Per Week	5.7%	4.1%
Once a week	7.7%	6.7%
Never	2.6%	2.6%

E. Chi-Square Independence Test: *Recycling Performance vs Role on Campus (Student/Staff)*

Observed	Student	Staff	Total
Daily	93	49	142
2-3 Times Per Week	16	3	19
Once a week	26	2	28
Never	9	1	10
Total	144	55	199

Expected	Student	Staff
Daily	102.8	39.2
2-3 Times Per Week	13.7	5.3
Once a week	20.3	7.7
Never	7.2	2.8

Chi Squared	Student	Staff
Daily	1.02297	1.94155
2-3 Times Per Week	0.31676	1.68938
Once a week	1.26664	16.46630
Never	0.34567	3.11106
Results	**26.16033441**	
	3 degrees freedom	
	100% Significance	

% of responses	Student	Staff
Daily	46.7%	24.6%
2-3 Times Per Week	8.0%	1.5%
Once a week	13.1%	1.0%
Never	4.5%	0.5%

F. Chi-Square Independence Test: *Recycling Performance vs Undergrad Students/Graduate Students*

Observed	Undergrad	Graduate	Total
Daily	32	61	93
2-3 Times Per Week	6	10	16
Once a week	3	23	26
Never	3	6	9
Total	44	100	144

Expected	Undergrad	Graduate
Daily	28.4	64.6
2-3 Times Per Week	4.9	11.1
Once a week	7.9	18.1
Never	2.8	6.3

Chi Squared	Undergrad	Graduate
Daily	0.40126	0.21050
2-3 Times Per Week	0.20576	0.12346
Once a week	8.14918	1.06294
Never	0.02083	0.01042
Results	**10.18433622**	
	3 degrees freedom	
	97.5% significance	

% of responses	Undergrad	Graduate
Daily	22.2%	42.4%
2-3 Times Per Week	4.2%	6.9%
Once a week	2.1%	16.0%
Never	2.1%	4.2%

G. Chi-Square Independence Test: *Recycling Performance vs Previous Experience*

Observed	No HS Program	HS Program	Total
Daily	10	72	82
2-3 Times Per Week	3	24	27
Once a week	8	10	18
Total	21	106	127

Expected	No HS Program	HS Program
Daily	13.55905512	68.44094488
2-3 Times Per Week	4.464566929	22.53543307
Once a week	2.976377953	15.02362205

Chi Squared	No HS Program	HS Program
Daily	1.266687333	0.175928796
2-3 Times Per Week	0.71498543	0.089373179
Once a week	3.154597309	2.523677847
Results	7.925249895	
	2 degrees freedom	
	95% significance	

% of responses	No HS Program	HS Program
Daily	7.9%	56.7%
2-3 Times Per Week	2.4%	18.9%
Once a week	6.3%	7.9%

H. Chi-Square Independence Test: ***Recycling Performance vs Knowledge of Recycling Guidelines***

Observed	Extremely	Very	Moderately	Slightly	Not At All	Total
Daily	19	53	56	11	1	140
2-3 Times Per Week	1	1	9	6	1	18
Once a week	1	2	17	4	3	27
Never	1	1	3	4	2	11
Total	22	57	85	25	7	196

Expected	Extremely	Very	Moderately	Slightly	Not At All
Daily	15.71	40.71	60.71	17.86	5.00
2-3 Times Per Week	2.02	5.23	7.81	2.30	0.64
Once a week	3.03	7.85	11.71	3.44	0.96
Never	1.23	3.20	4.77	1.40	0.39

Chi Squared	Extremely	Very	Moderately	Slightly	Not At All
Daily	0.5682	2.8479	0.3969	4.2746	16.0000
2-3 Times Per Week	1.0412	17.9326	0.1584	2.2867	0.1276
Once a week	4.1234	17.1232	1.6466	0.0773	1.3814
Never	0.0551	4.8355	1.0448	1.6860	1.2915
Results	69.9859513				
	12 degrees freedom				
	99.5% significance				

% of responses	Extremely	Very	Moderately	Slightly	Not At All	Total
Daily	10%	27%	29%	6%	1%	71%
2-3 Times Per Week	1%	1%	5%	3%	1%	9%
Once a week	1%	1%	9%	2%	2%	14%
Never	1%	1%	2%	2%	1%	6%
Total	11%	29%	43%	13%	4%	

I. Chi-Square Independence Test: *Recycling Performance vs Clarity of Recycling Guidelines at WPI*

Observed	Extremely	Very	Moderately	Slightly	Not At All	Total
Daily	1	11	41	43	42	138
2-3 Times Per Week	1	1	5	6	5	18
Once a week	1	2	12	7	5	27
Never	1	1	2	4	2	10
Total	4	15	60	60	54	193

Expected	Extremely	Very	Moderately	Slightly	Not At All
Daily	2.86	10.73	42.90	42.90	38.61
2-3 Times Per Week	0.37	1.40	5.60	5.60	5.04
Once a week	0.56	2.10	8.39	8.39	7.55
Never	0.21	0.78	3.11	3.11	2.80

Chi Squared	Extremely	Very	Moderately	Slightly	Not At All
Daily	3.4600	0.0069	0.0882	0.0002	0.2734
2-3 Times Per Week	0.3931	0.1592	0.0710	0.0272	0.0003
Once a week	0.1940	0.0048	1.0837	0.2775	1.3050
Never	0.6284	0.0496	0.6147	0.1986	0.3183
Results	7.34443761				
	12 degrees freedom				
	Insignificant				

% of responses	Extremely	Very	Moderately	Slightly	Not At All	Total
Daily	1%	6%	21%	22%	22%	72%
2-3 Times Per Week	1%	1%	3%	3%	3%	9%
Once a week	1%	1%	6%	4%	3%	14%
Never	1%	1%	1%	2%	1%	5%
Total	2%	8%	31%	31%	28%	

J. Chi-Square Independence Test: ***High School Program vs Opinion of Adding Bins on Campus***

		More Bins ?		
	Observed	**Yes**	**No**	**Total**
Did your HS have recycling?	**Yes**	64	18	**82**
	No	42	3	**45**
	Total	**106**	**21**	**127**

Expected	**Yes**	**No**
Yes	68.44	13.56
No	37.56	7.44

Chi Squared	**Yes**	**No**
Yes	0.30816	1.09567
No	0.46957	6.57400
Results	8.4474	
	1 degrees freedom	
	95% Significance	

% of Responses	Yes	No	**Total**
Yes	50.39%	14.17%	**64.57%**
No	33.07%	2.36%	**35.43%**
Total	**83.46%**	**16.54%**	

K. Atwater Kent Walkthrough Observations

Main Floor
- Side exit to AK 116 (next to door at bottom of stairs)
- Side exit leading to Fuller Labs (door near vending machine)
- Outside front entrance near the staircase
- Recycling bin needed in AK 111

Second Floor
- ECE Department main office
- AK 227 only has 1 small recycling/trash bin, fairly big room (need bins at each door)
- Room 202, 212A
- Across from elevator/student mailboxes

Third Floor
- Near 321 at top of stairs
- Hallways (outside 310, 314, 315)

All: Recycling bins in bathrooms (currently only trash bins)

Note: couldn't get into all classrooms/offices, but these are areas of high foot traffic, so more bins in these locations increases likelihood of people recycling

Test: Run for one week, gather data prior and after launch, compare positives/negatives of test