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RESEARCH ARTICLE

Using Feedback to Improve Suburban Curbside Recycling and Reduce Contamination Rates

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ABSTRACT: Though curbside recycling is common in many parts of the U.S., contamination rates are problematic. Contamination occurs when people include nonrecyclables in recycling bins or recyclable material in the wrong recycling bin. This can lead to the entire load being hand-sorted or disposed of as trash and sent to landfills. This paper presents a case study that investigates how to influence residents in a township to sort recyclables and reduce contamination correctly. The goal was to test whether immediate feedback on a recycling quiz can improve recycling-related knowledge and confidence. Participants (N=81) were randomly assigned to one of two groups. Both groups took a survey with a quiz on their phone or computer. One group (N=45) had immediate feedback on their quiz questions in the form of seeing the correct answer immediately after answering each question, and the other group (N=36) did not receive feedback. A follow-up quiz was administered approximately one week later to assess whether their knowledge level had increased after the initial quiz. Both paired-sample t-tests and two-sample t-tests were performed. Results indicate that the group with immediate feedback significantly increased actual knowledge (a 6 percentage point increase in score on the quiz), perceived knowledge (13% increase), and confidence levels (12% increase) in recycling correctly. Further, the confidence and perceived knowledge levels were significantly greater for the group with feedback than the group without feedback. The results indicate that educating residents with immediate feedback about curbside recycling could decrease contamination rates.

KEYWORDS: Behavioral and Social Sciences, Sociology and Social Psychology, Recycling, Feedback, Reducing Contamination Rates, Curbside Contaminations.

Introduction

Our planet is in a global climate crisis, facing warming temperatures, extreme weather events, rising sea levels, and more, and immediate and long-term solutions are needed. After a United Nations report on climate change in 2022 concluded that harmful carbon emissions are at the highest level ever, scientists have declared that it is "now or never" to act on climate change and that if humanity waits any longer, it will be too late.[1] In 2023, the Synthesis Report of the Intergovernmental Panel on Climate Change (IPCC) concluded that humans are "unequivocally" responsible for climate change over the past 200 years.[2] In response to the IPCC report, the UN Secretary-General António Guterres declared, "The climate time-bomb is ticking" and "…our world needs climate action on all fronts — everything, everywhere, all at once."[3]

One of the actions needed in the fight against climate change is waste reduction. This involves reducing the use/consumption of products, reusing products, and avoiding landfills by recycling. This reduces reliance on virgin materials, produces less greenhouse gas emissions, and reduces environmental impact from landfills.[4] According to estimates from the World Bank, more than two billion tons of solid waste are globally generated annually. The World Bank reported that this annual waste generation will increase to almost four billion tons per year by 2050.[5] It is vital that people understand the full potential of recycling in regards to helping fight climate change. The World Bank has noted that behavior change and public participation are key to a functional waste system. They support designing incentives and awareness systems to encourage waste reduction, source separation, and reuse.

Many townships and communities in the United States use curbside recycling for source separation. With curbside recycling, recyclable materials are collected directly from households, typically in designated bins for pickup. This can be an efficient and convenient way to divert recyclable material from landfills and thus reduce the volume of landfills. However, residents need to understand and participate in this recovery system. A recent report from The Recycling Partnership, an NGO, estimated that 84% of Americans view recycling as a valuable public service.[6] This report estimates that only 11.9 out of 37.4 million tons of recyclable material are successfully captured by the U.S. curbside recycling system from single-family homes. This rate is only 32%, so much needs to be done to increase this rate. The report estimates that if all 37.4 million tons were placed back into productive use rather than disposed of, this would reduce U.S. greenhouse gas emissions by 96 million metric tons of carbon dioxide equivalent and conserve an annual energy equivalent of 154 million barrels of oil.[6]

The overuse of single-use plastics and limited recycling of those plastics is a significant challenge, especially in the United States. In the first-ever global analysis of all mass-produced plastics manufactured, researchers concluded that only 9% of plastic waste had been recycled. Twelve percent were in-

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cinerated, and the rest (79%) were in landfills or the natural environment.[7] The authors of the study predicted that, unless there is a big change in plastic production and waste management, then by 2050, there will be approximately 12,000 million metric tons of plastic waste in landfills or the natural environment.[7] The large increase in plastic is mainly attributable to single-use containers. Since plastic is not biodegradable, it accumulates in landfills. The United States sends most of its plastic waste to landfills, where it produces greenhouse gases.[8] A transition to a circular economy, where little is sent to landfill, is needed.

A circular economy is essential to reduce the adverse effects of climate change. In the traditional linear economy, resources are made into products and thrown away. In a circular economy, there is a reduction in materials used, materials are reused and/or shared with others who can use them, and waste is repurposed. This cycle then continues for as long as possible. The goal of a circular economy is zero waste. An efficient and effective recycling program can be part of a circular economy.[9] Other countries have had success in moving towards a circular economy. For example, Germany passed the Circular Economy Act in 2012, which set a target for 2025 with a 55% recycling rate.[10] Germany exceeded this target ahead of schedule with a current recycling rate of approximately 67%.[11] However, the United States has one of the lowest recycling rates worldwide.[12] Recycling is not mandated by federal law in the United States but rather by cities or states, if at all. According to estimates, only 21% of residential recyclables are properly recycled in the United States.[12] Local recycling programs often pay high processing fees, with some cities and towns spending millions of dollars on recycling.[13] Another recycling issue is the high contamination rate. Over half of U.S. households have had access to curbside recycling for years. Yet, studies indicate that many items can be recycled but are not, and also, many items get thrown in the curbside recycling bins that should not be, leading to high contamination rates. The Recycling Partnership documents a 17% inbound contamination rate by weight in curbside containers.[6] It is anticipated that this rate could be reduced through public education as to what can go in curbside recycling containers. The cost of recycling and improper recycling by residents have been cited as community challenges.[14]

Understanding the full potential of recycling can influence reducing the devasting effects of climate change. An estimated 10% increase in recycling rates could lead to an overall 1.5-2% decrease in urban waste.[15] Lack of knowledge has been cited as a cause of improper recycling, and there have been calls for public awareness campaigns.[16,17] Prior research has indicated that policy interventions related to municipal solid waste recycling lead to positive economic outcomes and reduced carbon emissions.[18] By spreading awareness about recycling, individuals learn and may become further inclined to recycle. Increasing recycling rates will lead to lower greenhouse gas emissions and the preservation of natural resources.[4] In summary, an overall increase in recycling rates will lead to less waste in landfills, less soil and water contamination, and lower carbon dioxide emissions.

In this study, the author investigates how to increase public awareness of curbside recycling. In Pennsylvania, USA, where this case study is based, reports indicate that the state's efforts to educate citizens on recycling have fallen short while waste generation has grown.[19] Contamination rates in some townships are high, with an average contamination rate in the United States of 17%.[6] This study aims to determine if there is a way to reduce contamination in curbside recycling by having residents take a quiz on local recycling rules in which immediate feedback is provided to the residents.

Prior research on feedback indicates that providing feedback results in gains in long-term retention of information.[20] In educational settings, providing feedback to people who answer multiple-choice questions has positively affected learning.[21,22] Research indicates that feedback can not only positively affect learning from mistakes made on tests,[23] but also can positively affect the learning and retention of correct answers.[24] A research study showed that participants who took a general knowledge multiple-choice exam with feedback improved in two ways: they corrected their wrong answers on the next test and also remembered answers they initially got right but were not confident about.[24] The retention of correct low-confidence answers was twice as high when feedback was given versus a no-feedback condition.[24]

In this study, I predict that taking a multiple-choice quiz on township recycling rules with an immediate feedback component will lead to positive outcomes. These include increased confidence in correctly sorting recyclables and an increase in both self-perceived knowledge and actual knowledge about correctly sorting recyclables.

Hypotheses

Hypothesis 1: Taking a quiz with immediate feedback will increase township residents' confidence in correctly sorting recyclables.

Hypothesis 2: Taking a quiz with immediate feedback will increase township residents' self-perceived knowledge about correctly sorting recyclables.

Hypothesis 3: Taking a quiz with immediate feedback will increase township residents' actual knowledge about correctly sorting recyclables.

Methods

Procedure:

An online survey with a quiz component was used to collect data and examine the impact of immediate feedback on confidence, self-perceived knowledge, and actual knowledge about correctly sorting recyclables. Following approval by an IRB, the survey was administered to residents of a suburban township with curbside recycling. All participants were residents of the same township. All subjects provided informed consent before taking the survey. Participation was voluntary. There was no deception and no known risks or discomforts. Participants were free to stop the survey/quiz at any time. All individual responses were kept confidential and were used to research ways to improve recycling efforts in the township. The participants took the survey online on their phone or computer. The initial survey took approximately 5-10 minutes to complete. A fol

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low-up survey was administered approximately one week later, which took approximately 3-5 minutes to complete.

Participants:

Participants were recruited at community events and through township newsletters. They were told that if they completed the initial and follow-up surveys, they would be entered into a drawing for a gift card.

A total of 81 completed responses were obtained. All participants were 18 or older and indicated they lived in a township household with curbside recycling. The demographics of the participants are documented in Table 1.

Table 1: Demographic information of participants. All participants were 18 or older, and the majority of participants (78%) were female.

	N	%
Gender		
Female	63	78%
Male	18	22%
Age		
18-26	4	5%
27-42	20	25%
43-58	37	46%
59-68	10	12%
69+	10	12%

Conditions:

Participants were randomly assigned to one of two groups: Feedback group or No-feedback group. Both groups had initial survey questions assessing their perceived knowledge and confidence levels about what can and cannot be recycled in the township. Then, participants took a quiz to determine their actual knowledge. The Feedback group received immediate feedback on their answers, meaning they could see what questions they got right/wrong immediately after submitting their answers and then saw the correct answers. The No-feedback group did not receive feedback and was not informed if they got the questions right or wrong. The No-feedback group served as the control group, as they did not receive quiz feedback. Then, participants in both groups were again asked questions assessing their perceived knowledge and confidence levels in what can and cannot be recycled in the township. Both groups were invited to take a follow-up survey/quiz approximately one week later. The follow-up asked the same questions as the initial quiz to determine if participants had learned and remembered the information.

Measures:

1. Confidence in recycling correctly. Before taking the quiz, all participants were asked to rate their confidence in correctly sorting recyclables in the township on a scale of 1 - 5: "I am confident with what and how to recycle in XXX Township." [The name of the township has been withheld for privacy purposes.] After taking the quiz, participants were asked this same question again.

2. Perceived knowledge of recycling rules. Before taking the quiz, all participants were asked to report their knowledge levels of recycling in the township on a scale of 1 - 5: "I know what can and can't be recycled in XXX Township." After taking the quiz, participants were asked this same question again.

3. Actual knowledge of recycling rules. Participants took a quiz with questions about specific recycling rules in the township. The quiz included multiple-choice questions about what specific items can be placed in which curbside bins. For example: "What items should go in your blue curbside bins?" The quiz also included true/false questions about how to put the items in the recycle bins, for example: "All items in the blue recycle bins should be clean and dry." and "It is ok to put all of my recycling in plastic bags, then put it in the curbside bins." An example of a page of the quiz is presented in Figure 1.

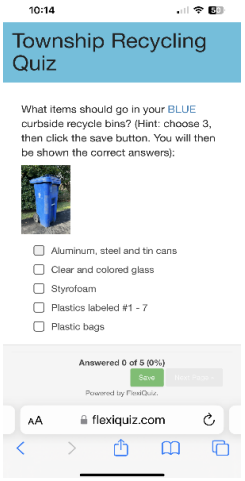

Figure 1: Sample page of the recycling quiz. Participants took the quiz on their phone or computer.

Analysis:

This study uses a between-subjects and within-subjects experimental design, where feedback level is manipulated in a case study. Subjects were randomly assigned to one of two experimental groups, and responses to the case were obtained through an online survey/quiz. Analyses were conducted using both paired-sample t-tests and two-sample t-tests.

Results and Discussion

Confidence levels in recycling correctly:

Before taking the quiz, all participants were asked, on a scale of 1 - 5, to rate their confidence in correctly sorting recyclables in the township: "I am confident with what and how to recycle in XXX Township." There was no significant difference in answers in confidence levels between the two groups before taking the quiz. All participants then took a short quiz on recycling rules in the township. The Feedback group received immediate feedback on the quiz questions; they immediately saw if they had answered each question correctly, and if not, they saw the correct answer. The No-feedback group answered the quiz questions but received no feedback and did not know if they had responded to the questions correctly or not. After the quiz, all participants were asked again to rate their confidence in correctly sorting recyclables in the township. Figure 2 shows the mean responses for both groups before and after the quiz.

Within Subjects:

Participants in the Feedback showed significantly increased confidence levels after taking the quiz. Confidence levels increased by .47 points from 4.04 before the quiz to 4.51 after the quiz (p-value < 0.001).

Participants in the No-feedback group had no significant change in confidence levels after taking the quiz.

Between Subjects:

Before taking the quiz, the Feedback and No-feedback groups had no significant difference in confidence levels. After taking the quiz, participants in the Feedback group were significantly more confident (Mean=4.51) than the No-feedback group (Mean=4.03) (p-value = 0.009).

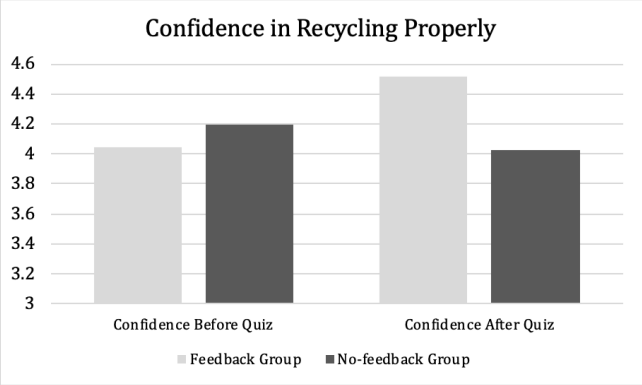

Figure 2: The mean scores for confidence levels before and after taking the quiz. The feedback group was significantly more confident after taking the quiz.

The results of the within-subject and the between-subjects tests provide support for Hypothesis 1. Taking a quiz with immediate feedback increased township residents' confidence in correctly sorting recyclables. Participants who received feedback had a 12% increase in confidence. This is in contrast to the participants who did not receive feedback, who had a decrease in confidence of 4%. These results are consistent with prior research on feedback in educational settings, which has shown that feedback helps not only correct wrong answers but also allows individuals to remember answers that they got right but were not initially confident about.[24]

Self-reported knowledge of recycling rules:

Participants were asked to report, on a scale of 1 - 5, their knowledge levels of recycling in the township, "I know what can and can't be recycled in XXX Township," before taking the quiz. Then, after taking the quiz, they were again asked about their knowledge level. Figure 3 shows the mean responses for both groups before and after the quiz.

Between Subjects:

Before taking the quiz, self-reported knowledge was not significantly different between the Feedback and No-feedback groups. Participants in the Feedback group showed a significant increase in self-reported knowledge level after taking the quiz. Self-reported knowledge levels increased by .57 points from 3.98 before the quiz to 4.55 after the quiz (p < 0.001). Participants in the No-feedback group also had a significant change in self-reported knowledge levels after taking the quiz, though not as much of an increase as the Feedback group. The No-Feedback group increased by .25 points from 3.75 before the quiz to 4.0 after the quiz (p = 0.027).

Within Subjects:

After taking the quiz, participants in the Feedback group, who had received immediate feedback on their quiz questions, had a significantly higher self-reported knowledge level (M=4.55) about recycling correctly than participants in the No-feedback group (M=4.00), (P = 0.001).

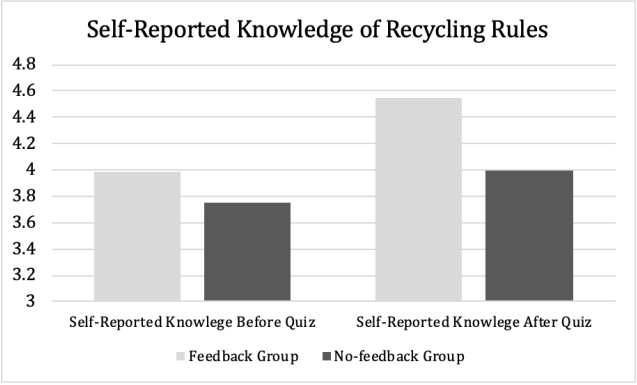

Figure 3: The mean score of self-reported knowledge before and after the quiz. Participants in the Feedback group showed a significant increase in self-reported knowledge level after taking the quiz.

The results of the within-subject and the between-subjects tests provide support for Hypothesis 2. Participants who received feedback had a 13% increase in self-reported knowledge. This is in contrast to the participants who did not receive feedback, who only had a 7% increase in self-reported knowledge. This is consistent with prior research on the role of feedback in educational settings.[23]

Actual knowledge of recycling rules:

Participants were given a quiz in the initial survey to assess their knowledge of recycling rules in the township. Participants were asked to take a follow-up survey approximately one week later. Fifty-two of the 81 participants responded to the follow-up survey, including 26 in the Feedback group and 26 in the No-feedback group. All participants who took the follow-up survey were again given the same quiz. Actual knowledge of recycling rules was measured by participants' scores on the questions in this quiz one week later. The Feedback group, which had immediate feedback on their quiz in the initial survey, scored significantly higher in the follow-up survey (p = 0.008), indicating that their actual knowledge of recycling rules increased. The No-feedback group had no significant change in actual knowledge, as predicted. The results provide support for Hypothesis 3.

The results of the experiment provide support for each of the three hypotheses. This is consistent with prior literature that suggests that feedback on an assessment leads to positive outcomes.[20-23]

Conclusion

This study documents the results of an experiment in which the author investigates, in a local township, whether an intervention method, an interactive quiz with immediate feedback, can increase confidence and both actual and perceived knowl

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edge of what can and should go in curbside recycling bins. The study results indicate that both actual and perceived knowledge and confidence in recycling increased after a quiz with immediate feedback. These findings support the three hypotheses.

Limitations:

All participants in the study were volunteers and were recruited at community events and through township newsletters, which means that the sample may be made up of people who care more about the topic of recycling than if I had a true random sample. In addition, this research was limited to one suburban township.

Implications and Future Research:

An efficient and effective recycling system is part of a circular economy and one requirement in the fight against climate change. Though reducing consumption and reusing materials are priorities, recycling is also very important. The Environmental Protection Agency has indicated that increased collection and reduced contamination in the recycle stream are priorities and that solutions are needed.[9] The World Bank notes solid waste management is necessary for sustainable cities.[5]

The World Bank also notes that public participation and behavior changes are instrumental in tackling solid waste management challenges, and they support designing awareness systems.[5] My findings suggest improved knowledge and confidence with recycling after taking a quiz with feedback, but further research is needed to ensure actual changes in behavior and recycling outcomes. Future research could measure whether improved knowledge and confidence after taking a quiz with feedback has a measurable effect on recycling behavior and a reduction in contamination. In addition, future research could examine more suburban townships, other neighborhoods, and other demographic groups with curbside recycling. Future research could also explore different types of interventions, such as quizzes with delayed feedback or alternative forms of recycling education, including visual aids, to see if similar results can be achieved.

This study found that an interactive feedback-based recycling quiz may produce positive outcomes. This is consistent with prior studies that found that feedback in an educational setting may produce positive outcomes.[21-24] The Recycling Partnership notes that confusion and lack of confidence in recycling are barriers to participation, and they call for more communication, engagement, and tools to promote education and increase recycling.[17] Public schools may consider adding a quiz about local recycling rules with feedback as part of their science classes or during an assembly or science fair as a fun activity. Local libraries could host this type of quiz at their community events. Community leaders may want to include a similar quiz with feedback on their websites and township newsletters. More recycling and lower contamination rates in the recycling stream may lead to other positive consequences, such as lower township costs. Future research can study different ways to improve curbside recycling in the United States and other countries as one piece of our collective fight to combat the climate crisis.

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