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Evaluating the Effects of a Classroom-Based Bicycle Education Intervention on Bicycle Activity, Self-Efficacy, Personal Safety, Knowledge, and Mode Choice




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# Evaluating the Effects of a Classroom-Based Bicycle Education Intervention on Bicycle Activity, Self-Efficacy, Personal Safety, Knowledge, and Mode Choice

**A Research Report from the University of California Institute of Transportation Studies**


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**16. Abstract**

This study provides an evaluation of the effectiveness of classroom-based adult bicycle education in delivering changes related to bicycling activity, self-perceptions while bicycling, knowledge of the bicycling rules of the road, and mode choice in the San Francisco Bay Area. Evaluation of the intervention was conducted using self-administered surveys completed prior to the intervention and again six weeks after the course. Self-reported data was validated using objective data collected using the Ride Report app. Participants reported statistically significant increases in confidence while bicycling in both traffic and car-free areas, feelings of safety while bicycling in car-free areas, and knowledge of the rules of the road. Participants with initial low confidence increased bicycling activity and feelings of safety in traffic, compared to participants overall. App-collected bicycling data correlated nearly perfectly with self-reported data, suggesting that self-reported data can be used reliably. Classroom-based bicycle education courses are a cost-effective way to change bicycling self-perception and increase knowledge of the bicycling rules of the road.


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# Evaluating the Effects of a Classroom-based Bicycle Education Intervention on Bicycle Activity, Self-efficacy, Personal Safety, Knowledge, and Mode Choice

UNIVERSITY OF CALIFORNIA INSTITUTE OF TRANSPORTATION STUDIES

July 2019

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# Executive Summary

Transportation accounts for most of the United States' carbon dioxide emissions, and on-road transportation is the greatest source of California's greenhouse gas emissions. A desire to reduce the impacts of climate change has motivated many transportation planners to explore ways to encourage more people to travel by carbon-free modes, such as bicycling.

Strategies to support increased bicycle use are frequently summarized under the broad domains of engineering, education, and enforcement. While the effects of engineering and enforcement on bicycling and road safety are well-studied, research on the effects of education approaches is limited. Furthermore, research on adult bicycling education has thus far focused exclusively on on-bicycle courses.

This research addresses the paucity of evidence on the effects of classroom-based bicycle education on adults. Outcomes of interest include frequency of bicycle use; the confidence, feelings of safety, and knowledge of bicycling; use of a bicycle for everyday trips; and changes in transportation modes used to travel in daily life.

We used a pre-test post-test research design to examine the effect of the intervention on these outcomes. We surveyed participants of a two-hour, classroom-based bicycle education course in the San Francisco Bay Area before taking the class and again six weeks later. Because the course was offered at different times of the year, we were able to control for the effects of climatic conditions and other seasonal trends on bicycling. For a subgroup of participants we also objectively measured bicycling behavior before and after the intervention using a smartphone app to validate what participants self-reported regarding bicycling activity.

We found a significant increase in participants' feelings of safety and confidence, and self-reported knowledge about the rules of the road. We also found increased frequency of bicycle riding for fun or recreation. No change was found in bicycling activity besides bicycling for fun or recreation, and there was no evidence that participants shifted their travel to a bicycle. The course affected subgroups differently; it was less likely to benefit older individuals for self-reported confidence in traffic and self-reported knowledge of the rules of the road, while non-males and non-white participants bicycled more minutes after the course. The course was also more likely to benefit those with lower confidence bicycling in traffic prior to taking the course. Finally, we found that participant's self-reported activity almost perfectly agreed with app-based observations of how much they bicycled.

These results suggest that classroom-based bicycle education alone may not be enough to change bicycling habits. However, the increase in feelings of confidence, safety and knowledge may encourage class participants to seek out further training opportunities or support. Furthermore, these results are in line with existing research on on-bicycle courses, which are implemented at many times the cost of a classroom-based course. Planners should continue to ensure that these courses are available in their communities.

# Introduction

In 2016, the transportation sector surpassed the energy sector as the United States' greatest contributor to carbon dioxide ($CO_2$) emissions (*1*), while the on-road transportation sector has been the greatest source of California's greenhouse gas (GHG) emissions since at least 2000 (*2*). Both a mostly unchanging reliance on gasoline and diesel as the major fuel sources for vehicles and increased vehicle miles traveled (VMT) as the economy has recovered from the Great Recession have contributed to these emissions. The rise of transportation network companies (TNCs) such as Uber and Lyft have also increased VMT by drawing passengers away from walking, bicycling, rail, and carpools (*3*).

According to the 2016 U.S. National Household Travel Survey, 59.4 percent of vehicle trips are five miles or less and 35.2 percent are two miles or less (*4*). Shifting these short trips from cars to more sustainable modes of transportation has therefore been a goal of urban transportation planners. However, it is not known how well progress is being made toward that goal. A study by Le et al. found bicycle use in the United States has been increasing by 5 to 6 percent annually, but this rate of change was higher than was measured in the American Community Survey between 2009-2017 (*5*).

Decision-makers are encouraging opportunities to alter the transportation landscape to support people to bicycle more. For example, the Caltrans Active Transportation plan identifies active transportation as playing "a vital role in California's goal to reduce [GHG] emissions and [VMT]" and continues: "Walking and bicycling also have many positive benefits associated with personal health, economic benefits, and sustainable and equitable development" (*6*).

Despite the renewed interest in and demand for bicycling, safety remains a concern. In the U.S., the overall road safety improvements of the last thirty years have not translated into improved safety for active travelers. In this context, Vision Zero has emerged as a movement that, in the words of the United States-based Vision Zero Network, "seeks to eliminate all traffic fatalities and severe injuries nationwide — while increasing safe, healthy, equitable mobility for all" (*7*).

Locally, Vision Zero San Francisco (Vision Zero SF) has a stated goal to "integrate Vision Zero…policy goals into transportation and land use planning policy and code such as the transportation demand management ordinance to reduce need for driving and [VMT] to reduce opportunity of collisions involving vehicles" (*8*). This study will support Vision Zero SF's goals to reduce VMT by increasing the understanding around the role of bicycle safety education on mode shift and VMT reduction.

Because concern about safety is a known barrier to increased bicycling, strategies to encourage bicycle use frequently also lead to increased safety for people bicycling. For bicycling, prevailing strategies can be summarized under the broad domains of engineering, education, enforcement, and encouragement (the four "Es"). Within the four Es, education is a promising strategy that addresses safety and use, particularly because it increases bicyclist confidence (*9*).

While education strategies consist of both on-bicycle and off-bicycle (classroom-based) classes for all age groups, most research has studied on-bicycle interventions in children (*10*–*13*). Currently, bicycle safety education is taught across the United States and is primarily based on the Smart Cycling program created by the League of American Bicyclists (LAB). In addition to offering bicycle education curriculum, LAB offers the only nationwide bicycling instructor certification program (League Cycling Instructor or "LCI").

While classroom-based bicycle safety education has been shown to increase existing riders' confidence in a small number of studies, its role in increasing user knowledge, bicycle use, and causing mode shift has not been examined. The Caltrans Active Transportation plan also notes "no comprehensive study exists that evaluates the effectiveness of active transportation programs, limiting the ability to incorporate existing and planned programming into benefit-cost analyses or other tools and preventing an 'apples-to-apples' comparison to infrastructure projects" (*6*).

Understanding the impact of classroom educational programs is important because decision-makers need to understand the effectiveness of bicycle safety education, its usefulness to increase safety and demand, and its role in a multidimensional approach to improve active transportation and mobility. This study addresses this empirical gap by examining whether classroom-based bicycle education interventions increase:

- Frequency of bicycle use;
- The confidence, feelings of safety, and knowledge of bicycling;
- Use of a bicycle for everyday trips; and
- Changes in transportation modes used to travel in daily life.

In the next section, we review the literature to identify gaps in our current knowledge about the role that bicycle education plays in bicycle riding frequency, confidence, safety, knowledge, and mode shift. We then describe the study methodology, followed by results and a discussion of the implications. We end the report highlighting our main findings of relevance to cities and states seeking to fund bicycle safety education programs as strategies to increase bicycle mode share as well as to complement efforts to expand bicycling infrastructure.

# Literature Review

## The rationale for investing in bicycling

Human-induced climate change is likely to cause drastic changes to natural, managed, and human systems; these changes will likely include increased temperature, long-term sea level rise, species loss and extinction, ocean acidification, and risks to human security and economic growth (*14*). Increasing rates of urban bicycling has been suggested as a way to mitigate climate change (*15*). Studies in New Zealand and Canada have shown that increasing investment in active transportation infrastructure results in reduced VMT and therefore reduced $CO_2$ emissions (*16*–*18*). Other community-wide benefits of bicycling include reducing "air pollution, carbon emissions, congestion, noise, traffic dangers, and other harmful impacts of car use" (*19*).

Additionally, bicycling is good for the individual. Active transportation has been shown to increase lifespans and reduce deaths through increased physical activity (*16*), while bicycling in particular is associated with a 10 to 28 percent reduction in all-cause mortality risk (*20*). Health research on the dangers of sitting notes: "Advice can … be given with reasonable confidence, to encourage adults to create opportunities to limit their sitting time whilst at home, at work and **during transportation** [emphasis added]" (*21*). Bicycling also makes people happy. Zhu and Fan found that people in the United States are happiest when bicycling as compared to driving a car, riding in a car, taking transit, and walking (*22*). A study in a small touristic town in Greece found that over 90 percent of surveyed residents had a positive association with riding a bicycle (*23*).

Cities have implemented a variety of policies and programs designed to increase rates of bicycling including infrastructure, public transport integration, education and marketing, bicycle-sharing programs, and traffic laws (*24*). Investment in infrastructure is a promising way to increasing rates of bicycling. Bicycling rates increase as a result of building secure bicycle parking (*25*), increasing the connectivity of the bicycle network (*18*, *26*), increasing the proportion of protected bicycle lanes (*26*), or simply increasing the overall amount of bicycle infrastructure (*27*). Additionally, surveys reveal strong user preferences for bicycle infrastructure that is physically separated from motor vehicles (*28*, *29*).

Encouragement has been defined as creating a culture that welcomes and promotes bicycling (*30*). Encouragement strategies range from employer trip reduction programs to individualized marketing programs to events (e.g. Bike to Work Days, ciclovías, etc.) to education and training (*24*).

## Relevance of safe cycling

Despite these myriad strategies to increase bicycling, rates of fatalities while bicycling are increasing. As a percentage of total traffic fatalities, fatalities of people bicycling have increased from 1.7 percent in 2007 to 2.2 percent in 2016 (*31*). This is despite the fact that only one percent of people bicycled to work in the 50 biggest U.S. cities as of the 2008-2012 American Community Survey (*32*) meaning that people who bicycle are more likely to be in a fatal collision that would be expected based on exposure.

Concerns about safe bicycling frequently stand in the way of getting more people to bicycle. Roger Geller's now-iconic typology of the "Four Types of Cyclists" divided Portland residents into four categories: "'The Strong and the Fearless,' 'The Enthused and the Confident,' 'The Interested but Concerned.' The fourth group are non-riders, called the 'No Way No How' group" (*33*). About 60 percent of Portland residents are in the "Interested but Concerned" category and the key reason for their lack of bicycling is “fear of people driving automobiles” (*33*). Subsequent research validating the typology using a series of nationwide surveys in the United States found a similar distribution between the four groups, and found fear of traffic to be in the top four barriers to bicycling more among “Interested but Concerned” non-bicycle riders (*34*).

The concept of level of traffic stress (LTS) has emerged as a planning tool to identify the suitability of street segments for safe, low-stress bicycling. Mekuria et al. developed a system that classifies bicycles facilities into four LTS categories, ranging from 1 (suitable for children) to 4 (high stress) (*35*). The classification roughly adopts Geller’s typology by removing the “No Way No How” group and dividing “Interested but Concerned” into a child group and an adult group. With fewer inputs than a traditional model such as bicycle level of service, LTS is an attractive option to evaluate bicycling infrastructure. A study seeking to validate LTS as a tool to predict mode choice and route choice found LTS to be a valid measure of a household’s likeliness of bicycling but did not validate commute mode choice (*36*).

Another angle to address unsafe streets is U.S. cities’ widespread adoption of Vision Zero policies to eliminate traffic death and serious injury, heavily inspired by Swedish cities. Analysis of Swedish legislation reveals that Vision Zero is implemented through focus on the four E’s (engineering, enforcement, education and encouragement) (*37*). Engineering and encouragement were discussed earlier in this review; education will be discussed in the next section.

Enforcement of traffic laws has been demonstrated to reduce automobile crashes and related injuries (*38–40*). However, traffic enforcement has also been shown to be vulnerable to racial bias: police are more likely to stop Black drivers in both highway patrol and municipal police stops, and more likely to search Black and Hispanic drivers who have been stopped (*41*). On the other hand, the same safety effect from enforcement is found when the human role is replaced with speed cameras; camera ticketing systems have been shown to decrease severe injuries and death in Belgium (*42*) and Saudi Arabia (*43*). Automated enforcement technology, such as speed cameras and red light cameras, have therefore been posited as a solution the racial bias inherent in policing and could be implemented municipally with no police involvement whatsoever (*44*).

Increased bicycle use also has a safety double dividend: reduced traffic injuries due to the safety in numbers (SiN) effect. The SiN effect has been corroborated across neighborhoods (*45*), cities, and countries, resulting in personal injury risk decreasing by 34 percent as the community rate of bicycling doubles (*46*). The SiN appears to hold true both cross-sectionally and longitudinally (*47*) and has been supported with quantitative and mixed-methods research approaches (*48*). However, the mechanism through which SiN occurs is not clear. With increasing numbers, it may be that people bicycling behave differently. It is also likely that bicycling infrastructure is added or improved to accommodate the increasing number of people bicycling. And drivers are likely to adapt their behaviors and expect to see people on bicycles, thereby also increasing safety.

## Educational approaches to encourage bicycling and bicycling safety

Bicycle safety education has been encouraged in the United States by organizations such as the LAB, which offers both classroom-based and on-bicycle courses, for at least five decades. Classroom-based courses teach rules of the road, bicycling best practices, and theoretical techniques and skills, while on-bicycle courses encourage participants to practice basic and advanced bicycle handling skills with and without traffic (*49*). Bicycle education training has been suggested as a way to "overcome skill, knowledge and confidence related barriers to cycling" (*50*) and has also been touted as a solution to increase bicycling rates (*9*) or increase "participant frequency and duration of cycling...for leisure or commuter cycling" (*51*). Compared to building infrastructure, bicycle safety training can be a more cost-efficient measure to achieve these goals (*9*).

Training and education could also target the non-cycling population. A survey of adults in five large U.S. cities found that people who primarily commute by auto "are significantly more negative toward bicyclists than toward other drivers" (*52*). Johnson et al. posit that negative attitudes could be influenced by representation of people bicycling in government driver education (*9*). Studies of driver education materials in Australia found very little information concerning people bicycling, and that the information that was present tended to be negative (*9*, *53*). A review of Canadian materials found misleading facts about who was at fault in crashes (*54*). These education materials could lead to "the very cyclist-motorist tensions that road safety authorities are seeking to address. It may also undermine government efforts to increase participation in cycling" (*53*). Including bicycle safety information in driver education could prove to be more effective than current education materials at preventing crashes; a review of studies in Australia, New Zealand, and the United States found no evidence that driver education reduces road crash involvement (*55*).

Despite the bicycle safety education goal of increasing the number of people bicycling safely, there is a lack of robust evidence suggesting that education classes increase riding frequency and safe riding habits (*56*, *57*). In fact, a recent review concluded "there is a paucity of high quality research in the area of bicycle skills training programmes." (*58*) and another states "there are few published studies of bicycle skills training, and little evidence is available to demonstrate whether such training does encourage more bicycling" (*59*). While a variety of research has been done on both children and adults for many different types of bicycle education around outcomes such as change in skill, riding frequency, purpose (bicycling to school or work), knowledge, confidence, rate of injury, and bicycle ownership levels, to our knowledge no research examines the effect of classroom-based (off-bicycle) bicycle safety education on changes in travel behavior in adults.

## Bicycle safety education and impact in youth

Drastically more research on bicycle education has centered on children and youth than on adults, and findings are mixed. A review of more than 25 studies on youth bicycle education found no intervention effect on injury, an even split on whether or not knowledge was gained, and slightly more than one-third of studies reported increases in behavior or attitude change (*58*). A review of studies specifically searching for changes in frequency of bicycling found, out of six studies on children, five that reported increases in overall bicycling and three reporting increased bicycling to school (*59*).

Outcomes vary based on the type of training administered. Most documented interventions in youth include or primarily consist of an on-bicycle training. This training may be off-road (in a car-free environment such as a playground or park), or on-road to include bicycling with traffic. It may also consist of riding in a group. Off-road, on-bicycle trainings have found mixed results: an increase in total bicycling skill (*10*, *11*), no increase in bicycling to school or riding frequency (*10*, *12*, *60*), an increase in bicycling to school and riding frequency (*61*), increased knowledge (*12*, *13*, *62*, *63*), increased confidence riding in parks (*12*, *13*), increased confidence riding on the street (*13*), increased overall confidence (*61*), and no change to safe bicycling behavior, knowledge or attitudes (*64*). On-bicycle trainings incorporating a traffic element found similarly mixed results: increased knowledge (*12*, *63*), increased confidence cycling on roads (*12*), an increase in bicycling to school (*13*, *61*), no increase in bicycle frequency (*60*), and an increase in bicycling frequency (*61*).

Other interventions have involved classroom training sessions only (no bicycle riding). Interventions of this type have found an increase in bicycle safety knowledge (*65*, *66*), a decrease in bicycle injuries (*66*), and increased likelihood of wearing a helmet (*67*). A subset of this intervention type is individualized computer training; a study of this intervention type for young elementary school students showed an increase in knowledge over those that did not take the computer training (*68*). However, few studies report on interventions consisting only of classroom instruction. Even fewer studies report on a multi-prong approach; an intervention consisting of classroom lessons, then on-bicycle, off-road instruction, then a ride on city streets resulted in increased knowledge of bicycle safety, bicycle-specific street signs, and hand signals, and increased confidence (*69*). The study's results on riding frequency were contradictory: children self-reported riding more frequently to school and on the weekend, but also reported riding fewer times per week (*69*).

## Bicycle safety education and training in adult populations

There is a limited number of studies examining the effectiveness and impact of bicycling interventions on adults (Table 1). Seven studies were identified for this review. Three studies were conducted in Australia (*50*, *51*, *70*), two in the UK (*9*, *71*), one in the United States (*72*), and one in the Netherlands (*73*). Six studies were conducted as a one-group pre-test post-test design (*9*, *50*, *51*, *70*, *71*, *73*) while one study utilized a two-group randomized controlled design

(*72*). Apart from the Schenider et al. study (*72*), no study accounted for participant self-selection.

Participants in all studies were majority women, ranging from 69.7 percent (*50*) to 100 percent (*73*). Of the studies that reported participant age, the majority reported middle-aged participants (between 30-59) (*50*, *51*, *71*–*73*) with the exception of Zander et al., which focused on older adults and as a result reported a mean age of 61 years old (*70*). Few studies reported on participant race; two specifically studied non-white populations (*72*, *73*) while another study's initial sample was 57 percent white (*71*).

While the interventions studied varied in duration, all consisted of some sort of on-bicycle training. Two studies evaluated a multi-pronged approach that lasted twelve weeks and included a bicycling skills training course alongside additional resources such as weekly group rides and access to a bicycle, helmet, and lock (*72*) or mentors and a resource pack (*70*). Other studies consisted of either four one-hour one-on-one sessions (*9*), six hours of instruction broken into two- or three-hour sessions in a small group of eight students (*51*), or a set of 15 cycling lessons (*73*). Two studies do not specify the details of the intervention (*50*, *71*).

All studies collected baseline information either prior to beginning the study (*50*, *70*, *72*) or at the first intervention session (*9*, *71*). Except for one study employing a semi-structured interview qualitative approach (*70*), all studies utilized pre-course self-administered paper or online surveys. Follow-up time varied between the studies. Several studies followed up with participants via self-administered survey or interview immediately upon completion of the intervention (*50*, *51*, *70*–*73*). Some of these studies scheduled additional follow-ups at three months and 12 months via telephone (*50*) or self-administered survey (*71*) while others completed additional follow-up two months after by telephone (*51*) or self-administered survey (*72*). One study conducted a follow-up survey only after three months (*9*).

All studies using surveys measured some outcome related to frequency of bicycling, and all those studies except one (*51*) found an increase in cycling either generally (*9*, *50*), for commuting (*9*, *71*), or for utility or leisure purposes (*71*–*73*). Some studies saw an increase at the first follow-up that was not maintained at the second follow-up (*50*, *72*), though in one study the increase was stable only for participants who previously were infrequent riders (*50*). Two studies asked participants to self-report the change in their bicycling behavior and found the vast majority to report either increased or maintained rates of bicycling (*50*, *51*).

A similar mix of results was seen for the duration of bicycling before and after the study. While three studies saw an increase in the amount of time people bicycled weekly (*9*, *50*, *71*), another study saw no change except for those who had not ridden a bicycle prior to the intervention (*51*). Rissel and Watkins (*50*) noted that the increase in minutes at both three months and 12 months could have been due to self-selection of those who elected to participate in the 12-month follow-up.

**Table 1. Characteristics of bicycle education training studies of adult populations**

| Study and location | Intervention | Study design, group (sample size) | Study instrument | Validation | Key outcomes |
|---|---|---|---|---|---|
| **Johnson and Margolis 2013 United Kingdom** | On-bicycle: four one-hour individual training sessions | One-group pre-test post-test:<br>Baseline (471)<br>Three-month follow-up (130) | Baseline: self-administered online survey<br>Follow-up: self-administered survey | None | Increased bicycling frequency<br>Increased physical activity<br>Increased confidence |
| **Rissel and Watkins 2014 Australia** | On-bicycle: bicycle training course (details unknown) | One-group pre-test post-test:<br>Baseline (4145)<br>Post-intervention (2250)<br>Three-month follow-up (423)<br>12-month follow-up (125) | Baseline & follow-up 1: self-administered survey<br>Follow-up 2 & 3: telephone survey | None | Increased bicycling skills<br>Increased confidence |
| **Schneider et al. 2018 United States** | On-bicycle: bicycling instruction and weekly group rides for 12 weeks | Two-group randomized controlled:<br>Intervention - baseline (21)<br>Intervention - week 12 (14)<br>Intervention - week 20 (13)<br>Control - baseline (16)<br>Control - week 12 (10)<br>Control - week 20 (9) | Self-administered survey | Randomized control | Decrease in eight barriers to bicycling at 12 weeks<br>Decrease in two barriers to bicycling at 20 weeks<br>Increased bicycling for leisure and nonwork transportation |

| Study and location | Intervention | Study design, group (sample size) | Study instrument | Validation | Key outcomes |
|---|---|---|---|---|---|
| **Transport for London 2016 United Kingdom** | On-bicycle: bicycle training course (details unknown) | One-group pre-test post-test:<br>Baseline and post-intervention (800)<br>Three-month follow-up (258)<br>12-month follow-up (101) | Self-administered survey | None | Increased bicycling frequency<br>Increased safety and confidence<br>Increased bicycle access |
| **Telfer et al. 2006 Australia** | On-bicycle: six hours of instruction (two or three sessions) with eight students | One-group pre-test post-test:<br>Baseline (113)<br>Post-intervention (81)<br>Two-month follow-up (105) | Baseline & follow-up 1: self-administered survey<br>Follow-up 2: telephone survey | None | Increased confidence and knowledge<br>No change in frequency or duration overall<br>Increased bicycling duration for those who had previously not bicycled |
| **van der Kloof et al. 2014 Netherlands** | On-bicycle: 15 cycling lessons | One-group pre-test post-test:<br>Baseline (206)<br>Post-intervention (174)<br>Completed both (83) | Self-administered survey | None | Increased bicycling skills<br>Increased empowerment<br>No change in bicycle access |
| **Zander et al. 2013 Australia** | On-bicycle: 4.5-hour course, mentors, resource pack, and riding two hours/week for 12 weeks | One-group pre-test post-test:<br>Baseline (17)<br>Post-intervention (11) | Semi structured interview | None | Increased bicycling frequency<br>Increased confidence<br>Increased empowerment |

Several studies examined the effect of bicycle training on overall physical activity. Three studies found an increase in minutes spent on overall physical activity (*9*, *50*, *51*), though this could have been due to self-selection in the case of Rissel and Watkins (*50*).

Results examining the change in bicycle ownership were mixed. Both Johnson and Margolis (*9*) and Transport for London (*71*) noted an increase in the number of people owning or having access to a working bicycle after the intervention. Van de Kloof et al. (*73*), however, saw no increase in bicycle ownership. Additionally, only white participants in the Transport for London (*71*) study reported an increase in bicycle ownership.

Feeling of confidence and safety were consistently higher across studies after intervention. All survey-based studies asked about feelings of safety and/or confidence on a five- or six-point Likert scale. Studies that employed qualitative methods in lieu of or alongside quantitative methods found more nuanced changes in participant feelings, including feelings of increased mental strength and empowerment (*70*, *73*). When looking at confidence and feelings of safety by gender, men reported higher baseline levels of both. However, the intervention appeared to have an equal effect on the two genders studied; post-intervention, men and women reported increases of a similar size (*71*).

Few studies asked about cycling knowledge but of those that did, participants self-reported increase in skills knowledge (*50*) and knowledge of road rules, bicycle maintenance and ability to access bicycling information (*51*).

In summary, existing research on the effects of adult bicycle education is predominantly limited to on-bicycle interventions. Those studies have found a general increase in bicycling frequency and duration, an increase in overall physical activity, mixed results about change in bicycle ownership, and an increase in feelings of confidence, safety, and knowledge. Most of this research has been done in the United States, the United Kingdom, Australia, and the Netherlands. By contrast, classroom-based bicycle education studies have focused on changes in knowledge among youth. There is a paucity of studies on adults, and there is a gap in understanding changes in confidence, riding behavior, and mode choice. Furthermore, few have used research designs that allow researchers to make robust causal statements about the effectiveness of the education interventions and no studies have objectively measured bicycling activity. Finally, it is not known whether certain participants of classroom-based educational interventions (for example, those with least experience, or those with moderate confidence) benefit the most. This study aims to address these gaps.

# Methods

We used a quasi-experimental, pre-test post-test research design to examine whether a bicycle education course increases the self-reported frequency of existing and new riders, their confidence, perceived safety, and knowledge, and the proportion of people that use a bicycle for everyday trips. In addition, we examined the validity of self-reported bicycle use for a subsample of participants by comparing self-reports with behavior inferred from a smartphone app.

Our design exploits the fact that the education course is implemented at different points in time, which allows the comparison of behaviors of those who have taken the course relative to those who have not taken the course in that same period. At a given point in time, a prospective student effectively serves as a counterfactual for students that had already received the intervention. The lack of a control group is ameliorated because future participants who have not been trained act as controls. The approach is similar to an interrupted time series design in which time is measured in student-specific clocks, with seasonal dummy variables capturing secular trends in bicycling. This approach works well with interventions delivered at a clearly defined point in time such as this one and where short-term outcomes are expected (*74*).

## Classroom-Based Bicycling Skill- and Knowledge-Building Intervention

In the San Francisco Bay Area, multiple nonprofits and private companies offer bicycle safety education. We partnered with two geographically distinct San Francisco Bay Area bicycle advocacy and education nonprofits, one in Alameda County (AC) and another in San Francisco County (SFC). Both offer free bicycle education courses to anyone interested in learning to ride a bicycle or learning how to bicycle more safely and confidently, and offer a similar menu of adult courses, including: Adult Learn to Ride (teaching adults how to ride) and Traffic Skills 101 (a two-part course with a classroom component and an on-bicycle component designed to teach the basics of traffic skills to beginning and intermediate riders). Each organization also offers child-specific courses designed to teach kids how to bicycle and how to bicycle safely. These courses are funded through a variety of public and private grants. Both nonprofits have taught classes that adhere to curriculum from the LAB Smart Cycling program for over a decade.

The intervention is a two-hour, classroom-based Traffic Skills 101 (TS101) course taught by both nonprofits. The course covers basic rules of the road, equipping a bicycle, helmet fit, avoiding bicycle theft, bicycling in traffic, handling intersections, preventing common crashes, route planning, and riding after dark. All instructors had undergone the same training to be a certified LCI. Precise sociodemographic characteristics of the instructors are not available; however, instructors employed to teach for one nonprofit are somewhat diverse in gender, race and age. All classes presented by the other nonprofit were taught by a male, white, older instructor.

Although the intervention had been implemented in an ongoing manner prior to the start of the study, researchers began surveying participants who attended classes starting in October 2018 and continuing through June 2019. Over these nine months, 31 classes were taught in English in nine cities across the San Francisco Bay Area (one was cancelled because of poor air quality due to severe wildfires). Most classes were offered on weekend afternoons, while some were given during weekday evening hours. Classes were taught in public locations such as libraries, YMCAs, universities, and churches.

**Table 2. Number of classroom-based TS101 courses surveyed, by nonprofit and month**

| | Oct. 2018 | Nov. 2018 | Dec. 2018 | Jan. 2019 | Feb. 2019 | Mar. 2019 | April 2019 | May 2019 | June 2019 |
|---|---|---|---|---|---|---|---|---|---|
| **Nonprofit 1** | 4 | 1 | 3 | 1 | 3 | 4 | 4 | 6 | 1 |
| **Nonprofit 2** | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |

To ensure our ability to detect a statistically significant difference due to the intervention, we relied on past survey data from one of the nonprofits. We used the outcome "riding confidence in traffic" and estimated we needed 425 participants, that with 50% attrition would allow us to detect a 15 percent improvement in riding confidence to be detectable 80 percent of the time at a 95 percent level of confidence. Thus, we aimed for 450 participants (225 per location).

## Outcomes and measurement

### *Outcomes*

We measured outcomes on three domains: bicycle activity; self-efficacy, personal safety and knowledge; and mode shift (Table 3). Our main source of data is a self-reported survey implemented before and after the intervention (referred to as current survey data). To augment the sample, we also use previously collected data from a similar self-reported survey implemented by one of the nonprofit partners before and after the intervention from April 2017 through October 2018 (henceforth referred to as "pre-study survey"); and we use Ride Report, a tested and widely-used smartphone app that measures bicycling activity (https://ride.report/). We describe each outcome and data collection instrument next.

### *Survey development and implementation*

The before and after surveys were designed and harmonized based on questions from existing surveys used by the nonprofit partners. The before survey contained questions about demographic characteristics such as age, gender identity, and race/ethnicity, whereas both the before and after instruments contained information about the study outcomes. We measured bicycling activity with questions taken from existing surveys about when the participant last rode a bicycle, the purposes for riding a bicycle, bicycle ownership and experience bicycling in traffic. Additional questions on riding duration were taken from the International Physical Activity Questionnaire (*75*). We measured bicycling confidence and feelings of safety with two questions on riding in traffic and in car-free areas such as a park or bicycle path. Bicycling knowledge were measured with one question.[1] Modal split questions measuring the share of

[1] The question asking participants to rate their level of knowledge had five possible options: "Poor," "Fair," "Uncertain," "Good," "Excellent." About eight months into the study, we discovered that the after survey only offered participants four options to rate their level of knowledge, omitting the highest rating ("Excellent"). The option was, at that time, added back to the survey.

trips taken by different travel modes were taken from Barcelona's TAPAS survey (*76*). We also included questions to measure whether bicycling was being considered as an option, even if not used, following the stages of change model (*77*). Finally, questions on station-based and dockless bicycle-share were included, but not a question on dockless e-scooters because they had not debuted at the time the survey was developed. The before and after surveys are included in Appendix A.

**Table 3. Outcomes, variables, and data sources**

| Domain | Outcome | Variables(s) | Source |
|---|---|---|---|
| **Bicycle activity** | Bicycling frequency | Percent ridden in last week; riding purpose in last month | Current survey data; Ride Report app; pre-study survey data |
| | Bicycling time | Minutes ridden per week | Current survey data; Ride Report app |
| | Other bicycle activity metrics | Owning a bicycle; using bicycle share; experience in traffic score from scale | Current survey data; pre-study survey data |
| **Self-efficacy, personal safety & knowledge** | Self-efficacy in traffic; self-efficacy in car-free areas | Efficacy score from scale | Current survey data; pre-study survey data |
| | Safety in traffic; safety in car-free areas | Safety score from scale | Current survey data; pre-study survey data |
| | Knowledge | Knowledge score from scale | Current survey data; pre-study survey data |
| **Shift** | Modal substitution | % trips by bicycle | Current survey data |
| | Bicycle as modal option | Stages of change score | Current survey data |

Participants were recruited using existing practices by the nonprofits, including email newsletters, social media posts, website information, and word of mouth (Appendix B). Participants who signed up for the TS101 course were subsequently sent information about the study from the nonprofit partner, including an invitation to take the before survey via Qualtrics. Participants were offered a $5 gift card for taking the survey. Upon arriving at the course, those who had not already taken the survey were invited in-person by a research assistant.

Participants could either log into the survey on their personal smartphone or take the survey on a provided e-tablet. Participants then attended the bicycle education course.

Approximately six weeks after taking the course, participants were invited to take the after survey (also on Qualtrics) via email and text message. Participants were incentivized with another $5 gift card for taking the after survey. For approximately four weeks, follow-up emails and text messages were subsequently sent to participants who had not taken the survey.

### *Agreement between self-reported and app-inferred cycling behavior*

We partnered with Knock Software, Inc., creator of the Ride Report app (

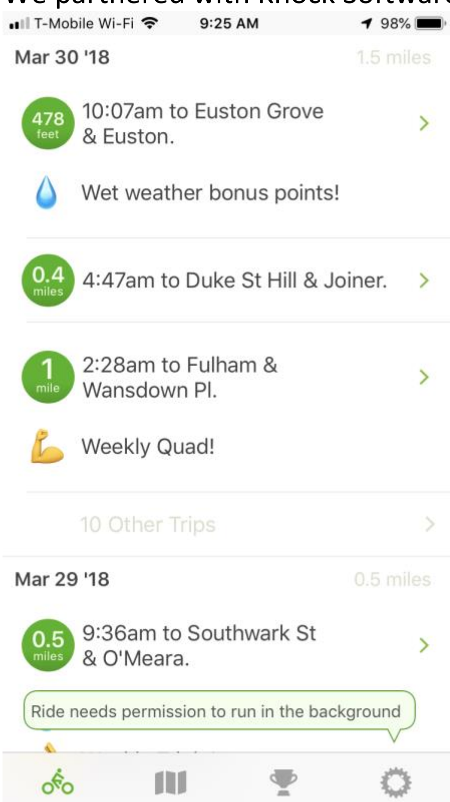


Figure 1), to collect data on participants' riding behavior to examine agreement with self-reported measures of riding frequency. Ride Report is a mobile app designed to automatically track bicycling and other transportation activity. Using machine-learning algorithms that take advantage of smartphone accelerometers and gyroscopes, Ride Report automatically detects when users travel and identifies the transportation mode, including bicycling (*78*). Ride Report data has also been used to crowdsource community feedback on bicycling routes (*79*, *80*). Comparing bicycling data from the app with self-reported bicycling activity data allows us to examine the quality and validity of the self-reported data.

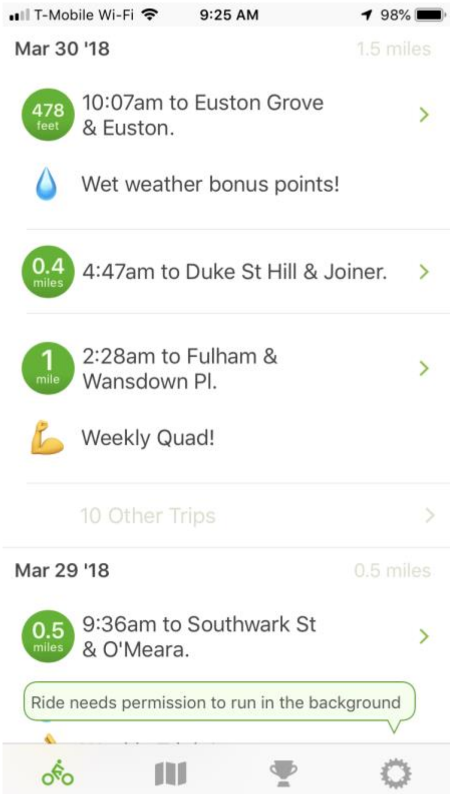


**Figure 1. Screenshot of Ride Report app.**

After completing the before survey, participants were invited to download the Ride Report app. They were offered another $5 gift card for downloading the app and consenting to share their data with the study.

For those who opted to download the app, Ride Report inferred data on participants' bicycling trips, including distance bicycled, average speed, duration, and start and end time. Trip data were anonymized except for a key to link the rider with the survey and shared with the UC Berkeley team only for those participants who consented to share their data. To protect privacy, no spatial data was provided to the research team.

## Statistical analysis

### *Accuracy of self-reported bicycling minutes*

For post-course survey data, we compared self-reported riding time for the past week with Ride Report-registered time for the same week. For pre-course survey data, however, we were unable to match the time period of the Ride Report data with the self-reported data because participants were invited to download the Ride Report app only after they completed the before survey. As a result, for the pre-course data we compared average weekly bicycling time from Ride Report for the entire time period before the course with the self-reported data on riding time the week prior to the survey. All comparisons of agreement were conducted with

Pearson correlation coefficients, with higher values denoting higher agreement. We use the Landis and Koch (*79*) criteria to interpret agreement, with values of zero indicating no agreement, 0–0.20 indicating slight agreement, 0.21–0.40 indicating fair agreement, 0.41–0.60 indicating moderate agreement, 0.61–0.80 indication substantial agreement, and 0.81–1 indicating almost perfect agreement.

### *Unadjusted before and after changes*

A comparison of before and after data for each participant provides an initial understanding of possible intervention impacts. For all the outcomes considered, answers to questions were compared using proportion tests (for % variables) or *t*-tests (for continuous variables), all accounting for the matched nature of the data.

### *Adjusted before and after changes*

Because there may be systematic differences between the before and the after periods, such as secular trends as well as personal and other attributes that may interact with the intervention to influence overall outcomes, we used regression analysis to estimate the effects of the intervention. Analytically, our approach measured associations of the outcomes of interest (dependent variables) to participation in the intervention while controlling for other covariates.

$$outcome_{i,t} = \beta_0 + + \beta_1 \text{after}_{i,t} + \beta' \text{W}_{i,t} + \boldsymbol{\beta}'' \text{X}_{i,t} + \boldsymbol{\beta}''' \text{T}_{i,t} + \epsilon_{i,t}$$

where *outcome* refers to the outcome of interest for person *i* at time *t*; $\text{after}_{i,t}$ is the variable of interest – a dummy variable which takes value of 1 if the observation is after the course intervention, or 0 otherwise; $\mathbf{W}_{i,t}$ is a time-varying and person-varying vector of covariates measuring climatic conditions (precipitation and wind) affecting cycling (more on this below); $\mathbf{X}_{i,t}$ is a vector of demographic covariates (sex=1 if male, race/ethnicity=1 if non-white, and age entered as a continuous variable); $\mathbf{T}_{i,t}$ is a vector of dummy variables adjusting for the impact of seasonality on outcomes; and betas are estimated coefficients or vectors of estimated coefficients. For the seasonality dummy variables, each observation was assigned one of four seasons based on the week prior to when the survey was completed (spring=March through May; summer=June through October; winter is the reference category). The functional form of the equation estimated depends on the outcome and were either logistic regression for binary variables or negative binomial regression for count models (Table 4).

In addition, for observations that are collected from both our survey and the pre-study survey, we include a dummy variable, a fixed effect to adjust for systematic differences associated with the two different data sources.

### *Measuring precipitation and wind*

Atmospheric conditions may affect one's decision to ride a bicycle (*81*). Due to the temperate nature of the San Francisco Bay Area, we adjusted for precipitation and wind speed. Hourly weather data from the National Oceanic and Atmospheric Administration's Local Climatological

Data online map tool were collected from nine Bay Area weather stations for all dates between January 1, 2017 and July 15, 2019. We focused on precipitation and wind speed for commuting hours (9am to 7pm) to account for riders' decision to either bicycle to work/school or bicycle home. We used data from the weather station closest to each participant's reported home address, home zip code or, if these were unavailable, class location. Two continuous variables between zero and seven were calculated for each participant, one for precipitation and one for wind, counting the number of days in the week prior to the self-reported survey in which precipitation or wind exceeded a given threshold. Thresholds used were any precipitation and the 90$^{th}$ percentile of observed wind speed in the sample days.

### *Robustness checks and sensitivity analyses*

A concern with the study is that only individuals interested in improving their skills and safety will sign up for the class. This self-selected group of individuals are likely to be different from the rest of the population. We mitigate this concern by using a subsample of participants who 1) received a ticket due to a bicycle moving violation and are allowed to go through the training course instead of paying a fine (this option is only possible in Berkeley, as no other jurisdiction has adopted this policy), or 2) attended the class to chaperone their child for whom the class was a prerequisite of attending "Bike Camp" over the summer. These two sets of individuals attended the class because of an exogenous requirement (addressing a ticket or child training). This allows us to compare their outcomes to all others who self-selected into the class.

**Table 4. Outcomes and regression models used**

| Outcome | Model used |
|---|---|
| Rode in week prior | Logistic regression |
| Days rode in past week | Zero-inflated negative binomial regression |
| Minutes rode in past week | Zero-inflated negative binomial regression |
| Rode in month prior | Logistic regression |
| In last month: | |
| Rode for work/school | Logistic regression |
| Rode for errands | Logistic regression |
| Rode to/from transit | Logistic regression |
| Rode to another destination | Logistic regression |
| Rode for exercise | Logistic regression |
| Rode for fun/recreation | Logistic regression |
| Own bicycle | Logistic regression |
| Experienced bicycling in traffic | Logistic regression |
| High confidence while riding in: | |
| Traffic | Logistic regression |
| Car-free area | Logistic regression |
| High feeling of safety when riding in: | |
| Traffic | Logistic regression |
| Car-free area | Logistic regression |
| High knowledge level of rules of the road | Logistic regression |
| Proportion of all trips taken in past week by: | |
| Walking | Negative binomial regression |
| Bicycling | Negative binomial regression |
| Driving | Negative binomial regression |
| Transit | Negative binomial regression |
| TNC | Negative binomial regression |
| Considered riding a bicycle but didn't | Logistic regression |
| Frequency of considering riding a bicycle | Logistic regression |

### *Relevance of the course intervention for specific subgroups*

It is possible that specific subgroups (e.g., older or inexperienced riders) are more or less sensitive to the intervention. Although our study was not powered to detect these possible subgroup effects, we performed additional analyses to explore these. This was achieved by including an interaction term between the variable describing the subgroup of interest and the *after* variable in the regression model. The subgroups tested included age, race/ethnicity, sex, baseline confidence in traffic, and baseline safety in traffic.

In addition, we examined the sensitivity of our results to our thresholds of the atmospheric variables, precipitation and wind. We tested the 95$^{th}$ percentile of precipitation for the sampled day and the 75$^{th}$ percentile for wind in the sampled day. We included each new variable individually, and then together in the statistical models.

Finally, we ran another model including a dummy variable summarizing which nonprofit taught the course to determine if there were systematic differences. These differences could be the result of how the course is taught, different recruitment methods, and differing riding conditions in each geographic location.

The study protocol was approved by the Institutional Review Board at the University of California, Berkeley.

# Results

## Participant sample description

Approximately 250 adults attended a bicycle education course during the current study recruitment period, although exact numbers are unknown due to missing attendance records. Of that number, we recruited 182 participants (~72 percent participation rate) of which 113 completed both the before and after surveys. The remaining 69 were lost to attrition and only completed the before survey (40 percent attrition rate). As discussed, to increase our sample size, we used additional data from a prior survey distributed by one of the nonprofit partners (n=201; the pre-study survey). As a result, the total sample with before and after data was 158 and the total sample of participants with before data only (no after data) was 383. In the following summaries of participant characteristics we stratify the results by current study and pre-study survey data.

Comparisons between the sociodemographic characteristics of both current study and pre-study participants and census data suggest that women and non-Hispanic white and Asian participants are overrepresented in our sample, whereas Black and Hispanic participants are underrepresented (Table 5). This means that members of these groups are more (or less) likely to take bicycle safety education than would be expected based on the population. The total study sample, including from both data sources and those lost to attrition, contains a higher proportion of women than the total population, and nearly double the number of women currently bicycling. Women are also more likely than men to respond to the follow-up survey and be represented in the before and after sample. Older participants were less likely to be lost to attrition from the before to the after survey. Participants were mostly taught by the nonprofit serving Alameda County (60 percent vs. 40 percent for San Francisco County, Table 5). Comparisons are made to county totals for simplicity even though participants may not live in the county in which they attend a bicycle education course.

**Table 5. Sociodemographic characteristics of participants (AC = Alameda County; SFC = San Francisco County)**

| | Population | | Bicycling population | | Total sample | | | Before and after sample | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | AC | SFC | AC | SFC | All (n=383) | AC (n=144) | SFC (n=239) | All (n=158) | AC (n=95) | SFC (n=63) |
| Age (median) | 37.3 | 38.3 | 36.9+ | 34.3+ | 35.5 | 44.5 | 35.5 | 44.5 | 44.5 | 35.5 |
| Sex (%) | | | | | | | | | | |
| Woman | 50.9 | 49.0 | 33.9 | 30.1 | 60.5ǂ | 55.3* | 63.6 | 62.4# | 59.6** | 66.7 |
| Genderqueer | - | - | - | - | 1.3ǂ | 2.1* | 0.8 | 1.3# | 1.1** | 1.6 |
| Race/ethnicity (%) | | | | | | | | | | |
| Asian | 29.5 | 34.2 | 14.5 | 16.9 | 34.2 | 36.8 | 32.6 | 38.6 | 35.8 | 42.9 |
| Black | 10.7 | 5.1 | 7.6 | 1.8 | 1.8 | 4.2 | 0.4 | 3.2 | 4.2 | 1.6 |
| Hispanic | 22.5 | 15.3 | 18.1 | 13.3 | 12.8 | 11.8 | 13.4 | 15.2 | 14.7 | 15.9 |
| Non-Hispanic White | 32.2 | 40.8 | 46.1 | 57.9 | 48.8 | 43.8 | 51.9 | 44.3 | 44.2 | 44.4 |

+Taxicab, motorcycle, bicycle or other means

ǂn=380; *n=141; #n=157; **n=94

Note: Total sample and before and after sample are listed by county in which the course took place. Individual participants may reside in a different county. Both include data from the current study survey and pre-study survey.

Source: Population data from 2017 ACS 5-year estimates for Alameda County, CA and San Francisco County, CA. Universe: Total population. Age: TableS0101. Sex: Table B01001. Race/ethnicity: Table B03002. Bicycling population data from 2017 ACS 5-year estimates for Alameda County, CA and San Francisco County, CA. Universe: Workers 16 years and over. Age: Table B08103. Sex: Table B08006. Race: Extrapolated from tables B08103, B08105B, B08105D, B08105H, and B08105I.

The before survey for the current study asked participants to select barriers that prevent them from bicycling more from a pre-populated list (Table 6). While safety was selected as a top concern for both the total sample and the before and after sample, those who replied to the after survey were less concerned about distance of trips and number of hills. The before and after population was also more likely to list any of the barriers as a concern.

**Table 6. Initial barriers to bicycling identified by study participants (%), current study survey**

| | SF Bay Area Population | Total sample (n=182) | Before and after sample (n=119) |
|---|---|---|---|
| Safety concerns | 48.6 | 43.96 | 47.06 |
| Weather | - | 41.76 | 42.02 |
| Lack of bicycle lanes | 26 | 38.46 | 39.5 |
| I don't want to arrive sweaty | - | 34.07 | 36.97 |
| Trips are too far to bicycle | - | 31.87 | 27.73 |
| Too much to carry | - | 31.87 | 33.61 |
| Theft concerns | - | 29.12 | 32.77 |
| Too many hills | - | 18.13 | 16.81 |
| Not enough energy/strength | - | 13.19 | 15.97 |
| Bicycling is too slow | - | 10.99 | 11.76 |
| Transit restrictions | - | 6.59 | 6.72 |

Source for Bay Area data: National Household Travel Survey 2017.

Differences in baseline bicycle activity, self-efficacy, personal safety, and knowledge between participants who completed the before and after surveys and those lost to attrition for the current study tend to be small (Table 7). For those who completed the before and after surveys for the prior study, differences in bicycling activity and bicycling self-efficacy were more pronounced. Participants who completed both surveys were more likely to bicycle for commuting, exercise, errands (current survey only), other destinations and exercise (pre-study survey only). Before and after participants in the current survey were less likely to own a bicycle, while those in the pre-study survey were more likely to do so. Participants who completed both surveys were also more likely to report high levels of experience in traffic (4 or 5 on a 5-point Likert scale, with 1 = "Inexperienced" and 5 = "Very experienced").

**Table 7. Baseline bicycle activity; self-efficacy, personal safety and knowledge; and modal split**

| | Total sample | | | | Before and after sample | | | |
|---|---|---|---|---|---|---|---|---|
| | Current survey | n | Pre-study survey | n | Current survey | n | Pre-study survey | n |
| Rode in week prior (%) | 48.35 | 182 | 44.28 | 201 | 47.79 | 113 | 51.11 | 45 |
| Days rode in past week | 1.69 | 182 | 1.33 | 201 | 1.62 | 113 | 1.47 | 45 |
| Minutes rode in past week | 102.71 | 182 | - | - | 90.74 | 113 | - | - |
| Rode in month prior (%) | 67.58 | 182 | 64.18 | 201 | 69.03 | 113 | 73.33 | 45 |
| In last month: | | | | | | | | |
| Rode for work/school (%) | 28.02 | 182 | 29.35 | 201 | 28.32 | 113 | 35.60 | 45 |
| Rode for errands (%) | 28.02 | 182 | 23.38 | 201 | 30.97 | 113 | 22.20 | 45 |
| Rode to/from transit (%) | 15.93 | 182 | - | - | 15.93 | 113 | - | - |
| Rode to another destination (%) | 21.43 | 182 | 1.49 | 201 | 23.01 | 113 | 4.40 | 45 |
| Rode for exercise (%) | 30.77 | 182 | 31.34 | 201 | 30.09 | 113 | 33.30 | 45 |
| Rode for fun/recreation (%) | 35.16 | 182 | 38.81 | 201 | 32.74 | 113 | 37.80 | 45 |
| Own bicycle (%) | 81.32 | 182 | 68.66 | 201 | 80.53 | 113 | 80.00 | 45 |
| High experience bicycling in traffic (%) | 33.52 | 182 | - | - | 34.51 | 113 | - | - |
| High confidence in: | | | | | | | | |
| Traffic (%) | 32.42 | 182 | 11.73 | 179 | 29.20 | 113 | 15.00 | 40 |
| Car-free area (%) | 83.52 | 182 | 72.19 | 187 | 84.07 | 113 | 61.90 | 42 |
| High safety in: | | | | | | | | |
| Traffic (%) | 14.44 | 180 | 6.74 | 178 | 11.61 | 112 | 5.40 | 37 |
| Car-free area (%) | 83.98 | 181 | 82.70 | 185 | 84.82 | 112 | 78.60 | 42 |
| High rules of the road knowledge (%) | 41.21 | 182 | 19.07 | 194 | 40.71 | 113 | 18.60 | 43 |
| In past week: | | | | | | | | |
| Walking trips (%) | 31.98 | 182 | - | - | 32.38 | 113 | - | - |
| Bicycling trips (%) | 12.99 | 182 | - | - | 12.60 | 113 | - | - |
| Driving trips (%) | 34.49 | 182 | - | - | 35.00 | 113 | - | - |
| Transit trips (%) | 0.40 | 182 | - | - | 0.56 | 113 | - | - |
| TNC trips (%) | 20.07 | 182 | - | - | 19.35 | 113 | - | - |
| Considered riding a bicycle but didn't (%) | 48.35 | 182 | - | - | 53.10 | 113 | - | - |
| High frequency of considering bicycling (%) | 10.44 | | - | - | 13.27 | | - | - |

Participants who completed the current before and after survey were more likely to have high feelings of confidence (4 or 5 on a 5-point Likert scale, with 1 = "Not confident" and 5 = "Very confident") and safety (4 or 5 on a 5-point Likert scale, with 1 = "Not safe" and 5 = "Very safe") in a car-free area than the total sample surveyed, but were less likely to feel highly confident or safe in traffic. However, participants from the pre-study survey who took both surveys were more likely to feel highly confident in traffic. They were less likely to feel highly safe in traffic, and less likely to feel highly confident or safe in a car-free area. Both before and after samples were less likely to report high levels of knowledge of the bicycling rules of the road (4 or 5 on a 5-point Likert scale, with 1 = "Poor" and 5 = "Excellent").

The population that responded to both surveys was more likely to travel by foot, car or transit, and was more likely to consider choosing a bicycle for their transportation mode than the total sample.

## Accuracy of self-reported bicycling activity

Pearson correlations were used to assess agreement between self-reported bicycling minutes and Ride Report-observed minutes. Although the sample was small (n=14), there was almost perfect agreement between self-reported minutes on the after survey and the corresponding minutes observed on Ride Report ($r = 0.9474$, $p < 0.00$). This indicates that the self-reported data agrees highly with the objectively measured data.

For the before survey, there was moderate agreement between self-reported riding minutes the week prior to the survey and the average weekly riding minutes after the survey (but before the course) ($r = 0.4564$, $p < 0.136$; n=12) though the results are not statistically significant. When a single outlier was removed, the correlation indicated substantial agreement ($r = 0.7344$, $p < 0.01$; n=11), which suggests that observations of past bicycling behavior agree well with self-report data, even if the dates do not correspond.

## Unadjusted impacts of bicycle education course

An initial approach to describe the impacts of the course is to examine how the outcomes changed from before to after taking the course. We call these comparisons "crude" because they do not adjust for various attributes that differed across participants such as socio-economic characteristics, when participants rode, and the nonprofit imparting the course. In the next subsections we report crude changes for our three main outcome categories: bicycling activity; self-efficacy, personal safety, and knowledge; and travel mode.

### *Changes in bicycle activity*

Most bicycle activity indicators are not statistically different between the before and after surveys (Table 8). Only two purposes for which participants rode in the past month changed significantly: riding for fun/recreation increased by 13.9 percentage points ($p < 0.01$) while riding to/from transit decreased from 15.93 percent of respondents to none ($p < 0.00$). A significant change in experience bicycling in traffic ($p < 0.05$) suggests that participants bicycled more in traffic and as result reported increased experience riding in those conditions.

Even though participants appear to have ridden more after the course as compared to levels before the course, most differences were not statistically significant. Similarly, outcomes concerning days and minutes rode during the past week and bicycle ownership were not statistically different between the before and after surveys.

**Table 8. Comparison of bicycling outcomes before and after the course (mean or percent)**

| | Before | After | Change | n | p-value |
|---|---|---|---|---|---|
| Rode in week prior (%) | 48.73 | 53.16 | 4.43 | 158 | 0.215 |
| Days rode in past week (count) | 1.58 | 1.74 | 0.16 | 158 | 0.240 |
| Minutes rode in past week (count) | 219.30 | 246.92 | 27.62 | 37 | 0.316 |
| Rode in month prior (%) | 70.25 | 74.68 | 4.43 | 158 | 0.189 |
| In last month: | | | | | |
| Rode for work/school (%) | 30.38 | 34.81 | 4.43 | 158 | 0.200 |
| Rode for errands (%) | 28.48 | 28.48 | 0.00 | 158 | 0.500 |
| Rode to/from transit (%) | 15.93 | 0.00 | -15.93 | 113 | 0.000 |
| Rode to another destination (%) | 17.72 | 18.99 | 1.27 | 158 | 0.386 |
| Rode for exercise (%) | 31.01 | 34.81 | 3.80 | 158 | 0.236 |
| Rode for fun/recreation (%) | 34.18 | 48.10 | 13.92 | 158 | 0.006 |
| Own bicycle (%) | 80.38 | 82.91 | 2.53 | 158 | 0.281 |
| Experience bicycling in traffic* | 2.61 | 2.81 | 0.20 | 113 | 0.023 |
| Confidence in: | | | | | |
| Traffic* | 2.32 | 2.83 | 0.51 | 152 | 0.000 |
| Car-free area* | 4.04 | 4.33 | 0.29 | 155 | 0.000 |
| Safety in: | | | | | |
| Traffic* | 2.04 | 2.43 | 0.39 | 146 | 0.000 |
| Car-free area* | 4.05 | 4.33 | 0.29 | 153 | 0.000 |
| Rules of the road knowledge* | 2.82 | 3.79 | 0.97 | 156 | 0.000 |
| In past week: | | | | | |
| Walking trips (%) | 32.38 | 26.62 | -5.76 | 113 | 0.004 |
| Bicycling trips (%) | 12.60 | 13.96 | 1.36 | 113 | 0.304 |
| Driving trips (%) | 35.00 | 38.09 | 3.09 | 113 | 0.129 |
| Transit trips (%) | 0.56 | 14.28 | 13.72 | 113 | 0.000 |
| TNC trips (%) | 19.35 | 6.78 | -12.57 | 113 | 0.000 |
| Considered riding a bicycle but didn't (%) | 53.10 | 47.79 | -5.31 | 113 | 0.382 |
| Frequency of considering riding a bicycle* | 1.14 | 1.03 | -0.12 | 113 | 0.004 |

*Scale 1-5 (low to high)

### *Changes in self-efficacy, personal safety and knowledge*

Participants reported a significant ($p < 0.01$) increase across all measures of self-efficacy, personal safety, and self-rated bicycling knowledge. The large increase in knowledge of nearly 1 point makes sense given that the intervention focused heavily on providing facts about the rules of the road to participants. Increased feelings of confidence and safety could be attributed to either feelings of security while bicycling due to the increased knowledge or could be related to increased bicycling frequency and therefore practice in various bicycling situations.

### *Changes in travel modes*

There was no statistically significant change in the percent of trips taken by bicycle from before to after the course. However, participants reported significant changes in their use of other transportation modes. Specifically, participants reported walking less and taking fewer TNCs ($p < 0.01$) while they increased their use of public transportation ($p < 0.01$). This may be related to external factors (e.g., rain, wind or season) that are not accounted for in a simple test of comparison.

When asked about frequency of considering bicycling but deciding against it, participants didn't report a significant change between before and after the course. This could be either because participants considered bicycling less often for all trips, or that participants considered bicycling and decided to ride, thus leading to a decrease in the number of times they considered bicycling and did not choose to. Of those who reported "yes" to considering bicycling but deciding against it, there was little change in how often they considered bicycling. Both pre-intervention and post-intervention, participants who did consider bicycling reported "almost never" considering bicycling but deciding against it.

## Overall impacts of bicycle course: Adjusted effects

As discussed, crude comparisons between before and after data are subject to possible bias. To address this, we used regression analysis to estimate the effects of the intervention. Because the courses were taught at different points in time, we compared behaviors of those who have taken the course relative to those who have not taken the course in that same period. At a given point in time, a prospective student effectively served as a control for students that had already received the intervention. In the next subsections we report estimated changes due to the course for our three main outcome categories: bicycling activity; self-efficacy, personal safety, and knowledge; and travel mode. We report average marginal effects, which indicate a change in the outcome (probability or count) after the course compared to before the course, while adjusting for individual characteristics, weather conditions, and season.

### *Changes in bicycle activity*

We see little evidence of increased bicycling activity after the course (Table 9). Most differences between the before and after surveys are not statistically significant, though the sign of the coefficient is positive. Although there was no evidence of increased experience bicycling in traffic, there was an increased probability of 11 percentage points ($p = 0.1$) of reporting high experience in traffic in a simpler regression model without controlling for socioeconomic characteristics or weather variables (data not shown). Looking at bicycling purpose, the probability of bicycling for fun or recreation was 13 percent higher ($p < 0.05$). These results are similar to those identified in crude averages.

**Table 9. Estimated average marginal effects of bicycle education class [95% confidence interval] by outcome**

| | N | Marginal effect‡ | 95% CI | |
|---|---|---|---|---|
| Rode in week prior (yes=1) | 541 | 0.04 | [-0.07,0.14] | |
| Days rode in past week (count) | 541 | 0.16 | [-0.29,0.61] | |
| Minutes rode in past week (count) | 295 | 23.74 | [-27.91,75.38] | |
| Rode in month prior (yes=1) | 541 | 0.03 | [-0.07,0.13] | |
| In last month: | | | | |
| Rode for work/school (yes=1) | 541 | 0.04 | [-0.06,0.14] | |
| Rode for errands (yes=1) | 541 | 0.01 | [-0.08,0.10] | |
| Rode to/from transit (yes=1) | - | - | - | - |
| Rode to another destination (yes=1) | 541 | 0.01 | [-0.06,0.07] | |
| Rode for exercise (yes=1) | 541 | 0.04 | [-0.07,0.14] | |
| Rode for fun/recreation (yes=1) | 541 | 0.13 | [0.02,0.24] | ** |
| Own bicycle (yes=1) | 541 | 0.04 | [-0.06,0.13] | |
| Experienced bicycling in traffic (yes=1) | 295 | 0.08 | [-0.04,0.21] | |
| High confidence while riding in: | | | | |
| Traffic (yes=1) | 516 | 0.11 | [0.01,0.21] | ** |
| Car-free area (yes=1) | 526 | 0.12 | [0.04,0.19] | *** |
| High feeling of safety when riding in: | | | | |
| Traffic (yes=1) | 510 | 0.08 | [-0.01,0.16] | * |
| Car-free area (yes=1) | 522 | 0.09 | [0.02,0.15] | ** |
| High knowledge level of rules of the road (yes=1) | 534 | 0.46 | [0.37,0.56] | *** |
| Count of all trips taken in past week by: | | | | |
| Walking | 295 | -1.16 | [-1.98,-0.35] | *** |
| Bicycling | 295 | 0.28 | [-0.83,1.38] | |
| Driving | 295 | 0.17 | [-1.45,1.80] | |
| Transit | 295 | 2.33 | [1.38,3.29] | *** |
| TNC | 295 | -2.08 | [-2.93,-1.22] | *** |
| Considered riding a bicycle but didn't (yes=1) | 295 | -0.09 | [-0.23,0.04] | |
| Frequency of considering riding a bicycle but didn't | 295 | -0.03 | [-0.11,0.05] | |

Notes: All regression models adjust for age, gender (male=1), race/ethnicity (nonwhite=1), any precipitation during the prior week, wind (=1 if > 90th percentile), season, before/after survey status, and source of data (current or pre-study, as applicable). *, **, *** indicate statistical significance at 90%, 95%, and 99% levels of confidence, respectively. Results for "rode to/from transit" not shown because none of the participants reported bicycling to transit in the after survey.
‡For binary outcomes (yes=1), marginal effects are for logistic regression model and represent a change in the probability of the outcome. For proportion outcomes and count outcomes (days, minutes), marginal effects are for negative binomial part of a zero-inflation negative binomial model and represent a change in the number of trips by each mode.

Changes in bicycle activity can also be visualized by estimated the average marginal effect for before and after the course. These are model-estimated values for specific participant characteristics and riding conditions (nonwhite, non-male, at median age taking the class in the winter, with median wind and precipitation). These trends are visible for both overall bicycling activity (Figure 2) and bicycling purpose in the past month (Figure 3).

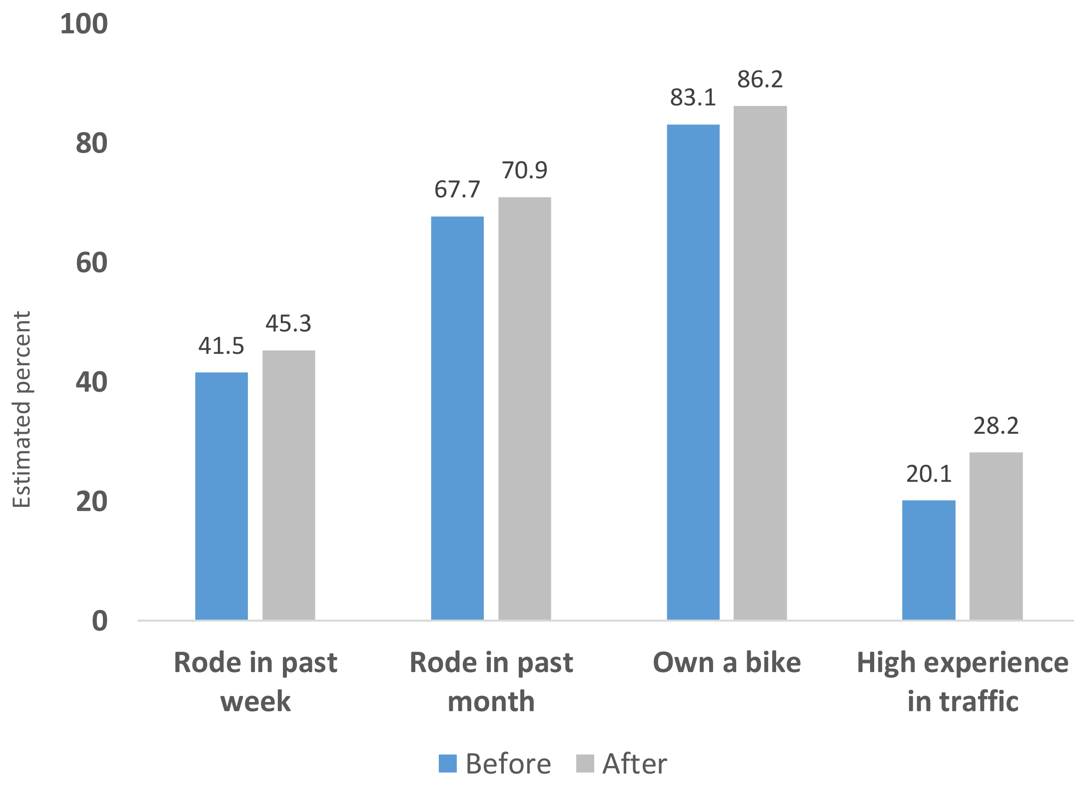


**Figure 2. Estimated average marginal effects of bicycle education class on bicycling activity**

Note: *, **, *** indicate statistical significance at 90%, 95%, and 99% levels of confidence, respectively. Estimated for nonwhite, non-male, median age participant who took both before and after surveys taking the class in the winter during the current study and riding during periods of median wind and precipitation).

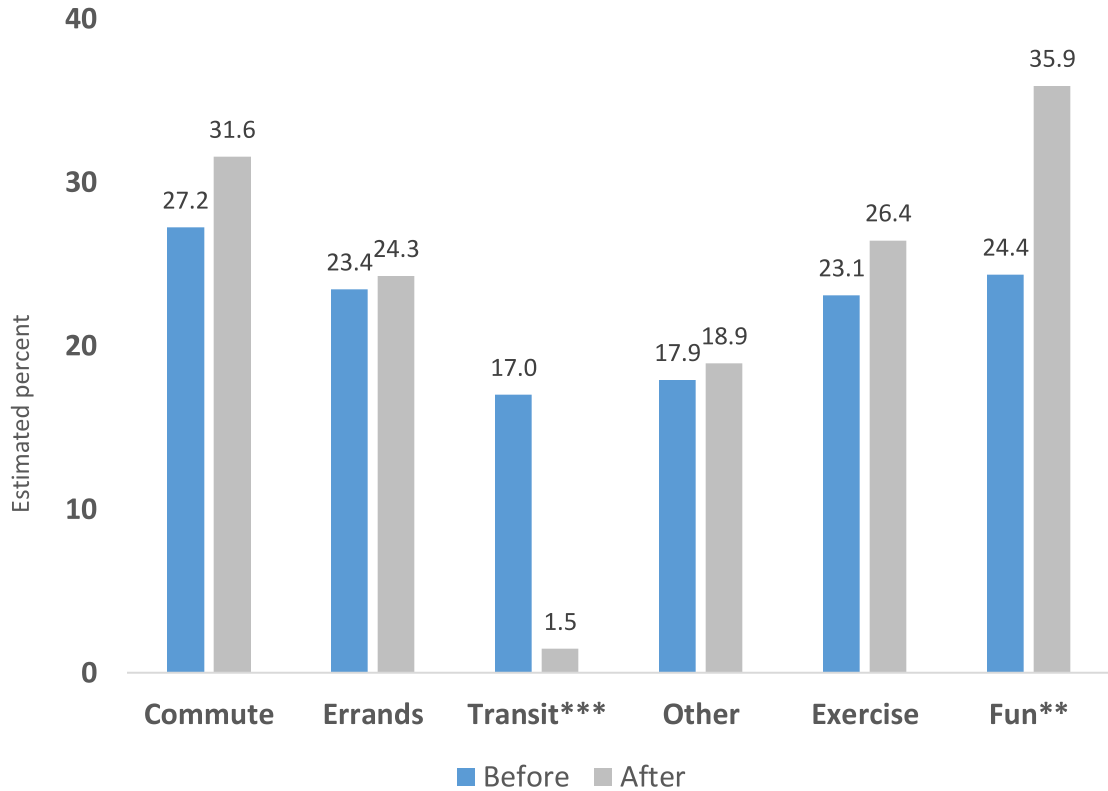


**Figure 3. Estimated average marginal effects of bicycle education class on bicycling purpose in last month**

Note: *, **, *** indicate statistical significance at 90%, 95%, and 99% levels of confidence, respectively. Estimated for nonwhite, non-male, median age participant who took both before and after surveys taking the class in the winter during the current study and riding during periods of median wind and precipitation.

## *Changes in self-efficacy, personal safety, and knowledge*

Across all measures of self-efficacy, personal safety, and knowledge, we find significant increases among participants after the course. The probability of reporting high confidence bicycling in traffic or car-free areas increased by 11 percent ($p < 0.05$) and 12 percent ($p < 0.01$) after the course, respectively. The probability of reporting high feelings of safety in traffic or car-free areas increased by 8 percent ($p < 0.1$) and 9 percent ($p < 0.05$) after the course, respectively. The probability of reporting high knowledge of rules of the road increased by 46 percent ($p < 0.01$). Visualizing these changes using estimated average marginal effects before and after the intervention shows the overall effects of the intervention on personal safety, self-efficacy and knowledge (Figure 4).

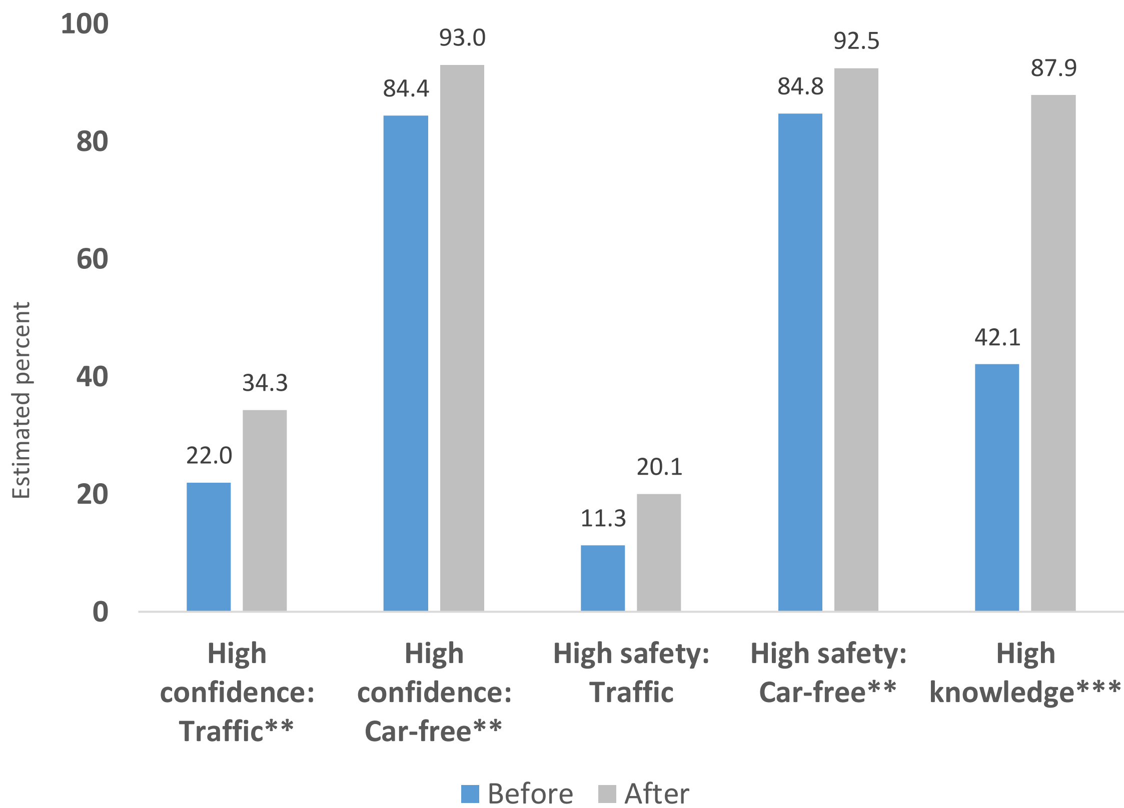


**Figure 4. Estimated average marginal effects of bicycle education class on self-efficacy, personal safety, and knowledge**

Note: *, **, *** indicate statistical significance at 90%, 95%, and 99% levels of confidence, respectively. Estimated for nonwhite, non-male, median age participant who took both before and after surveys taking the class in the winter during the current study and riding during periods of median wind and precipitation.

### *Changes in travel modes*

The before and after surveys asked participants to list how many trips they made in the past week by foot, bicycle, car, public transportation, and rideshare service, with the goal of answering the research question: Do bicycle education classes increase bicycle mode share and/or cause mode shift towards bicycling? While there were significant changes in the proportion of trips by foot, transit and TNC, there was no change in the count of trips made by bicycle (Table 9).

### *Are there differences in effects by subgroups?*

To examine whether subgroups of participants benefited more or less from the course, we examined the moderating effect of a subset of participant demographic characteristics (male, nonwhite, and age) and self-reported confidence and safety perceptions riding in traffic at baseline (before the intervention). As described in the Methods section, this involves including an interaction term between the moderating variable and the course, as well as main effect for the moderating variable.

In terms of participant demographics, older individuals benefited less from the course than younger participants for self-reported confidence in traffic and self-reported knowledge of the rules of the road.

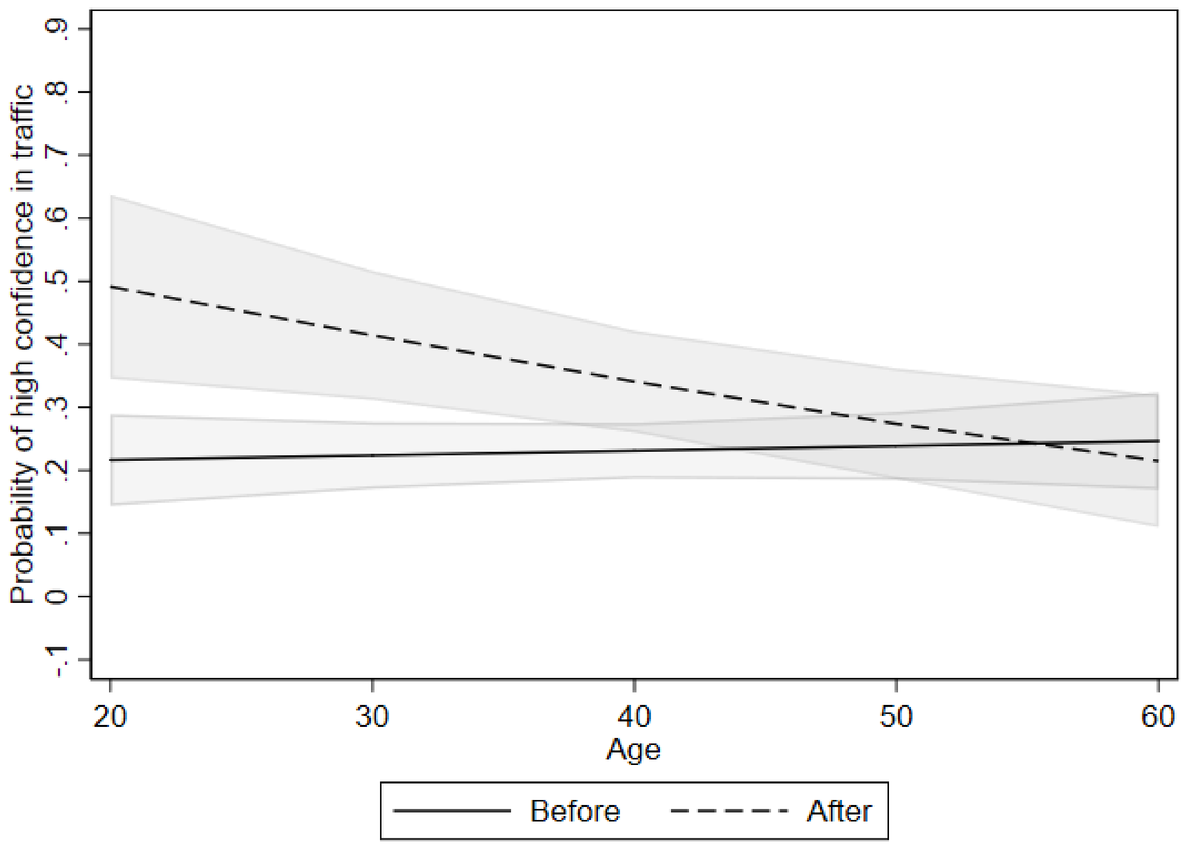


Figure 5 and Figure 6 show by age how participants self-reported confidence riding in traffic and knowledge of the rules of the road before and after the course. The effect is higher for younger individuals but begins decreasing as participant age increases. The effect of the intervention for non-males (women and genderqueer participants) was higher for minutes bicycled in the past week, outcomes related to transit use, and feelings of safety and confidence in traffic, relative to males (results not shown). Finally, non-white participants increased their minutes bicycled and were less likely to use TNCs after the intervention (results not shown).

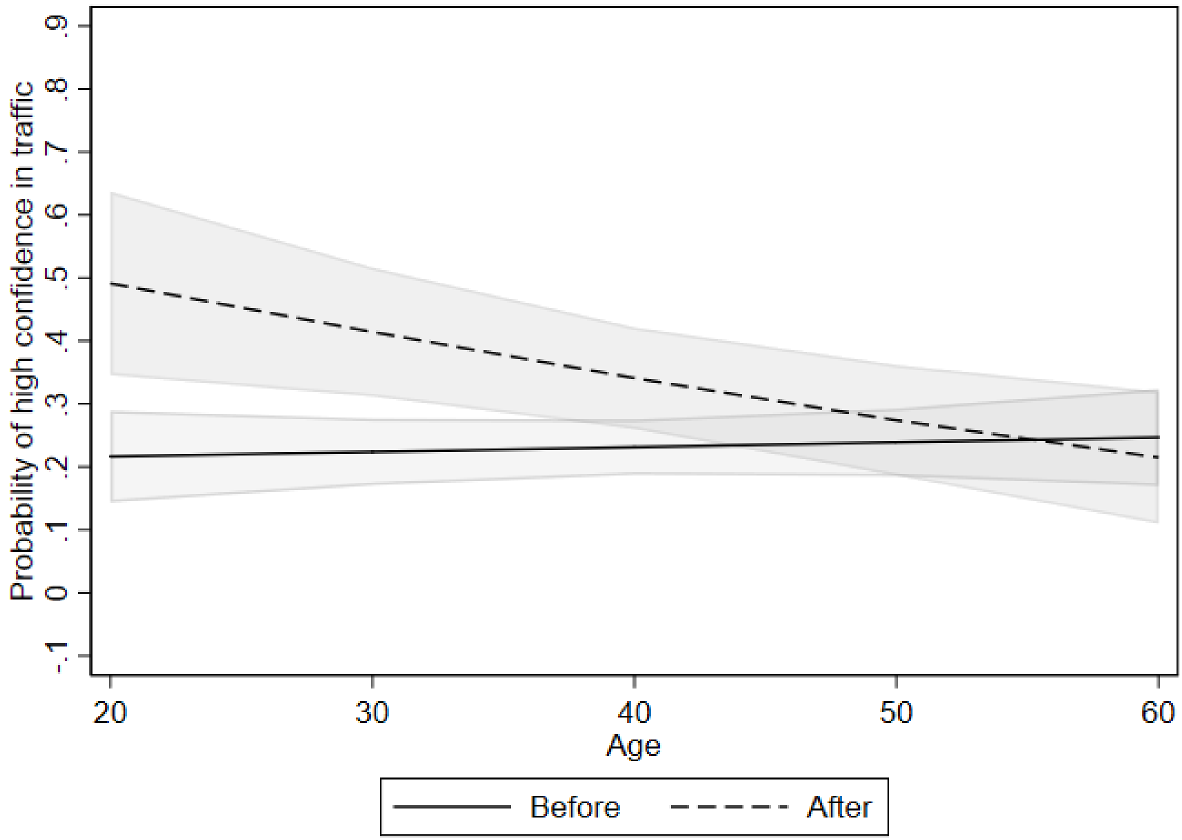


**Figure 5. Self-reported high confidence in traffic by age (gray areas represent 95% confidence intervals)**

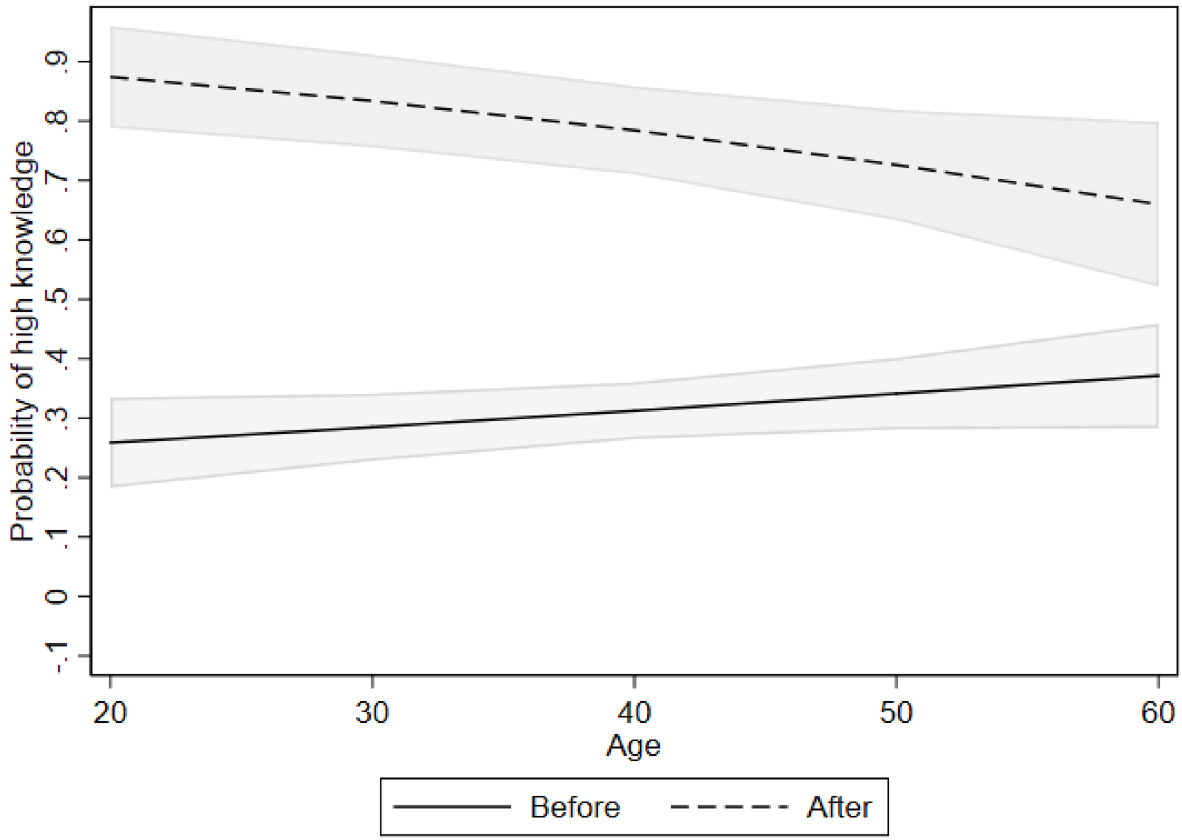


**Figure 6. Self-reported high knowledge of the bicycling rules of the road by age (gray areas represent 95% confidence intervals)**

In terms of confidence in traffic, we found that participants with lower confidence at baseline (pre-course) benefited more from the course than participants with higher confidence. Their change in minutes bicycled, riding for exercise, and in perceived safety riding in traffic was higher.

Figure 7 and Figure 8 show how participants reported minutes bicycled and perceived safety riding in traffic before and after the course as base confidence in traffic ranges from 1 (low) to 4+ (high). This means that the educational intervention examined was most beneficial for participants with low confidence riding in traffic. Participants with low baseline safety in riding were more likely to drive after the course (results not shown).

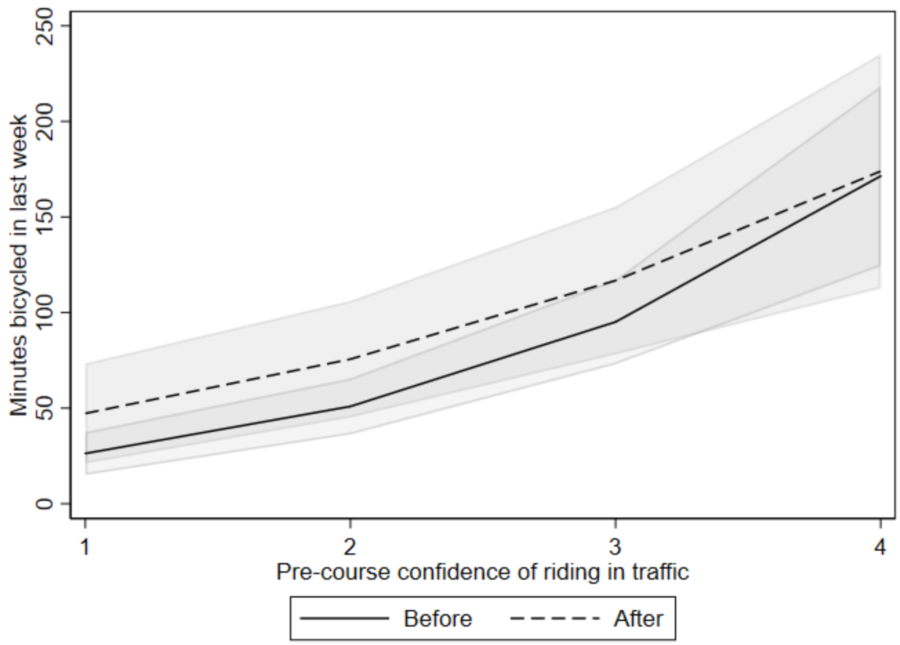


**Figure 7. Self-reported minutes bicycled in past week by pre-course confidence riding in traffic (gray areas represent 95% confidence intervals)**

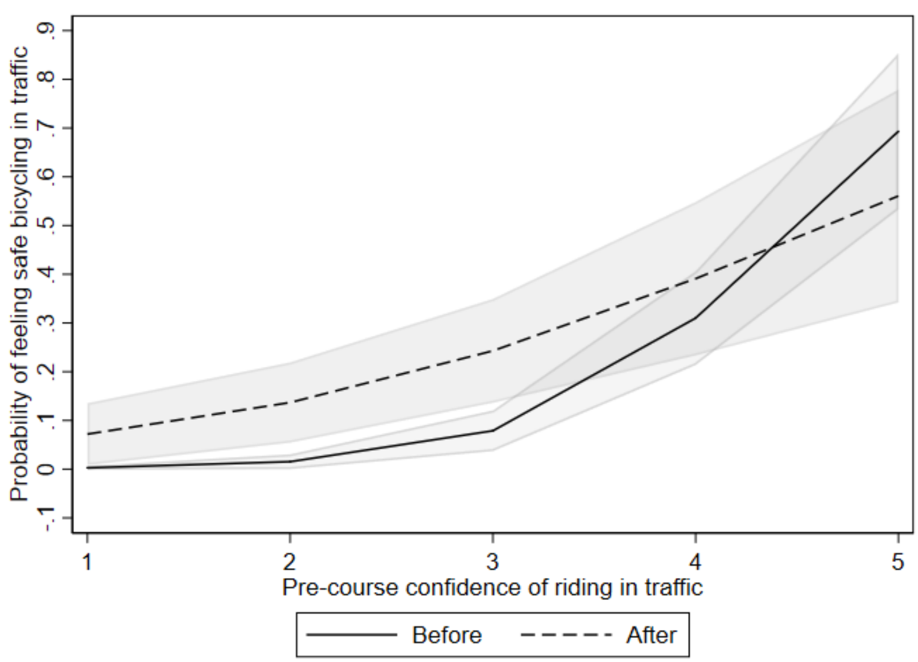


**Figure 8. Self-reported feeling of safety in traffic by pre-course confidence riding in traffic (gray areas represent 95% confidence intervals)**

## *Checking the robustness of our analyses*

As noted in the methods, examining a group that did not self-select into the class (e.g. people who received a ticket while bicycling and parents accompanying their children to a mandatory class in order attend summer cam) can allow us to mitigate concerns of using a self-selected pool of participants. In no instances did inclusion of the ticket-receivers and camp parents variable change the intervention coefficient and its significance (results not shown). The variable was significant for four outcomes, however. This group is significantly more likely to have bicycled in the past week, bicycled to errands in the past month, have a high confidence bicycling in traffic, have high rules of the road knowledge, drive a car for transportation, and is less likely to walk as a mode of transport (results not shown). An analysis of the interaction between this group and *after* results in no difference in outcome between this group and the study population (results not shown). This suggests that this group may not be different enough from the study population to understand the effects of self-selection. Those in the class for receiving a ticket were already bicycling when they were cited, so they may not gain much from the class. Those whose children were attending Bike Camp may have signed up their kids because the parents are enthusiastic bicycle riders themselves.

A sensitivity analysis understanding the effects of how weather was measured involved separately changing the precipitation variable to be more stringent (from any precipitation to precipitation at the 95$^{th}$ percentile or above) and the wind variable to be less stringent (from wind at or above the 90$^{th}$ percentile to wind at or above the 75$^{th}$ percentile) and examining whether the estimated effects of the course changed for the outcomes. The sign of every intervention coefficient and its significance remained unchanged (results not shown). Of note, the significance and direction of the precipitation and wind coefficients changed in some models, with both improved and worse model fit resulting from the changes to these weather variables. When changing the wind variable, five of eight significance changes indicated better model fit, while three of five significance changes after changing the precipitation variable indicated worse model fit as judged by likelihood ratio information criteria. When changing both variables, the changes were again nearly evenly split, with three of five changes to coefficient significance indicating worse model fit. This suggests that more research is necessary to determine both the appropriate wind and precipitation thresholds that influence cycling behavior, and perhaps other measurements of environmental factors that may influence this behavior.

When examining whether the nonprofit that delivered the course had an impact on the estimated effects, we found no differences in the estimated effects (results not shown). This is positive and suggests that bicycle education classes can be delivered differently (for example a single staff member like in one nonprofit, presumably increasing the fidelity of the intervention, or by different volunteer instructors like in the other nonprofit) and this does not have an impact on the outcomes. However, we did see some geographic differences within the participant population. Individuals taught in San Francisco have a higher probability of riding to work/school, for errands, or for another destination than individuals taught in the East Bay. This may be related to the geography of San Francisco. The San Francisco participants also have a lower probability of being highly confident riding in a car-free area, perhaps because bicycling paths and trails in San Francisco are limited, and a lower probability of owning a bicycle.

# Discussion

## Implications

This study aimed to understand the effect of a two-hour, classroom-based bicycle training course on participants' bicycle activity; self-efficacy, personal safety and knowledge; and travel mode choice.

The course resulted in a significant increase in class participants' self-efficacy riding with and without traffic, feelings of safety riding with and without traffic, and self-reported knowledge of rules of the road. These effects were particularly important for younger participants and those who reported having lower riding confidence before the course. As the age of participants increased, the effect of the course on confidence riding in traffic and knowledge of the rules of the road began decreasing. Although participants reported riding more for fun and recreation after the course, overall we did not find evidence of increased bicycling activity after the course or of considering riding a bicycle even if they did not end up using it. Finally, we also found that individual self-reported data on bicycle activity during the past week has high agreement with objectively measured bicycle activity during the same time frame. Future studies can use such self-reported measures with confidence.

Our findings regarding self-reported safety, confidence, and knowledge are consistent with results found in the literature from other types of bicycle training interventions (*9*, *50*, *51*, *70*, *71*, *73*), though no other study of adults examined an entirely classroom-based intervention. Of studies that centered on classroom-based trainings in children, these results agree with findings of increased knowledge (*65*, *66*). However, Transport for London (*71*) found that increases in feelings of safety and confidence peaked about three months from the course and had dropped by the one-year mark, though levels remained above baseline.

Contrary to our results of no changes in bicycle use and activity, other studies have suggested increased bicycling activity after training, although studies examined on-bicycle courses (*9*, *70*–*73*). The difference may be due to lack of bicycling skills or concern about riding a bicycle. It is probable that many people who take a bicycle education class in a classroom are interested in bicycling but are concerned about getting on a bicycle. Even though the class may improve their confidence and feelings of safety, as seen in the data, it may not be enough for more than a subset to change their behavior.

Nevertheless, people who reported initially feeling low confidence bicycling in traffic did report increased bicycle activity on two metrics: minutes bicycled in the past week and bicycling for exercise. This suggests that the course encouraged people to bicycle who would not have attempted it prior to taking the class, such as women, who were more likely to report low confidence bicycling in traffic prior to taking the course.

The classroom-based bicycle education course examined in this study is the first of two courses; the second course is an on-bicycle class that lasts between four and six hours. The increased confidence, feelings of safety and knowledge may encourage participants to sign up for the on-bicycle class. Based on prior results of studies of on-bicycle classes (*9*, *70*–*73*), participants who take the on-bicycle class may eventually bicycle more frequently.

Additionally, the classroom-based course is significantly less expensive for the nonprofit partners to implement, suggesting that even a low-cost investment in bicycle education can result in benefits.[2]

The results for travel mode choice show no change in the proportion of trips taken by bicycle. This suggests that alone, a two-hour classroom course on bicycling safety is not sufficient to encourage mode change. Indeed, researchers struggle to identify how best to change transportation behavior. A review of research into the effects of built environment infrastructural changes, for example, on walking and bicycling behavior change found mixed results (*82*).

It is also of note that the demographics of the classes differ from both the general population and the population that commutes to work by bicycle. The proportion of women that takes the classes is nearly double the bicycling population, and over ten percentage points higher than the general population. This could indicate that the marketing techniques employed by the nonprofit partners are better at targeting women or are reaching more women. This could also indicate that women are interested in bicycling, but the current bicycling landscape is not supportive for them to ride. For example, research has shown that women are more likely to ride on off-road paths compared to roads with no bicycle facilities (*83*). Women are also more likely to assume traditional gender roles including childcare, cooking and housework that may not be conducive to bicycling (*84*). Content in the courses that discuss specifically how to ride safely on on-road bicycle infrastructure or how to bicycle with a family may support more women riding.

Beyond gender, both Black and Hispanic class participation is lower than the general population and the bicycling population. This may be due to a variety of factors. First, though the classes are held across the Bay Area, only a few were held in neighborhoods with high proportions of Black and Hispanic residents. Although many people travel to the classes (some participants

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[2] The standard LCI rate set by the LAB is $50/hour. A two-hour classroom-based course with one instructor can be provided for approximately $200 including set-up and clean-up time. A six-hour on-bicycle course requires one head instructor ($60/hour) and at least three assistant instructors ($50) and would cost approximately $1,500 including set-up and clean-up time.

came to classes from cities in other counties, for example), it could be expected that most would be more likely to attend a class in their neighborhood. Second, when one member of the research team went to survey at a class in a predominately Black neighborhood of East Oakland, participants of color were distrustful of UC Berkeley and did not feel comfortable filling out the survey because it would require providing identifying information. Third, the current methods of recruitment for the classes rely heavily on electronic forms of communication (email, website, social media). This may exclude people without access to a computer or smartphone. Research shows that Mexican-Americans and Blacks are less likely to own a computer and have Internet access when compared with White families. This is not due entirely to income; income differences explain between 10 and 30 percent of the access gap (*85*).

Our study has important limitations to acknowledge. First, although we aimed for 225 participants total (450 with 50 percent attrition), we had 113 participants who took both surveys alongside 45 from the pre-study survey for a total of 158 participants. This decreased the power of our study to detect associations at the pre-established levels.

Second, the analysis did not account for external reasons that might cause individuals to bicycle more or less and that can be correlated with study participation. For example, if participants are injured, then the longer we observed them the more likely they were to be bicycling less due to injuries. We also did not track if the participants took additional bicycle education courses with the nonprofits.

Third, we did not account for the fidelity of the interventions, such as the fact that different instructors teach the classes. Thus, even though our estimates are of average effects, it may be that higher quality instruction yields different outcomes than lower quality instruction.

Fourth, we originally aimed to understand the effect of the course on bicycle-share and dockless bicycles. However, the survey was designed months before dockless bicycle-share companies began replacing their bicycles with e-scooters. As a result, the question about dockless bicycle-share is dated in that it asks about Limebike – a product no longer offered in the SF Bay Area. Additionally, station-based bicycle-share offerings changed numerous times throughout the study period. In December 2018, Ford GoBike (now Bay Wheels, the region's sole station-based bicycle-share provider) announced hundreds of additional electric-assist bicycles in San Francisco and the expansion of e-bicycles to the East Bay. In February 2019, due to popular demand, the number of e-bicycles was increased by over 1,400 bicycles. In April 2019, Ford GoBike announced the removal of all e-bicycles due to faulty brakes. Furthermore, some bicycle-share stations were added in San Francisco during this time. It is possible that the changes to the bicycle-share system may have confounded efforts to understand participants' usage of bicycle-share. Therefore, we did not report on these results.

Fifth, as all participants currently bicycle or are interested in bicycling, we were not able to estimate the effect of the course on the population at large. One could argue that estimating a population-level effect is not even appropriate because expecting an entire population to take such a class would not be feasible or desirable. The effectiveness of the education program in question may arise *because* it allows people with an interest in improving skills to do so, rather than *in spite of it*.

The study also has several strengths. First, to our knowledge, this is the first study undertaken to evaluate a classroom-based bicycle education course, and the eighth study to examine the effects of bicycle education on an adult population. It is also the first study to examine the connection between bicycle education and travel mode choice. Second, the study utilized a strong before/after design which took advantage of different times of intervention delivery to address concerns around bias and temporal trends. Finally, the study employed a novel smartphone app to collect data on participants and validate self-reported measures. This strengthens future research that relies on self-reported data.

# Conclusion

This study is the first to evaluate key impacts of a two-hour classroom-based bicycle education course on bicycle use; self-efficacy, personal safety, and knowledge; and travel mode choice. We found that bicycle education can have a positive influence on participants' feelings of confidence and safety while riding in traffic or in car-free areas, as well as on knowledge related to the bicycling rules of the road. Although it is possible that this increased knowledge and confidence will translate into actual safety benefits, we did not examine this outcome. This possibility should be examined in further research. While we detected changes in bicycling activity among those with initial low confidence, we did not detect overall changes in bicycling use and activity and travel mode shifts. Further research is needed to understand behavioral change related to transportation interventions.

Due to the cost-effective nature of this type of education, planners should consider continuing to fund or increasing funding toward these efforts. Classroom-based bicycle education is a low-cost way to complement cities' Vision Zero and mode shift goals by encouraging adults to feel safer and more confident riding a bicycle. By implementing education alongside other strategies, such as building infrastructure, cities can take a multi-pronged approach that may help shift people onto bicycles.

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# Appendix B: Sample recruitment material

E-newsletter from one nonprofit partner

Bicycle Education Pre-Course Survey

Projects Contacts Library Help

Survey Actions Distributions Data & Analysis Reports

Bicycle Education Pre-Course Survey

iQ Score: Fair

Published

Consent form

Block Options

QID1

## University of California at Berkeley
### Consent to Participate in Research

**UC Berkeley Bicycle Education Study**
CPHS # 2018-08-11324

**Introduction and Purpose**
My name is Daniel Rodríguez, PhD. I am a researcher at the University of California, Berkeley. You have signed up for a bicycle education class with either the San Francisco Bicycle Coalition (SFBC) or Bike East Bay (BEB) and therefore are eligible to participate in a study to evaluate the effects of bicycle education classes on bicycling confidence, frequency and habits.

**What does the study involve?**
If you agree to participate in this research, I will ask you to complete an online survey before you attend the bicycle education class. The survey will involve questions about your current bicycling confidence, frequency and habits, and should take about 10 minutes to complete.

You are also eligible to download the RideReport mobile phone app.You will need a smart phone and be willing to use cellular data or have Wi-Fi to use RideReport. If you agree to use the app, you will need to log-in using your email address. When you download and install Ride Report, it will run in the background of your smartphone. The app automatically senses when you are riding a bicycle and collects data about your ride. Knock Software will ask for your consent to share anonymized data on your trip before sharing any information with UC Berkeley. The data shared with UC Berkeley will include the date, time, length and speed of bicycle trips. The data will NOT include identifying information or location information such as trip origins and destinations or GPS routes. I ask that you leave RideReport running prior to attending the bicycle education class and at least three weeks after attending the bicycle education course.

Finally, about a month after the bicycle education class, I will ask you to complete a second short survey about your bicycling confidence, frequency and habits. The survey will take about 5 minutes to complete.

**Benefits**
There is no direct benefit to you from taking part in this study. It is hoped that the research will help local and state transportation agencies, nonprofits, and researchers better understand the role of bicycle education in changing bicycling behavior.

**Risks/Discomforts**
You may be uncomfortable or upset answering questions in the surveys. If you agree to answer the surveys, you can decline to answer a question or stop your participation at any point. You may also be uncomfortable using the RideReport app to track your bicycling behaviors, so you are free to stop using the app at any time.

As with all research, there is a chance that confidentiality of your data could be compromised; however, we are taking precautions to minimize this risk.

**Confidentiality**
Your study data will be handled as confidentially as possible. If results of this study are published or presented, individual names and other personally identifiable information will not be used.To minimize the risks to confidentiality, I will encrypt all survey results and all trip data collected via smartphone application and store the data in a password-protected folder on a password-protected computer in a locked office.

All identifiable information from surveys will either be eliminated completely or coded, the key to which will be kept in a separate encrypted and password-protected file on a password-protected computer in a locked office in a location separated from the rest of the survey data that will also be encrypted and kept on a password-protected computer in a locked office. Only my research team will have access to the passwords to unlock these files.

When the research is completed, I will save the data for possible use in future research done by myself or others. I will retain these records for up to five years after the end of this study. Your name and contact information will be destroyed within one year following the collection of the survey data and payment of compensation (see next section).

RideReport will also retain your data. If you no longer want RideReport to collect your data after the study is over, you will need to delete the app from your phone.

**Compensation**
In return for your time and effort participating in the study, you will receive by mail a Visa gift card for up to $15. You will receive $5 for taking the pre-course survey, another $5 for downloading the RideReport app and agreeing to its terms of use, and a final $5 for taking the post-course survey. To be eligible for any compensation you must participate in at least one of the activities (pre-course survey, app, or post-course survey). The gift card with the total value will be mailed to you within one year of your participation in the study.

**Rights**
***Participation in research is completely voluntary.*** You are free to decline to take part in the project. You can decline to answer any questions and are free to stop taking part in the project at any time. Whether or not you choose to participate, to answer any particular question, or continue participating in the project, there will be no penalty to you or loss of benefits to which you are otherwise entitled.

**Questions**
If you have any questions about this research, please feel free to contact me or another member of the research team. You can reach me, Daniel Rodríguez, PhD, at 510-642-3111 or danrod@berkeley.edu, or you can reach Libby Nachman, Graduate Student Researcher, at libby.nachman@berkeley.edu. If you have any questions about your rights or treatment as a research participant in this study, please contact the University of California at Berkeley's Committee for Protection of Human Subjects at 510-642-7461, or e-mail subjects@berkeley.edu.

**If you agree to take part in the research, please print a copy of this page to keep for future reference, then click on the "Accept" button below, then click the arrow to proceed.**

○ Accept

Add Block

Course Information

Block Options

QID3

Thank you for taking the time to answer the following. Your answers will help us understand your bicycling activity and experience. Only adults (18+) are eligible to fill out this survey. If you do not wish to answer a question, feel free to skip it and move to the next question. All answers will remain confidential. You can take additional steps to protect your privacy by clearing your browser's history, cache, cookies, and other browsing data. **At the end of the study you will be mailed a gift card for $5 for filling out this survey. If you fill out the post-class survey, you will receive another $5, and if you download the RideReport app and agree to its terms of use, you will receive another $5 for a total possible $15 gift card.**

QID31

Email address *(required to participate in the study)*

QID4

**Part 1: Course information**

QID5

With which organization did you sign up for a class?

- San Francisco Bicycle Coalition (classes in San Francisco)
- Bike East Bay (classes in the East Bay)

Display This Question:
If With which organization did you sign up for a class? San Francisco Bicycle Coalition (classes in San Francisco) Is Selected

QID35

What is the date of the class you are taking? (mm/dd/yyyy)

Display This Question:
If With which organization did you sign up for a class? Bike East Bay (classes in the East Bay) Is Selected

QID6

In which city is your class being taught?

Alameda

Display This Question:
If With which organization did you sign up for a class? Bike East Bay (classes in the East Bay) Is Selected

QID7

What is the date of the class you are taking? (mm/dd/yyyy)

Display This Question:
If With which organization did you sign up for a class? Bike East Bay (classes in the East Bay) Is Selected

QID8

How did you hear about this class?

Add Block

Riding behavior

Block Options

QID9

**Part 2: Riding behavior**

QID10

When did you last ride a bicycle?

- More than 12 months ago
- In the last 12 months
- In the last three months
- In the last month
- In the last week
- Never

Display This Question:
If When did you last ride a bicycle? In the last month Is Selected
Or When did you last ride a bicycle? In the last week Is Selected

QID11

In the past month, for which purposes did you ride a bicycle outside?
*(Choose all that apply)*

- I did not ride a bicycle
- I rode to work and/or school
- I rode to run errands
- I rode to or from transit (bus or train)
- I rode to another destination (social event, place of worship, etc.)
- I rode for exercise
- I rode for fun or recreation
- Other

Display This Question:
If When did you last ride a bicycle? In the last week Is Selected

QID12

During the past seven days, on how many days did you ride a bicycle?

- Every day
- 6 days
- 5 days
- 4 days
- 3 days
- 2 days
- 1 day
- I did not ride a bicycle last week

Display This Question:
If When did you last ride a bicycle? In the last week Is Selected

QID13

During the past seven days, overall how much time did you spend riding a bicycle?

Hours
Minutes

JS

QID14

Do you own a bicycle?

- Yes
- No

QID15

Have you ever used Ford GoBike (short-term bike rental with stations around the Bay Area)?

- Yes
- No

QID16

Have you ever used a dockless short-term rental bicycle in the Bay Area (such as Jump, Limebike, etc.)?

- Yes
- No

QID17

In the past seven days, how frequently did you use the following transportation modes to get places?
*If, for example, you walked to the bus, please check both walk and bus.*

| | Never | 1-4 times | 5-10 times | 11 or more times |
|---|---|---|---|---|
| Walk | | | | |
| Bicycle or bicycle share | | | | |
| Drive | | | | |
| Bus or train (Muni, AC Transit, BART, Caltrain, etc.) | | | | |
| Rideshare service (Uber, Lyft, etc.) | | | | |
| Other | | | | |

QID18

Did you ever consider using a bicycle for a trip in the past seven days, but decide against it?

- Yes
- No

Display This Question:
If Did you ever consider using a bicycle for a trip in the past seven days, but decide against it? Yes Is Selected

QID19

How often did you consider riding a bicycle but decide against it?

- Almost never
- Sometimes
- Almost always
- Always
- I only used a bicycle

Add Block

Riding Experience and Confidence Block Options

QID20

**Part 3: Riding Experience and Confidence**

QID21

How would you rate your amount of experience riding a bicycle in urban traffic?

- Very experienced
- Somewhat experienced
- Mixed experience
- Somewhat inexperienced
- Inexperienced

QID22

How **confident** do you feel riding a bicycle in the following locations (even if you don't currently ride there)?

| | Very confident | Quite confident | Uncertain | A little bit confident | Not confident |
|---|---|---|---|---|---|
| Urban traffic | | | | | |
| A park, bike path or another car-free area | | | | | |

QID23

How **safe** do you feel riding a bicycle in the following locations (even if you don't currently ride there)?

| | Very safe | Quite safe | Uncertain | A little bit safe | Not safe |
|---|---|---|---|---|---|
| Urban traffic | | | | | |
| A park, bike path or another car-free area | | | | | |

QID24

How would you rate your knowledge of your rights and responsibilities when bicycling in your city? (The rules of the road)

- Excellent
- Good
- Uncertain
- Fair
- Poor

Add Block

Reasons keeping you from biking more — Block Options

QID25

**Part 4: Reasons keeping you from biking more**

QID26

Which of the following reasons keeps you from using a bike for daily trips as much as you might?
*(Choose all that apply)*

- Biking is too slow
- Don't want to arrive sweaty/disheveled
- General safety concerns
- Lack of bike lanes/safe bike infrastructure
- Not enough energy/strength
- Bike theft concerns/not enough secure parking
- Too many hills
- Too many transit restrictions (bus/BART/train/ferry/etc.)
- Too much to carry
- Trips are too far to bike
- Weather (cold/heat/rain/etc.)
- Other

Add Block

Your information — Block Options

QID27

**Part 5: Your information**

QID28

How old are you?

- Less than 18 years
- 18-34 years
- 35-54 years
- 55-64 years
- 65 years or older

QID29

What is your gender?

- Woman
- Man
- Transgender
- Genderqueer
- Prefer not to state
- Other gender identity

QID30

With which ethnicity(ies) do you identify?
*(Choose all that apply)*

- American Indian or Alaskan Native
- Asian (including, but not limited to, Chinese, Filipino, Japanese, Korean, Vietnamese)
- Black or African-American
- Indian Subcontinent
- Latino/a or Hispanic
- Middle Eastern
- Pacific Islander or Native Hawaiian
- White/Caucasian/European American
- Prefer not to state
- Other ethnicity(ies)

QID32

Cell phone number

JS

*

QID33

May we text you reminders about the course and the follow-up survey?

- Yes
- No

QID34

Mailing address *(required to send gift card)*

Name

Address

Address 2

City

State

Postal code

Add Block

End of Survey

Survey Termination Options...

Bicycle Education Post-Course Survey

Projects Contacts Library Help

Survey Actions Distributions Data & Analysis Reports

# Bicycle Education Post-Course Survey

iQ Score: Fair | Published

Course Information | Block Options

QID3

Thank you for taking the time to answer the following. Your answers will help us understand your bicycling activity and experience. Only adults (18+) are eligible to fill out this survey. If you do not wish to answer a question, feel free to skip it and move to the next question. All answers will remain confidential. You can take additional steps to protect your privacy by clearing your browser's history, cache, cookies, and other browsing data. **At the end of the study you will be mailed a gift card for $5 for filling out this survey. If you filled out the first survey before the class, you will receive another $5, and if you downloaded the RideReport app, you will receive another $5 for a total possible $15 gift card.**

QID4

**Part 1: Course information**

QID31

Email address *(please use the same email address you used in the first survey; should be the email at which you received the invitation to this survey)*

[ ]

iQ JS *

Add Block

Riding behavior | Block Options

QID9

**Part 2: Riding behavior**

QID10

When did you last ride a bicycle?

- More than 12 months ago
- In the last 12 months
- In the last three months
- In the last month
- In the last week
- Never

Display This Question:
If When did you last ride a bicycle? In the last month Is Selected
Or When did you last ride a bicycle? In the last week Is Selected

QID11

In the past month, for which purposes did you ride a bicycle outside?
*(Choose all that apply)*

- I did not ride a bicycle
- I rode to work and/or school
- I rode to run errands
- I rode to or from transit (bus or rail)
- I rode to another destination (social event, place of worship, etc.)
- I rode for exercise
- I rode for fun or recreation
- Other [ ]

Display This Question:
If When did you last ride a bicycle? In the last week Is Selected

QID12

During the past seven days, on how many days did you ride a bicycle?

- Every day
- 6 days
- 5 days
- 4 days
- 3 days
- 2 days
- 1 day
- I did not ride a bicycle last week

Display This Question:
If When did you last ride a bicycle? In the last week Is Selected

QID13

During the past seven days, overall how much time did you spend riding a bicycle?

Hours

Minutes

QID14

Do you own a bicycle?

- Yes
- No

QID15

Have you used Ford GoBike (short-term bike rental with stations around the Bay Area) since you answered the last survey?

- Yes
- No

QID16

Have you used a dockless short-term rental bicycle in the Bay Area (such as Jump, Limebike, etc.) since you answered the last survey?

- Yes
- No

QID17

In the past seven days, how frequently did you use the following transportation modes to get places?
*If, for example, you walked to the bus, please check both walk and bus.*

| | Never | 1-4 times | 5-10 times | 11 or more times |
|---|---|---|---|---|
| Walk | | | | |
| Bicycle or bicycle share | | | | |
| Drive | | | | |
| Bus or train (Muni, AC Transit, BART, Caltrain, etc.) | | | | |
| Rideshare service (Uber, Lyft, etc.) | | | | |
| Other | | | | |

QID18

Did you ever consider using a bicycle for a trip in the past seven days, but decide against it?

- Yes
- No

Display This Question:

If Did you ever consider using a bicycle for a trip in the past seven days, but decide against it? Yes Is Selected

QID19

How often did you consider riding a bicycle but decide against it?

- Almost never
- Sometimes
- Almost always
- Always
- I only used a bicycle

Add Block

Riding Experience and Confidence

Block Options

QID20

**Part 3: Riding Experience and Confidence**

QID21

How would you rate your amount of experience riding a bicycle in urban traffic?

- Very experienced
- Somewhat experienced
- Mixed experience
- Somewhat inexperienced
- Very inexperienced

QID22

How **confident** do you feel riding a bicycle in the following locations (even if you don't currently ride there)?

| | Very confident | Quite confident | Uncertain | A little bit confident | Not confident |
|---|---|---|---|---|---|
| Urban traffic | | | | | |
| A park, bike path or another car-free area | | | | | |

QID23

How **safe** do you feel riding a bicycle in the following locations (even if you don't currently ride there)?

| | Very safe | Quite safe | Uncertain | A little bit safe | Not safe |
|---|---|---|---|---|---|
| Urban traffic | | | | | |
| A park, bike path or another car-free area | | | | | |

QID24

How would you rate your knowledge of your rights and responsibilities when bicycling in your city? (The rules of the road)

- Excellent
- Good
- Uncertain
- Fair
- Poor

Add Block

Class Evaluation

Block Options

QID25

**Part 4: Class Evaluation**

QID26

How likely are you to recommend this course?

- Very likely
- Somewhat likely
- Uncertain
- Somewhat unlikely
- Very unlikely

QID35

Please rate the following parts of the course:

| | Excellent | Good | Uncertain | Fair | Poor |
|---|---|---|---|---|---|
| Instructor(s) | ○ | ○ | ○ | ○ | ○ |
| Location | ○ | ○ | ○ | ○ | ○ |
| Length of Course | ○ | ○ | ○ | ○ | ○ |
| Overall Course | ○ | ○ | ○ | ○ | ○ |

QID36

Do you have any additional comments about the class or suggestions for improvement? Is there any concern keeping you from bicycling that was not addressed adequately in the course?

Add Block

End of Survey Survey Termination Options...

Berkeley UNIVERSITY OF CALIFORNIA

Qualtrics.com Contact Information Legal

# Appendix A: Survey instruments

Before course survey

After course survey

Gmail

# Classes to get you ready for Bike To Work Day

1 mensaje

**Eliana Marcus-Tyler, SF Bicycle Coalition** <eliana@sfbike.org>

To view this email as a web page, go here.

SAN FRANCISCO BICYCLE COALITION BIKE ED NEWSLETTER UPCOMING URBAN BICYCLING WORKSHOPS

Dear

Last week we celebrated our biggest Bike & Roll to School Week to date, with thousands of students and their families from all over the city discovering the freedom and joy of biking and rolling to school. Now we're building on that momentum and gearing up for **Bike to Work Day on May 9th**. Join in on the fun and help us to make it another record-breaking event! To prepare, sign-up for one of our upcoming classes, and get ready to be a part of the best biking day of the year.

The SF Bicycle Coalition is the city's leading provider of bicycle safety education, and this short, monthly email has the info on all our upcoming free bicycle education classes. If you're not already getting it regularly, sign up to get rolling!

*Know someone who wants to bike in San Francisco? Pass this email on! We want everyone to have the chance to get moving with one of our free classes.*

**FEATURED CLASS**

## Adult Learn to Ride at NOW Hunters Point

Saturday, May 11 | 10:30 am - 1:30 pm
*NOW Hunters Point, 155 Jennings St.*

You're never too old to learn to bicycle! Instructors will work one-on-one to teach the basics of balancing, starting, stopping and steering a bike, as well as proper helmet fit and adjustment. Most people learn to ride their bike while taking the class, but even if they don't, they will leave with tips to continue teaching themselves to ride.

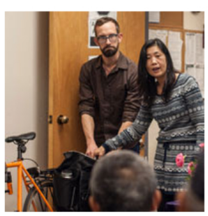
START ROLLING

## Sunday Streets: Bayview/Dogpatch

Sunday, May 5 | 11:00 am - 4:00 pm
*Exact Location TBA*

Come out for a day of car-free streets in the Bayview/Dogpatch. If you have a little one who's eager to get rolling on two wheels, bring them along to our free **Freedom From Training Wheels** drop-in classes (11:00 am - 2:30 pm). Our experienced teachers will help new young bikers to start balancing and pedaling without depending on training wheels! Or volunteer to assist our teachers. Also, look out for our Bike Education Outreach Team who is ready to answer any questions about our classes.

WANNA RIDE?



## Smart City Cycling 1: Classroom

Tuesday, May 7 | 6:30 - 8:30 pm
*SF Bicycle Coalition, 1720 Market St.*

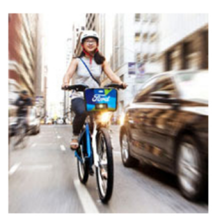
Looking to get comfortable riding in San Francisco? Join us for a presentation covering all you need to know for biking in SF and the Bay Area. This is the perfect class for anyone already riding to hone their skills, or people interested in riding but intimidated by urban traffic. This comprehensive course uses the curriculum of the League of American Bicyclists and is the first in a series of classes. It will prepare you for our upcoming Smart City Cycling 2 and 3 on-bike workshops.

COME LEARN!

## Intro to Urban Biking with Ford GoBikes

Thursday, May 30 | 6:30 - 8:30 pm
*SF Bicycle Coalition, 1720 Market Street*

Have you always wanted to ride in San Francisco but haven't been sure about how to safely do so? Are you curious about how to use Ford GoBikes? Get the answers to all your questions at our Intro to Urban Biking with Ford GoBikes class. We'll cover the basics of how to safely and confidently bike in SF and how you can incorporate Ford GoBikes into your ride. The first half of the course will be in the classroom, and then in the second half we'll get on the road and try out Ford GoBikes. Four lucky class participants will win an annual membership for unlimited Ford GoBike rides!



BIKE SHARING IS CARING

*Many of our education projects are made possible by the San Francisco County Transportation Authority through a grant of Proposition K local transportation sales tax funds.*

SFMTA

## Exploratorium After Dark: Let's Ride Bikes

Thursday, May 2 | 6:00 - 10:00 pm
*Exploratorium, Pier 15, The Embarcadero*

Pedal on down to the Exploratorium's After Dark event focused on bikes! You'll get to learn about the science behind bicycles, engage with hands-on mechanical and safety exhibits, and be wowed by unusual bike builds. When you arrive, you can park your bike in our free bike valet parking. Keep an eye out for our Bike Education Outreach Team who is ready to answer all of your questions about our upcoming bike classes.

GET EXPLORING

## Bike to Work Day

Thursday, May 9th | 7:00 am - 7:30 pm
*Citywide*

Bike to Work Day is the best day of the year to bike! Join the huge celebration by riding to work, stopping at one of 26 energizer stations around the city, getting fun free swag, and spreading the joy of biking. Taking one of our free classes is a great way to get yourself ready!

BIKE TO WORK

**Thank you for your interest in bicycle education!**

**Eliana**
**--**
**Eliana Marcus-Tyler**
Program Coordinator



San Francisco Bicycle Coalition
1720 Market Street
San Francisco, CA 94102