Running Head: Energy Saving Behaviors

# INCREASING ENERGY- AND GREENHOUSE GAS-SAVING BEHAVIORS AMONG ADOLESCENTS: A SCHOOL-BASED CLUSTER-RANDOMIZED CONTROLLED TRIAL

**Abstract**

Individual behavior change can serve as a key strategy for reducing energy use to mitigate greenhouse gas (GHG) emissions and improve energy security. A theory-based, school-based intervention to promote energy- and GHG-saving behaviors was developed by applying strategies and approaches from prior successful work in health behavior change. The focus was on changing behaviors rather than increasing knowledge, awareness, and attitudes, making extensive use of experimentally validated behavioral theory and principles. The intervention was evaluated in a cluster-randomized controlled trial. Public high school students (N=165) in a required course were randomized by teacher to receive a five week, five-lesson behavior change curriculum promoting changes to reduce home electricity-, transportation-, and food-related energy use and GHG emissions or their usual coursework. Students reported their energy- and GHG-saving behaviors at baseline and six weeks later (one-week after the completion of the curriculum for the treatment group students). Effects were tested with hierarchical linear models to account for potential clustering within classrooms. Students randomized to receive the curriculum statistically significantly increased their total energy- and GHG-saving behaviors compared to controls (adjusted difference = 0.43 on a scale from 0-6 behavioral categories, 95% Confidence Interval = 0.07 to 0.80, $p$ =.02; number needed to treat [NNT] = 4.1). The largest effects occurred in hang drying clothing (adjusted difference = .098, 95% Confidence Interval [CI] .028 to .165, NNT = 4.1) and shutting off appliances and other energy-using devices when not in use (adjusted difference = .095; 95% CI .055 to .135; NNT 3.5). These results indicate that a theory-driven, school-based classroom intervention can increase energy- and GHG-saving behaviors among adolescents.

**Keywords**: residential; energy; climate change; greenhouse gas; social cognitive theory; school; behavior change; barriers; intervention; cluster-randomized controlled trial

## Introduction

Demand-side energy reductions can significantly contribute to addressing climate change and energy security problems. In the United States, a sizable portion of energy use comes from the residential sector – estimated to be about 22% from residential buildings and 16% from passenger cars and light trucks (Energy Information Administration 2008). In addition, the U.S. Department of Agriculture (USDA) estimates that food-related energy use accounted for about 16% of the U.S. energy budget in 2007 (Canning et al. 2010). Greenhouse gas (GHG) emissions follow a similar pattern (EPA 2006; Vandenbergh et al. 2008). Estimates indicate that reductions in home, transportation, and food-related energy use are achievable at little or even negative cost, making such reductions particularly attractive, at least in the short-term. Importantly, many experts agree that a major reason why reductions have not yet been achieved in these sectors involves obstacles that the social sciences are particularly well-suited to address (IPCC 2007; American Physical Society 2008; UNEP 2010; McKinsey & Company 2009). More specifically, it is estimated that energy and greenhouse gas-related behavior change[1] can reduce residential energy consumption by about 30 percent (Parker et al. 2006; Gardner and Stern 2008; Laitner, Ehrhardt-Martinez, and McKinney 2009; McKinsey & Company 2009). This is about 15% of total U.S. energy consumption – more than the total yearly energy consumption in Brazil or the UK, or the quantity of fossil fuels that would be saved and GHG emissions reduced in the U.S. by a 25-fold increase in wind plus solar power, or a doubling of nuclear power (Energy Information Administration 2008; Sweeney 2007). This information suggests that interventions promoting energy and greenhouse gas saving actions by individuals in the residential sector can potentially contribute significantly to addressing the problems of climate change and energy security.

In the past, academic researchers, utilities, government agencies, and non-governmental organizations have attempted to facilitate energy- and GHG-saving behavior change through

[1] By energy- and greenhouse gas-saving actions or behavior change we mean the following: changing habits or repeated behaviors such as hang drying clothes rather than using a clothes dryer and bicycling rather than driving; purchasing and installing technology such as an more energy efficient refrigerator; settings and control behaviors such as lowering thermostat temperature and reducing pool pump use; maintenance behaviors such as cleaning furnace filters; eliminating wasteful energy uses such as extra refrigerators and DVRs; and using window coverings to better reduce solar radiation in hot weather.

public education, educational programs, and campaigns. However, the majority have not directly measured behavioral outcomes, evaluation has been absent or insufficient (e.g. Geller 1981), or evaluations have measured change using variables such as knowledge or attitudes (e.g. Bickman 1973) that are weak proxies for behavior change (Poortinga et al. 2004; Zelezny 1999). Furthermore, the most frequent approaches to facilitating behavior change include, on the one hand, increasing awareness about the problem, explaining the science underlying the problem, or increasing knowledge about which actions will ameliorate the problem (e.g. Schultz 2002) and, on the other hand, the use of traditional marketing channels or techniques (e.g. Hunecke et al. 2010). However, these approaches are often insufficient to change behavior (Geller et al.1983; Bandura 1986; Stern 2000; Abrahamse et al. 2005; Zelezny 1999; Mckenzie-Mohr 2002; Corner and Randall 2011).

We attempted to address these issues in the present study by developing and evaluating a school-based intervention to promote energy- and GHG-saving behaviors among adolescents. First, we developed a behavior change intervention based on social cognitive theory, a theoretical framework frequently used to explain and successfully change health, educational, and social behaviors in experimental field and laboratory research and practice (Bandura 1986, 1991; Maccoby and Farquhar 1975; Farquhar et al. 1977).[2] The theory emphasizes factors that have been shown to have a strong influence on behavior, including one's skills to perform a behavior, and one's confidence in successfully performing a behavior and achieving the anticipated outcome – which is referred to as self-efficacy. Self-efficacy is a mental construct that reliably predicts subsequent behavior (e.g. Holden 1991; Bandura 1977, 1991, 1994), and its predictive and mediating power has been demonstrated across intervention studies involving many different health–related domains, including smoking, alcohol and other drug abuse, exercise, nutrition, sedentary behavior, weight control, and contraception (Strecher 1986). A particular strength of the intervention is that it targets psychological constructs that have been tied more closely to behaviors (e.g., behavioral specific knowledge, self-efficacy, intrinsic motivation) than more distal factors such as attitudes and general knowledge. Second, we evaluated the impact of the intervention using a cluster-randomized controlled trial design,

[2] For a review of studies applying social cognitive theory to successfully change behavior, see *Social Foundations of Thought and Action*, (Bandura, 1986) and *Self-Efficacy: The Exercise of Control*, (Bandura, 1997).

providing a rigorous, internally valid test for causal inference (Sibbald & Roland 1998; U.S. Department of Education 2003, Fuller et al. 2010).

We chose to develop a community-based intervention, rather than resources geared towards individuals or a media campaign for example, because community-based interventions have perhaps been the most successful to date in fostering environmental behavior change (Fuller et al. 2010; McKenzie-Mohr and Smith 1999). These programs offer the following benefits: (1) interpersonal contact, so that messages feel more personal and not anonymous, and so the norms of proximal others can be observed, (2) increased specificity of the intervention – providing information for “people like me”, and (3) enhanced learning through direct experience or observation of a close other (Bandura 1986, 1991). Community-based interventions are also amenable to additional tools that are often difficult to implement in other forms of interventions, including group feedback, cooperation and competition, and making public commitments for behavior changes.

To increase the aggregate energy- and GHG-savings from our intervention, we used a population-based approach; that is, we targeted an entire population rather than focusing only on individual high energy users/GHG emitters. Our strategy is grounded in previous research in chronic disease epidemiology and public health, indicating that the changes resulting from targeting the population as a whole for a modest shift in average behavior can be greater in aggregate than those occurring from focusing intensively on extreme individuals – this can be visualized as the change in the area under a population distribution curve resulting from shifting it slightly in its entirety, in contrast to blunting just one tail of the curve to a greater extent (Rose 1992, 1985). Furthermore, targeting the whole population seems to address the socially-conditioned roots of individual behavior and may also improve diffusion, because individuals reinforce one another’s behavior change that was originally promoted by the intervention.

We chose to target adolescents in schools for both conceptual and practical reasons. First, based on our formative research, we believe that many adolescents are already more motivated than adults to make energy- and GHG-saving behavior changes, possibly because they are more likely to believe they will be significantly impacted personally by climate change and energy security problems in their lifetimes. Second, adolescence is a life stage when individuals are starting to establish their own identities and to control most of their own behaviors, and establishing energy- and GHG-saving behaviors at this early age could have a great positive impact when magnified over a lifetime. Third, schools are a particularly suitable setting for community-based behavioral interventions (Bandura 1977), and provide a “captive audience” including almost all children. A school, a grade level within a school, and even a single classroom each represent their own defined communities; new attitudes, norms and behaviors can rapidly diffuse through these school communities. Fourth, teens are likely to be early adopters of behaviors to reduce their energy and GHG emissions. This, and the fact that they tend to participate in a variety of groups within their communities, makes them an appropriate group to start with for triggering broader diffusion of these behaviors throughout their current communities (e.g., families, peer groups, community organizations) and their future communities (e.g., colleges, workplaces). Fifth, experience and experimentation (Robinson and Borzekowski 2006) suggest it may be more effective to target children rather than parents when trying to influence family and household behaviors. Evidence from consumer behavior research also supports the role of children in influencing family behaviors (Beatty and Talpade 1994; Belch et al. 1985; Foxman et al. 1989). Therefore, we believe that one of the most effective ways to influence a large number of households is through the children living in those households. Finally, once demonstrated to be effective, a school-based intervention can be rapidly disseminated to many other schools, magnifying its potential effects across the population. The relative homogeneity of how schools function across the nation makes this possible, compared to other settings (e.g., households, workplaces). As a result, an effective school-based intervention to increase energy- and GHG-saving behaviors could be implemented more broadly in the near term in support of regional, national, and international energy and GHG reduction goals.

The objective of this research is to test whether a theory-based, school-based intervention can increase energy- and GHG-saving behaviors in adolescents. We describe our formative research and discuss in detail the application of theory and empirical findings to the development of the curriculum. Using a cluster-randomized controlled trial, we test whether our intervention changes energy- and GHG-saving behaviors among students in classrooms randomized to receive the curriculum compared to control classrooms. We present effects of the intervention on overall energy- and GHG-saving behavior, the primary outcome, as well as secondary outcomes for specific behaviors relating to the subcategories of home, transportation, and food energy use. We conclude with a discussion of the results and implications for future research and policy.

**Intervention Development: Application of Theory**

The dominant conceptual model guiding the macro- and micro-development of the intervention was Albert Bandura's social cognitive theory (Bandura 1986, 2001). Key elements and how they were applied are summarized in Table 1, and further described and illustrated below.

INSERT TABLE 1 HERE

Social cognitive theory suggests that behavior is performed in the context of three, mutually interacting types of influence, behavioral, personal and environmental, termed triadic reciprocality (Bandura 1986). When people perform or observe a behavior they gain skills and confidence, which increases the frequency of the behavior and improves their performance. Personal factors such as one's physical and mental traits, as well as their beliefs and emotions, influence one's actual and also perceived ability to perform a behavior. Environmental factors such as the physical surroundings and social context present opportunities and barriers to performing behaviors. Such environmental factors have been illustrated to have a substantial impact on energy and environmental behaviors (McKenzie-Mohr 1999, 2002; Cialdini and Goldstein 2004). Self-efficacy, or one's confidence they can perform a behavior and achieve its desired outcomes, can be enhanced using techniques related to all of these factors.

We created the intervention in a stepwise fashion. First, we identified potential target behaviors appropriate for our audience. We did this in a systematic fashion using a "working backwards" process previously developed for designing health behavior change interventions.[3] We started with the ultimate goal (e.g., reduced energy use and greenhouse gas emissions) and worked backwards in a stepwise manner to map all the potential mediating pathways, ultimately identifying individual behaviors at the origin of each causal chain of events (illustrated in Figure 1). Second, we applied principles of social cognitive theory to generate potential intervention

[3] The "working backwards" was developed and refined by the senior author for guiding behavior change intervention design.

strategies for enhancing perceived self-efficacy for the performance of those behaviors. This included converting the target behaviors into a series of challenging but manageable steps, identifying opportunities for behavioral and cognitive rehearsal and mastery, goal-setting and feedback, and anticipating potential barriers students may encounter and strategies they could adopt to overcome them. Third, we reviewed the entire intervention plan to ensure that we were maximizing opportunities for attention, retention, production and motivational processes in every element of the curriculum. Fourth, we applied the additional principles described above to further craft and frame specific messages and activities to enhance intrinsic motivation for the targeted behavior changes (also called outcome motivation) as well for participation in the intervention itself (also called process motivation) (Robinson 2010).

The final intervention was developed and refined over two years through an iterative process of formative research. This included informal interviews and focus groups to understand how energy- and GHG-saving behaviors fit into the lives of adolescents, and potential cognitive, behavioral, and social motivations for behavior changes. We designed initial intervention components based on these findings and relevant theory, and subsequently pilot tested them with representative samples of youth. Using direct observation and collection of formal and informal feedback from participants, we revised components based on the theoretical and conceptual principles described below. We continued to improve and retest the lessons, activities, materials, formatting, and sequencing, before piloting the entire curriculum with two groups of high school students. Feasibility and acceptability for fitting and implementing the intervention in a public high school classroom were key considerations of this process. We then made a last set of revisions based on our observations and student and teacher feedback before conducting the formal test of the intervention in a cluster-randomized controlled trial.

The final curriculum[4] included five classroom lessons, each lasting approximately 50 minutes. Based on pilot results, we chose to frame the curriculum as a media design workshop in which students work in teams to produce a YouTube style media message to persuade their peers to use behavioral strategies to reduce their impacts on climate change and energy insecurity (Robinson and Borzekowski 2006; Hekler et al. 2010). Lesson 1 introduced this frame, and

[4] All final curriculum materials can be downloaded here: http://peec.stanford.edu/behavior/HighSchoolCurriculum.php

kicked off the "workshop" with scripted presentations by students acting as climate change and energy experts advising other workshop participants. This established a discussion of climate change and energy security impacts of human energy and GHG-related behaviors. Learning to measure and change one's own behavior was presented as the first step in developing effective messages for others, so part of Lesson 1 was spent quantifying personal energy use and emissions. We introduced 1-Liter balloons as a unit of measurement for carbon dioxide ($CO_2$) equivalent emissions,[5] and students learned how to use worksheets to record their daily behavior changes in terms of balloons of $CO_2$ saved.

Lessons 2-4 provided more in-depth factual information, energy and environmental life-cycle exercises, feedback on personal, team, and class behaviors and $CO_2$ savings, and activities to set goals and overcome barriers for specific behaviors in three categories – home energy use, transportation, and food – one category each week, in that order. Based on our formative research, we identified target behaviors that were relevant to and potentially malleable for students: hang drying clothes; turning off appliances and other energy-using devices when not in use; biking, walking, taking the bus or carpooling instead of driving to and from school; driving more efficiently[6]; eating less meat; eating fewer packaged and processed snacks; and using a reusable beverage bottle filled with tap water instead of drinks from disposable bottles and cans.[7] Students were asked to select one behavior to change from the category covered in each of Lessons 2-4. At the end of each lesson, students worked on the design of their media messages. In Lesson 5, students shared the food they had prepared and were filmed performing their media messages.

INSERT TABLE 2 HERE

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[5] 1 lb $CO_2$ = 230 1-liter balloons. This is derived from the following: Molecular weight of $CO_2$ = 12+16+16=44; (454g/1) lb x (1 mole/44g) x (22.5L/1 mole) = 230L CO2/1 lb.

[6] Driving more efficiently was taught as an option for participants who lived far from school and had to drive. While the survey included questions to assess self-efficacy with respect to driving more efficiently, there were no questions to assess behavior change in driving efficiency because it was not a focus of the curriculum for most participants and survey space was limited for the numerous component behavior questions this would entail.

[7] We included reduction of bottled and canned beverages because the total energy required for bottled water can range from 5.6 to 10.2 MJ/l, compared to tap water production which usually requires about 0.005 MJ/ l, for treatment and distribution (Gleick and Cooley 2009). 1 kWh = 3.6 MJ

As noted above, perceived self-efficacy plays the central and direct role in the pathway to producing behavior change in social cognitive theory. There are four paths to building self-efficacy: performance and mastery, vicarious experiences or modeling, persuasion, and affective and physiological responses.  Successful performance and mastery have the strongest influence on increasing perceived self-efficacy because they involve performing a behavior first-hand and receiving immediate feedback, addressing and overcoming barriers that present themselves, overcoming challenges and fears of failure, and, as a result, producing a sense of resilient self-efficacy (Bandura 1994). As a result, performance and mastery opportunities formed the backbone of each element of the curriculum.

A second way to enhance self-efficacy is with vicarious experience through social models – in other words, observing a behavior carried out by another person, and the positive outcomes that result (Bandura 1994). In the transportation lesson, for example, we invented a character named Karen, a high school student who is inspired to ride her bicycle more often after visiting Europe and participating in its biking culture. Karen's basic characteristics were determined through our formative research into characteristics with which most students would identify. Through a guided activity, students developed goals, strategies, and specific plans to change their own transportation behaviors and to address perceived barriers in the way Karen had modeled to achieve success.

Persuasion – the process of encouraging or discouraging one towards action with symbols (e.g., verbally, or through text or pictures) - is a third way to influence self-efficacy. Influencing mood as well as affective and physiological states is the fourth way (Bandura 1994). In terms of impact, these tend to be weaker methods than actual performance and mastery and vicarious experience.  Alone, social persuasion (i.e., instructing people to change to achieve the anticipated outcomes) generally produces small effects (e.g. Miller et al. 1975). It also is harder to instill self-efficacy with verbal persuasion than it is to undermine it, for example, by persuading people that they lack capabilities. In addition, it may be difficult to alter emotional and physiological states in classroom settings. We apply these strategies in a variety of ways, however. For example, the emotional and knowledge-based information provided by the climate change "experts" is intended to persuade. Images of victims of natural climate disasters and highlighting social inequities are expected to elicit emotional responses in some students that could be resolved through discussion of potential actions students can take to address them. We also aim to create associations of positive arousal with success in declaring challenging goals and practicing behaviors. We used kinesthetic activities, such as the balloon exercise, lifecycle activities, and recipe activity, to leverage the tendency of individuals to misattribute arousal to people or events that are proximate to the true source of arousal (Schacter and Singer 1962).

Setting goals and receiving feedback, when used together, increase and maintain behavior change (Bravata et al. 2007; McCalley and Midden 2002; Becker 1978; Abrahamse et al. 2008).[8] Proximal, flexible, appropriately challenging and specific goals are most effective (Bandura and Schunk 1981; Bandura 1986; Locke et al. 1981). Furthermore, although setting individual goals is effective (Bandura 1986), setting team goals can be additionally empowering (Latham and Saari 1979). The balloon activity engaged students in quantifying 1 Liter of their $CO_2$ emissions. The balloons served as the visible, meaningful, and measurable feedback of their personal impact for behaviors targeted throughout the curriculum (e.g., driving one mile in an average sized sedan emits 180 balloons; doing one load of laundry in a dryer is about 900 balloons; and eating a hamburger is about 2000 balloons). Behavior logs and public displays of group results each week provided a system of setting iterative goals and receiving regular feedback for individuals and groups (see Figure 2 for an example). It also creates transparency of information, discourages free riding, and enhances perceptions of group or collective efficacy (Elley 2008; Farhar and Fitzpatrick 1989; Thompson Jr. 2000; Reeves 2008; Bandura 1986). Once goal-setting, feedback and quantification are addressed we turn to addressing barriers, or impediments that prevent the target behavior from occurring. We aim to help students overcome barriers in a variety of ways (McKenzie-Mohr and Smith 1999), including group discussion to identify barriers and brainstorm solutions, as well as through task-specific activities. A concrete example

[8] Goals coupled with feedback increase error management, thereby improving success; in other words, feedback regarding errors yields information for people about whether their picture of reality is aligned with what is required to attain their goal, and allows them to adjust their actions accordingly (Frese and Zapf 1994). Feedback also functions by providing confirmation of the effectiveness of one's actions, which improves confidence in long-term abilities (self-efficacy), and reinforces and increases the likelihood of similar future behavior (conditioning) (Bandura 1982; Bandura and Schunk 1981).

of the latter is a guided exercise to identify the optimal appliance configuration in a power strip in participants' bedrooms so they can more easily turn them off to reduce vampire energy use. Another way we address barriers was to provide maps and bus and bike routes to help students overcome a lack of information about non-car means of transportation.

In social cognitive theory, the four key processes of observational learning are identified as attention, retention, production, and motivation (Bandura 1986). These processes have been identified to describe learning from models but have proven equally applicable to behavior change intervention design (Robinson 1999; Robinson 2001; Robinson & Borzekowski 2006; Robinson et al. 2003; Robinson et al. 2001a; Robinson et al. 2001b; Robinson, T. N. 2001). As the third step in curriculum development we review the intervention to maximize opportunities for each of these processes. Attention is focus on an action, message or person performing an action. Attention regulates exploration and perception and is highly influenced by factors such as personal relevance, functional value, and perceptual and affective salience (e.g., color; novelty; fast-paced multi-sensory media; and interactivity). For example, we introduce students to the curriculum using attractive oversized worksheets and colored folders and markers, which are different from their typical in-class materials. We also punctuate the climate conference with relevant affective videos.

Retention, or memory, is a process influenced by the organization of information, attention, and rehearsal (e.g., including physical, cognitive, or imagined rehearsal, and inference from simulations and stories) (Bandura 1986). For example, the chain game, or life cycle activity, in which students physically act out the life cycle of energy use and GHG-emitting behaviors such as turning on a light; help participants remember how their behaviors connect to energy use and GHG emissions by articulating and chronologically linking all of the steps in between. The linked kinesthetic and cognitive elements of the activity are designed to enhance retention (Janiszewski et al. 2003; Klemmer et al. 2006; Begel et al. 2004). Repeating a similar activity in subsequent lessons also reinforces the information, which can also promote attitude change (O'Keefe 2002). As another example, the overall theme of designing and creating media messages is intended to increase retention of curriculum content because the process of formulating media messages mimic the same process students explore in the curriculum to change their own behaviors. The steps include teams revisiting the targeted behaviors, choosing one, identifying barriers, deciding how to help their fellow students overcome barriers, modeling the behavior, rehearsing it multiple times, and performing this message for an audience of their peers during filming.

Production processes involve the conversion of intentions, concepts, and other mental representations into actions through performance and mastery. As described above, these processes are most closely linked to enhanced perceived self-efficacy. Strategies to help move individuals from mental representations to action include: identifying the sub-steps required to execute an action, articulating and committing to a particular action through goal-setting, receiving feedback regarding whether these goals are being met, identifying and addressing barriers, and rehearsing or practicing the activity (which overcomes inertia and facilitates habit formation). The activities in lessons 2-4 were, in a large part, organized around moving individuals to action through these steps. Students rehearse target behaviors through activities such as the clothesline relay race and preparing a low GHG (meatless) meal. Furthermore, they rehearse the information and strategies being proposed through public presentation activities. Students assume expert roles and give short speeches to each other as part of the climate conference, and advocate for behavior changes through their media messages – both types of actions help shift attitudes (Festinger and Carlsmith 1959; Jones 1964).

Motivation is conceptualized as the level of desire to perform an action. Motivation is directly linked to expectations about outcomes that are likely to result from one's behavior, with the rewarding and punishing outcomes being external (e.g., material rewards or peer approval) or internal (e.g., gratification from mastering a challenge or collaborating with others). The outcomes may be learned through past, promised, or vicarious experiences (seeing and recalling the reinforced model). We designed the curriculum to tap into students' intrinsic motivation derived from their values, personal experiences, and perceptions of risk by including, for example, impacts on nature and animals, self or family, equity, the economy, and energy security in the climate conference (Mastrandrea et al. 2006; De Young 2000).

Other motivational techniques have been identified through decades of experiments on intrinsic and extrinsic motivation in education.[9] Lepper and colleagues highlight the “seven C’s” of intrinsic motivation, which include competence, challenge, curiosity, and control (control is influenced by choice, contextualization and individualization), as well as group factors such as context, community, and cooperation and competition (Lepper et al. 2008). We used the 7 C’s to promote intrinsic motivation throughout the intervention. For example, students are challenged to individually demonstrate competence when assuming expert positions in Lesson 1’s climate conference, engaging in public speaking, and arguing in favor of a particular position (Lepper et al. 2008; Bandura 1986; Wood 2000). In the recipe activity students face peer pressure to produce a palatable dish to share with their group members (Clasen and Brown 1985). Students are allowed to exercise perceived control and choice through personalizing details such as writing and drawing on folders, choosing group names, and selecting behaviors to change (Lepper et al. 2008).

We apply the group factors of cooperation and competition in several ways. A sense of community is built by sharing tasks in a challenging and novel educational experience. Cooperation is a salient motivator, as students share strategies for changing their behaviors, help each other make calculations on their worksheets, monitor and view collective progress in $CO_2$ savings, and collaborate on the design and execution of their media messages. Competition is implemented by showing feedback on balloon savings to student teams, and having students rank recipes and media messages, for example. In our pilot work, showing teams’ progress to the whole class, in contrast to asking individuals to perform computations without public display, showed an immediate increase in motivation (due to competitiveness, although the exercise is not explicitly framed as a competition) evidenced by willingness and expediency in doing the computations required to track balloon savings. Participation on teams and competition have been shown by others to be effective in reducing GHG emissions, both experimentally (Darby 2006a; Darby 2006b; Petersen et al. 2007) and anecdotally (McKenzie-Mohr and Smith 1999).

[9] We attempted to avoid certain extrinsic motivators, such as money, because these often result in a reversal or weakening of behavior once the external incentive is removed (Stern 2000; Stern and Gardner 1981; Hirst 1984). Moreover, it is important to consider intrinsic motivators when behavioral persistence is desired and resources are limited.

An additional approach to enhance motivation applies the Premack Principle. This principle states that behaviors that occur reliably without intervention can be leveraged to reinforce and motivate behaviors that require intervention – for example, by linking the performance of the most motivating activities contingently upon good performance in preceding less motivating activities (Premack 1965). We apply this principle by guiding students to change their own behavior through the more challenging self-change activities prior to creating and filming their media messages and sharing food in their groups, which are perceived as more motivating.

To further help illustrate the curriculum design process let us briefly consider how each theoretical technique is applied to one activity, the clothesline relay. A greatly simplified "working backwards" exercise and identification of steps are illustrated in Figure 1. We incorporated self-efficacy through rehearsal and mastery, as each student had to actually hang dry clothes correctly in order for their team to progress in the race. Goal-setting and feedback were applied by setting a challenge: to be the fastest team to hang up and take down clothes, with real-time feedback through observation of teammates and competitors. The race helped students overcome their perceived barriers about the time cost and difficulty of hang drying by experience and this was illustrated by recording and reporting back to them about their own perceptions of how time-consuming and difficult hang-drying was both before and after the activity, and students saw how it seemed faster and easier once they had tried it. We were able to harness the attention, retention, and motivation of participants through novelty, interactivity, repetition of the behavior, as well as competition and cooperation in teams. As this example shows, our goal was to ensure that activities in the curriculum were theory-rich and therefore more likely to change the targeted behavior.

## Method

We evaluated the curriculum in a cluster-randomized controlled trial over seven weeks, during April and May, 2009. The study was conducted at a public high school in Palo Alto, California. We used a course that is required for all tenth graders to provide a large, unselected population of students who were about the same age but of widely varying aptitudes and interest levels. Six teachers with eight class sections agreed to participate. Teachers were the unit of randomization. Three teachers with four classes were randomly assigned to the treatment condition and two teachers with four classes were randomized to the control condition. Parents or guardians provided written informed consent for their adolescents, and students provided their assent to participate in the study. The evaluation consisted of a baseline survey for all participants in the first week, followed by five lessons over five weeks delivered to the treatment group only, and a post-test survey a week later for all participants. All students in the treatment classes received the experimental curriculum, taught by a trained member of our research team with the usual classroom teachers present, as a standard part of their school curriculum. The control classes received their standard course content taught by their usual classroom teachers. Only those students with parental consent and assent were included in the evaluation. Thus, all non-specific elements of the study, including recruitment, consent and assent, classroom curriculum time, and surveys, were equated across the two study conditions to enhance internal validity. The study was approved by the school Principal and the Stanford University Administrative Panel on Human Subjects in Research.

### Measures

Survey questions were adapted from the previously validated Stanford Climate Change Behavior Survey (SCCBS) (Armel et al. 2011). The survey included questions regarding frequency and/or intensity of specific energy- and GHG-related behaviors in the categories of home electricity, transportation, and food; attitudes regarding the importance of environmental sustainability; perceived self-efficacy in performing these behaviors; and knowledge about behaviors that contribute to climate change. We examined the distributions of each item and eliminated the potential impact of outliers by winsorization (Tukey 1962) in which responses more than three interquartile ranges below the 25$^{th}$ percentile or above the 75$^{th}$ percentile were changed to the next higher or lower response, respectively.

We created indices from conceptually-derived clusters of items, supported by the results of principal components analysis with varimax rotation, for three of six major types of targeted behaviors used in this intervention (see Table 3 for the six indices and component items). Indices were computed by summing (for a meat consumption index and a processed and packaged snacks and beverages index) or averaging (home electricity index) responses to items that loaded highly on the same principal components factors and/or shared conceptual similarities, and not by using principal components factor loadings. To create a change variable the baseline index score was subtracted from the post-test value for each student. The distributions of the change scores were examined to check for normality before running analyses. Test-retest stability of the indices from baseline to post-test was calculated in the control sample only (reported in Table 3).

Questions that measured attitudes and knowledge were included as secondary outcome variables and potential mediators of behavior change. To measure attitudes, participants responded to the statement "Compared to other things in your life, environmental sustainability is..." on a six-point Likert-type scale ranging from "not at all important" to "the very most important" (Armel et al. 2011; Heckler et al. 2010). Perceived self-efficacy was measured by asking how confident participants were that they could perform specific targeted behaviors "at least half the time" on a Likert-type scale ranging from 1 (not at all confident) to 10 (very confident). Participants were also queried about their knowledge of whether 10 different behaviors: "driving to school, cutting down forests, leaving the television on, drilling for oil, eating a candy bar, eating a hamburger, burning coal in a power plant, using a clothes dryer, drinking soda, and flying in a plane," contribute to "global warming."

To gain insight into the potential real world impact of our intervention, and to allow for greater interpretability and comparisons with other interventions, we calculated effect sizes for our primary outcome, as well as for the indices and individual survey items. Specifically, Number Needed to Treat (NNT) indicates the number of students needed to be exposed to the curriculum in order to produce one more success (a greater total energy- and GHG-savings behavior change score) than if the same number of students were not exposed to the curriculum (controls). Ideally an NNT would be as close to 1.0 as possible (Kraemer and Kupfer 2006, Katona and Livingston 2002, McQuay et al. 1995, Barratt et al. 2004, and Chatellier et al., 1996). We calculated NNT with an area under the curve approach (Kraemer and Kupfer 2006). As another standardized effect size we calculated Cohen's *d*, which is expressed in standard deviation units. Cohen's *d* is calculated as the difference between two sample means divided by their pooled, within-group standard deviations, and allows one to compare the magnitudes of effects across different measures and measurement scales. It also is easily converted to other commonly used effect sizes (Kraemer and Kupfer 2006). Prior to the study, we determined that for a two-tailed 5% alpha level test, a total final sample size of at least 134 participants (67 in each group) would provide about 80% power to detect a number needed to treat (NNT) effect size = 3.6 or less, equivalent to a Cohen's $d = 0.5$ or greater (Cohen 1988; Kraemer and Thiemann 1987; Kraemer and Kupfer 2006).

**Results**

Of 229 potentially eligible students, parental consent was obtained from 183, with 165 (90%) of these completing baseline surveys, 84 treatment and 81 controls. Only thirteen students were lost to follow up (7 Treatment, 6 Control; $X^2 = 0.08$, $df = 1$, $p = 0.78$), resulting in 152 students in the baseline sample who also completed post-test surveys (92%). Nearly all participating students in both the treatment (92%) and control (94%) groups were tenth graders. Groups were also similar with respect to age (Treatment $M \pm SD = 15.5 \pm 0.06$, Control $M \pm SD = 15.4 \pm 0.6$; Wilcoxon Rank Sum Test $z = -1.08$, $p = 0.28$), gender (Treatment 63% female, Control 53% female; $X^2 = 1.70$ $df = 1$, $p = 0.19$ ), and race/ethnicity (Treatment versus Control: 40 vs. 46% White, 4 vs. 2% Latino, 0 vs. 1% African American, 36 vs. 38% Asian, 4 vs. 0% Pacific Islander, and 16 vs. 13% Other/Multi-Ethnic; $X^2= 4.90$, $df = 5$ , $p = 0.43$). Of the behavioral outcome measures assessed (Table 3) only the home electricity use index differed statistically significantly between groups at baseline (Wilcoxon rank sum test, z = -2.89, p = .004).

*Primary Outcome: Changes in Total Energy and Greenhouse Gas Saving Behaviors*

The primary hypothesis was that treatment group students would increase their overall energy- and GHG-saving behaviors significantly more than controls over the seven week period between baseline and post-test. To conservatively evaluate this hypothesis a summary total energy- and GHG-saving behavior score was calculated for each student from the six indices. Each student received a score of 1 for each index that improved from baseline to post-test (more energy- and GHG-savings) and a score of zero for each index that stayed the same or worsened (zero or less energy- and GHG-savings), and these scores were summed for the total energy- and GHG-saving behavior change score (possible range 0-6 for each student). In computing change scores, items were coded or reverse coded as necessary so that higher scores signified greater energy- and GHG-savings. Total energy- and GHG-saving behavior change scores were then compared between the treatment and control groups. Analyses followed intention-to-treat principles, where all participants were analyzed as they were randomized, regardless of subsequent participation and/or exposure to the intervention. Missing post-test values were conservatively imputed as the baseline value carried forward (thus coded as a change score of zero for that behavior).

For practical reasons, teachers were randomized to one of the two intervention arms, and the intervention was administered to a classroom (not to an individual student), potentially inducing a correlation among the outcomes from students within the same classroom. To address this, we made use of hierarchical linear models that included a classroom-specific random intercept (SAS Proc MIXED, version 9.3). More specifically, we regressed total energy- and GHG-saving behavior change score on treatment and baseline energy- and GHG-saving behavior scores. The model also included classroom as a random effect. For inference, we used the Kenward-Roger method for estimating degrees of freedom, as recommended when the number of subjects per cluster is less than 100 (Verbeke and Molenberghs 2000).

The treatment group significantly improved their overall energy- and GHG-saving behaviors compared to controls (adjusted difference = 0.43, 95% Confidence Interval = 0.07 to 0.80, $p = .02$). This difference between the treatment and control groups is illustrated in Figure 2, showing a relative shift to the right (more energy- and GHG-savings) in the distribution of the total energy- and GHG-saving behavior change scores among the members of the treatment group relative to controls (treatment *mean* ± *SD* = 2.06 ± 1.32, *median* = 2, *interquartile range* = 0-6; control *mean* ± *SD* = 1.62 ± 1.03, *median* = 1, *interquartile range* = 0-4). This difference between groups represents a 26.5% relative increase in this index of overall energy- and GHG-saving behaviors. The Number Needed to Treat (NNT) for the intervention is 4.1, which means we would need to expose about 4 students to the curriculum to produce one more success (a greater total energy- and GHG-savings behavior change score) than if the same number of students were not exposed (controls). The difference between groups can also be expressed as a

Cohen's *d* standardized effects size = 0.36.

Of note, an analysis comparing the distributions of change scores in the treatment and control groups using a non-parametric Wilcoxon rank sum - Mann-Whitney U-test that assumes independent errors and does not account for the cluster-randomized design produced similar results ($p = .02$), showing our findings are robust to this assumption.

To further confirm the results from the primary analysis, we also conducted a secondary analysis using the same hierarchical linear modeling approach, where the outcome was a continuous (scaled) overall energy- and GHG-savings behavior change measure. Specifically, each participant's raw change score from baseline to post-test for each of the six behavioral indices was converted into a standardized *z*-score, and then averaged over all six indices. The results were again consistent with the results of the primary analysis (treatment *mean* ± *SD* = 0.09 ± 0.5; control *mean* ± *SD* = -0.09 ± 0.4; adjusted difference = 0.17, 95% Confidence Interval = 0.03 to 0.31, $p = .015$).

*Changes in Specific Behaviors and Categories of Behaviors*

As an additional secondary analysis we investigated the effects of the intervention on each survey item and index. Means and standard deviations, adjusted differences between groups and their 95% confidence intervals are presented in Table 3. These results help to further describe and understand the results of the primary analysis in more detail by examining changes in each of the components of the total energy- and GHG-saving behavior score. We evaluated differences between the treatment and control groups using ANCOVA. Specifically, the baseline to post-test change was the dependent variable, the intervention group (Treatment vs. Control) was the independent variable, and the centered baseline value and the centered Treatment x centered baseline value interaction were included as covariates. We included the centered Treatment x centered baseline value interaction as a covariate in the analysis to produce an unbiased estimate of the main effect of treatment (Cronbach and Snow 1977; Finney and Mitchell 1984; Overall et al. 1981; Rogosa 1980). Results in Table 3 showed the treatment group made their greatest magnitude increases in hang drying and switching off appliances and other energy-using devices when not in use, compared to controls. Smaller changes favoring the treatment group were also apparent in reusable water bottle use.

We also report effect sizes in Table 3, as an indication of the magnitude impacts of our intervention. To aid readers, we report three effect sizes: relative percent change, Cohen's *d*, and NNT. A relative percent change for each variable was calculated to indicate the magnitude of change in the treatment group relative to the post-test rate that would be expected without intervention (as represented by the control group rate at post-test). Relative percent change is calculated as the adjusted difference in change divided by the post-test mean in the control group. Thus, an increase in a low prevalence behavior is shown to have a larger proportional effect compared to the same absolute increase in an already high prevalence behavior. For example, there was a 36% relative increase in hang drying attributable to our intervention, a 14% relative increase in turning off appliances and other energy devices, and a 16% increase in using reusable bottles and cups while away from home. The range of effect sizes reflects the varying impacts of our intervention across different behaviors. A Cohen's *d* value of .44 for hang drying and .76 for reducing home electricity use represent medium to large effects, respectively. The number needed to treat (NNT) suggests that the curriculum was efficient for producing change in some cases – for example, for hang drying, turning off appliances and other energy-using devices, and using a reusable bottle or cup when away from home, we would need to expose only about 3.5 to 8.7 students to our curriculum to get one additional student who improved these respective behaviors.

*Knowledge, Perceived Importance of Environmental Sustainability, and Self-Efficacy*

We performed ANCOVAs, similar to those described above, to test the effects of the intervention on changes in student knowledge, perceived importance of environmental sustainability, and self-efficacy for targeted behaviors, as secondary outcomes and potential mediating variables. There was a trend toward increased knowledge about behaviors that contribute to climate change among treatment group students compared to controls, ($F(1,163) = 3.21$, $p < 0.08$). There was no statistically significant difference between groups in changes in their perceived importance of environmental sustainability. However, self-efficacy for three behaviors increased significantly among treatment students compared to controls: switching off appliances and energy using devices ($p < 0.01$); driving more efficiently ($p < 0.05$); and eating fewer processed and packaged snacks ($p < 0.05$). Despite these changes, when we formally tested these variables as potential mediators of intervention effects using the MacArthur Network methods of Kraemer et al. (2001), using a conservative $\alpha < .01$ criterion, we found none met criteria as statistically significant potential mediators of the effect of the intervention on changes in GHG saving behaviors. However, these are lower powered exploratory tests.

*Potential Moderating Factors*

Moderators are variables present at baseline that affect the direction and strength of the relationship between the independent (treatment) and dependent (outcome) variables (Baron and Kenny, 1986). They help identify groups or characteristics of persons who respond more or less to the intervention, and thus may be targeted or avoided in future implementations. We tested all baseline demographic, knowledge, attitude and behavioral measures as potential moderators of intervention effects using the methods of Kraemer et al. (2001). Using a conservative $\alpha < .01$ criterion we found no significant potential moderators of the effect of the intervention on changes in energy- and GHG-saving behaviors. This result indicates that the intervention appeared to produce effects similarly across the entire population studied, as defined by the available characteristics measured.

Although specific characteristics could not be identified to define groups that responded more or less to the intervention, we also conducted a post-hoc, sub-group analysis for the three behaviors that changed the most to examine whether the group-level behavior changes seen in the primary analysis represented smaller changes in a large number of participants or larger changes in a smaller number of participants. This varied according to the behavior. 25% of treatment group participants increased their hang drying, and the average increase within that subset was 43% – indicating relatively large average changes in a sizeable quarter of those exposed to the curriculum. For switching off appliances and other energy using devices, 60% of treatment group students increased these behaviors by an average of 13%, suggesting relatively smaller average changes spread out over a large proportion of the students. 33% of treatment group students increased their use of reusable instead of disposable beverage containers by an average of 24%, suggesting moderate changes in about one-third of the students who were in classes receiving the curriculum.

*Process/Implementation Outcomes*

Some measures were collected from the treatment group through self-report as part of the curriculum delivery to reinforce behavior change, or after the post-survey to provide an assessment of the curriculum. One of these measures included estimated GHG emissions savings that students calculated with log worksheets completed during the classroom lessons. Figure 3 illustrates the cumulative total numbers of one-liter balloons of $CO_2$ saved between each lesson. The combined balloon savings for the four treatment classrooms of students was equivalent to a savings of about two million liters or 8,700 pounds (4.4 tons) of $CO_2$, or an average of about 70 pounds per person. This figure is several times higher than what we would expect based on the changes reported in the baseline and post-test surveys. There are several possible reasons for this discrepancy: these data reflect behavior changes in the treatment group only, without controlling for change in the control group (we did not collect these data for the control group); these data include all the behaviors that were targeted instead of just the behaviors that showed the largest change; and the possible social desirability of participants to report greater changes in the presence of the teacher or their peers (whether intentional or not).

In another separate measure administered at the end of the post-test survey, treatment group participants were asked to provide feedback on the intervention. These data indicate that on a scale where 1 = never, 2 = sometimes, and 3 = always, the average student rated meeting his or her electricity goal between “sometimes” and “always” (2.31), and other goals “sometimes” – transportation (2.05), and food (2.05). Students reported mean ratings of 4 to 5 on 7-point Likert scales for liking the curriculum and finding it fun and/or motivating .

## Discussion

We designed, implemented and evaluated a brief, social cognitive theory-based classroom curriculum that significantly increased energy- and GHG-saving behaviors among high school students. Our primary result was a statistically significant improvement in total energy- and GHG-saving behavior in the treatment group compared to the control group. Over 66% of treatment group students increased two or more categories of energy- and GHG-saving behaviors and 32% increased three or more categories of behaviors compared to 48% and 20% of control group students, respectively. In further examining these categories and their component behaviors in a secondary analysis, these overall effects were mostly explained by increases in hang drying and switching off appliances and other energy-using devices with smaller shifts from disposable to reusable bottles and cups. There was also a trend toward increases in knowledge about the behaviors that contribute to climate change, as well as statistically significant increases in self-efficacy for switching off appliances and other energy-using devices, driving more efficiently, and consuming fewer packaged and processed snacks.

This study has notable strengths related to both the intervention and the evaluation. First, the intervention was theory-based. Intervention development devoted particular attention to theory-driven principles shown to be effective in changing behavior (Bandura 1986) instead of, for example, emphasizing knowledge- and attitude-based approaches that are generally less effective for changing behavior (Zelezny 1999). As described above, the intervention was deliberately formulated to include multiple, integrated theoretical and conceptual models to maximize overall success. We began by identifying the most appropriate target behaviors linked to energy- and-GHG savings, and then iteratively developing activities by applying theoretical and practical techniques to increase self-efficacy through mastery, guided practice and modeling, incorporating opportunities for goal-setting and feedback, addressing barriers, leveraging opportunities and planning, and maximizing attentional, retentional, and motivational processes using empirically proven methods. We then piloted activities in samples similar to our target audience and revised them before testing them in the full-scale randomized controlled trial in our evaluation sample.

Also notable is the community-based intervention approach, targeting an entire population rather than a subset of individuals with the highest energy use or GHG emissions. For behaviors and problems that are common across the population, like the low frequencies of energy- and GHG-savings behaviors, targeting the entire population distribution for even small to moderate average changes can produce substantially greater total effects than concentrating on producing large changes among the smaller samples at the end(s) of the distribution (Rose 1985). The results suggest this was a useful approach. The intervention produces sizeable average changes in a substantial proportion of students exposed to the curriculum. We also strategically targeted adolescents because they may be more receptive to change. Also, they are more likely to influence family and community members than other individuals, and through their social networks, to reach a broad audience and promote social support, social interaction and the potential for rapid diffusion through the sample. This also increases the generalizability of the results and potential diffusibility of the curriculum to new populations and geographic settings.

In terms of evaluation, the study employed the gold standard of study design, a randomized controlled trial, to minimize threats to internal validity and to be able to causally attribute the outcomes to the intervention (Sullivan 2009). To our knowledge, this is the first report of a randomized controlled trial design used to evaluate a school-based energy- and GHG-reducing behavior change program. The great importance of using a randomized controlled trial design is illustrated by the observed changes in control group behaviors during the study (Allcott and Mullainathan 2010). Without randomization and a proper control group one cannot be certain whether changes associated with an intervention, in either direction, are due to the intervention itself or to some other factor. In addition, participation rates in the evaluation were high; randomization produced groups with similar baseline characteristics, a total of only 13 students balanced across the two groups were lost-to-follow-up, and outcomes were tested with an intention-to-treat analysis, all further enhancing both the internal validity and generalizability of the results. The hypothesis was addressed by fitting a hierarchical linear model that accounts for potential non-independent errors within classrooms consistent with the cluster-randomized design.

We utilized a *solution-oriented* approach, designed to directly inform practice and policy. We designed and rigorously evaluated a theory-driven, multiple-variable intervention in a real world sample in a real world setting to increase its relevance to a wide variety of practitioners and policy makers. This is in contrast to the more typical, reductionist approach commonly seen in academic research emphasizing observational designs and single-variable experiments, for purposes of theory development or explication. While this is also valuable research that can guide intervention development (including the present intervention) it generally results in greater delays in translation from the laboratory into practice in the community.

Also, we believe it is beneficial for researchers in the behavior and energy and climate change field to include descriptions of their interventions, design process, and theory application in some depth. At this early stage in the field, it can help other researchers, program designers and evaluators to better design and evaluate studies, as well as accumulate a broader body of knowledge to discern which theoretical tools and specific intervention approaches are most likely to be effective in specific populations and settings. Therefore, we include a detailed description above.

An advantage of our study was measuring self-reported behavior directly, whereas other programs have often measured indirect proxies or hypothesized mediators of behavior such as attitudes (Bickman 1972; Poortinga et al. 2004; Abrahamse et al. 2005; and Zelezny 1999). However, self-reports are also a potential limitation of this study. We relied on self-reports because objective measures of the target behaviors or energy use and GHG emissions were not feasible. Self-reports of behavior may be subject to potential measurement errors. Unless systematically biased, however, errors in measurement tend to increase variability of estimates and reduce statistical power, which may have limited our ability to detect all truly significant effects of the intervention (i.e., type II error) and/or attenuated the estimated effect sizes observed. On the other hand, the differences observed between groups could also potentially be explained by a differential social desirability bias in reporting by the treatment group compared to the control group.  We feel this is unlikely, however, because we observed differential effects across different behaviors rather than uniformly across all outcomes. We would expect socially desirable responses to be distributed more evenly across all outcomes assessed. In addition, our measures have been shown to have high correlational validity in a slightly older sample, and these measures also demonstrated satisfactory stability over seven weeks in our control sample. The increasing availability of energy sensors (e.g., The Energy Detective, SmartMeter deployments, and disaggregation analytics) is likely to increase the feasibility of objectively measuring energy use in future studies, and it also may be possible to identify more objective observational measures for some specific behaviors of interest. However, self-report is likely to remain the mainstay for measuring the broad array of energy- and GHG-savings behaviors in behavior change studies in the near-term.

Although the intervention proved effective overall and for a number of the individual categories and behaviors, the effects were not uniform across all targeted behaviors. It is of interest to speculate about several factors that may have contributed to the larger effects observed for home electricity conservation and hang drying compared to other behaviors. First, behaviors emphasized in earlier lessons were reinforced in subsequent lessons, so that students were given the most time to set successively more challenging goals, receive feedback, practice and build self-efficacy for changing electricity and hang drying behaviors, which were introduced in early lessons, than for transportation and food-related behaviors introduced in later lessons. Transportation behaviors also may have been subject to a ceiling effect. The majority of participating students were already riding their bicycles to and from school at baseline, due to a previous, 3-year intensive biking campaign in this school, so there may have been few remaining students able or willing to change who had not already done so. However, it is possible that this past bicycling campaign also served as a "foot in the door," predisposing the students to respond more favorably to other aspects of the intervention.  In addition, the responsiveness of students to the food lessons and the final lesson may have been substantially dampened by the co-occurrence of a tragic event involving a fellow student during the same week Lesson 4 was delivered, severely altering the mood of the entire school for at least several weeks.

It is also worth noting that in each lesson we asked students to change at least one – not all – of the targeted behaviors. This was an intentional design feature to promote intrinsic motivation through perceived control over behavioral choices, and to offer flexibility given substantial variations in the relevance of, and barriers to, specific behavior changes among adolescents. While this feature makes the curriculum more generalizable, it potentially attenuates the apparent magnitudes of effects because only a subset of students attempted to change any given behavior being assessed while changes were estimated as means for all students across all behaviors.

Based on observing implementation and student feedback, we believe the curriculum might be improved in several ways to better reflect the underlying theoretical principles. In particular, the allocated time for lessons could be increased to allow for additional reflection, discussion, and planning, particularly in the domains of identifying strategies to overcome perceived barriers and setting goals, given their importance in behavior change (Bandura, 1986, 1991). For example, upon examination of student folders after implementation, we found that only about 40% of students wrote down their goals. A verbal discussion of goals followed by time devoted to recording goals could increase participation in goal-setting and planning by increasing thoughtfulness and demonstrating a norm among those who share their goals (Latham and Saari, 1979). We also recommend further investigation of barriers to transportation and food behaviors, as well as an exploration of alternative ways to apply theoretical principles, for example through different exercises, to clarify how to improve the effectiveness of those lessons.

*Program Impact*

One can evaluate program impact in a number of ways. First, we examine the effects of the curriculum for its overall efficacy. To protect against type I error and minimize redundancy, we evaluate the intervention for its effect on a single primary outcome, a combination variable of overall energy- and GHG-savings behavior. The result confirmed our primary hypothesis, that a theory-based, school-based intervention significantly increased energy- and GHG-saving behaviors in adolescents. The primary analysis was a conservative test of the hypothesis, using a categorical outcome measure with limited variability that enhanced our confidence in the overall efficacy of the curriculum for changing behaviors. We also confirmed this result when rescaling our outcome measure as a continuous measure. The primary outcome results are illustrated in Figure 2 showing a substantial, easily discernible shift in the distribution of overall energy- and GHG-savings behaviors across categories among students receiving the intervention compared to students who received their standard curriculum.

We further explored results for each category and individual behaviors measured (Table 3). Responses are scored to enhance their interpretability. For example, hang drying is coded as the proportion of time clothes were hang dried instead of drying them in a clothes dryer. The same was true for most of the home electricity behaviors. Thus, the adjusted difference reported is the average absolute difference between the students who received the curriculum compared to the controls, after adjusting for their baseline behaviors. Exposure to the curriculum produced an absolute increase of about 10% more hang drying and switching off appliances and other energy-using devices when not in use (and even greater changes in some of the individual electricity-saving behaviors), and about 8% more reusable bottle and cup use. These represent substantial changes averaged across all the students. The transportation and food-related behaviors are queried and coded as the number of one-way trips and servings per week, respectively, to allow direct interpretation of the results. The intervention appeared to be less effective in changing these behaviors, as discussed above.

In addition to the absolute changes, we report the relative percent change reflecting the proportional incremental change compared to the frequency of the behavior that is expected without the curriculum -- which is the frequency observed in controls in a randomized controlled trial. This effect size demonstrates how a similar absolute change represents a greater relative percent change for a behavior that is rare to start with versus a behavior that is already more commonly practiced, and is how changes are often reported.[10] Relative to controls, hang drying increased about 36%, home electricity-saving behaviors increased about 14%, and reusable bottle or cup use increased about 16% as a result of the curriculum.

Two other effect sizes commonly used by researchers are also reported. First, for normally distributed measures Cohen's *d* represents the differences in means between groups relative to their standard deviations (or amount of spread) and can be translated into the amount of overlap or non-overlap of their sample distributions. For example, the Cohen's *d* of about .40 for the overall energy- and GHG-savings behavior score indicates that about 58% of the treatment group had a higher score on this index than 58% of the control group and half of the treatment group has a higher overall score than about 65% of the control group. The Cohen's d of .44 for hang drying indicates that about 59% of the treatment group is greater than 59% of the control group and half of the treatment group is greater than about 67% of the control group. The Cohen's d of .76 for home electricity-saving behaviors indicates that about 65% of the treatment group is greater than 65% of the control group and half of the treatment group is greater than

[10] For example, an increase in the absolute rate of behavior from 10% to 20% is a 10% absolute increase but a 100% relative increase, while an increase in the absolute rate from 50% to 60% is still a 10% absolute increase but a 20% relative increase.

about 78% of the control group. In the behavioral sciences, a Cohen's d of .2 is generally considered a small effect, d = .5 a medium effect, and d = .8 a large effect, but these are relative terms to the specific area of behavioral science and the type of study and methods being used (Cohen, 1988). These definitions are most applicable to results from more controlled settings and targeted samples. In population-based intervention studies like this one, we would consider these effects sizes to be relatively larger in significance, where even small effect sizes can produce very large impacts in society-wide outcomes when multiplied and spread over a large population (Rose 1985).

Number needed to treat (NNT) is the other effect size reported. NNT is commonly used to describe the effects of clinical medical interventions but can be useful for judging the relative benefits of an intervention in concrete terms. In this study, the NNT indicates the number of students needed to be exposed to the curriculum in order to produce one more success (improved energy- and GHG-saving behavior) than if the same number of students were not exposed to the curriculum. The NNT of 4.1 associated with the overall effect indicates that about one in four students who receive the curriculum improve their overall energy- and GHG-savings behaviors more than controls. This indicates that this classroom curriculum is a relatively efficient approach to increasing energy- and GHG-savings behavior. It is a strong endorsement of the behavioral impact of a relatively brief, classroom-based intervention, directed at a non-selected, population-based sample. The NNTs for the individual behavioral categories of hang drying and home electricity-saving behaviors were also in the 3.5-4.1 range. Therefore, only three to four students need to receive the curriculum to produce one additional student who increases their frequency of hang drying and switching off appliances and other energy-using devices.

These effect sizes can help policy makers and educational program designers consider whether to adopt this curriculum and gauge the investment for the potential outcomes they may expect. For example, a policy maker can begin to ask how much they would be willing to invest to increase the absolute rate of hang drying by about 10%, which is a relative increase of 36% or equivalent to about one in four students in a school increasing their hang drying; and to increase the absolute rate of switching off appliances and other energy-using devices by about 9.5%, which is a relative increase of about 14%, or equivalent to about in one in three to four students in a school switching off more appliances and energy-using devices.

For further interpretation, it might be helpful to compare program impact to other energy-saving interventions. The survey measure was developed to validly measure behavior changes to evaluate the intervention, while minimizing participant burden and improving response reliability, rather than to enable easy conversion into units of energy or GHG savings. However, it is still possible to very roughly estimate energy impacts for some of the outcomes. For example, a clothes dryer accounts for about 5.8% of household energy use on average (EIA 2001), so a 36% relative increase in hang drying is equivalent to a reduction of 2% in household energy use.[11] This estimated change in just one of our targeted behaviors is roughly the same as the impact of 2% energy savings resulting from a successful social comparison-based utility billing program (Ayres et al. 2009; Allcott and Mullainathan 2010).

*Expediency and Scalability*

Behavioral interventions have the potential advantage of being very expedient: they can be implemented and, if effective, can produce results almost immediately. Behavioral interventions also may be rapidly duplicated across a large number of similar institutions, or designed so they tap into existing diffusion channels that touch large portions of the population. We chose to develop a school-based intervention, in part, because it could be readily diffused through schools nationally and perhaps internationally. However, some barriers still exist to disseminating school-based behavior change curricula. Schools are subject to many demands and, in our experience it is difficult for schools to find time to add even a brief five-lesson curriculum. Therefore, school boards, school administrators, teachers and parents will need to prioritize reduced energy use and GHG emissions for behavioral curricula like this one to gain entry to large numbers of schools. In addition, defined content standards generally vary from state to state in the U.S., and from country to country internationally, making it more challenging to align new curricula with required content standards. Another important potential barrier is teacher training. Our curriculum was developed to require only minimal preparation and training to implement. However, teacher familiarity and perceived expertise with the content area are known obstacles to teacher self-efficacy and implementation fidelity. It also is well-accepted that

[11] 36% of 5.8% is 2%.

even if widely disseminated and implemented, interventions may not produce the same effects when delivered outside of research settings. We remain optimistic, however, that school-based interventions shown to be effective when rigorously evaluated in real world settings, like the current study, represent one of the better potential strategies to produce expedient and scalable effects. In addition to schools, we believe this curriculum or adaptations of it may also be disseminated through other institutions, including groups such as churches and boy and girl scouts, and non-governmental organizations focusing on energy efficiency and reducing greenhouse gas emissions.

*Persistence and Long-term Benefits*

Persistence or maintenance of behavior changes is an important and understudied aspect of energy- and GHG-related behavioral research (Skumatz 2009). To date, energy-related behavior change studies have produced mixed effects for persistence (Ehrhardt-Martinez 2010; Leighty and Meier 2010). Persistent changes may be due to habit formation, as well as to one-time actions that are implemented (e.g., installing energy efficient technologies, changing settings, and eliminating waste). In this study, behaviors were assessed at baseline and after the completion of the intervention but not for longer-term persistence or diffusion through social networks. We judged that it was first important to demonstrate the short-term efficacy of this novel intervention before investing in a longer-term follow-up. However, now that short-term efficacy has been shown, future studies are now warranted to examine the effects over longer periods of follow-up and in additional populations and different geographic locations, to assess the potential for lasting impacts and generalizability to different samples.

In addition to immediate energy and GHG savings, intervening in youth is expected to produce even greater changes over their lifetimes. There are now examples of long-term effects resulting from a number of interventions in education. For example, the Perry Preschool program famously showed that preschool interventions can have dramatic benefits, including reduced crime and welfare costs, as well as increased college completion rates and stable family structure that are manifest over several subsequent decades (Barnett 1996). Interestingly, even very brief interventions targeting attitudes regarding values and social belonging can have lasting benefits, as illustrated by some recent studies in college students (Walton and Cohen 2011), and middle school students (Cohen et al. 2009; Blackwell et al. 2007). Behavioral changes can also be magnified due to ripple effects from one individual participant to many others through social networks (e.g. Hogan et al. 2004; Christakis and Fowler 2007). As discussed in the introduction, we deliberately targeted high school students in order to maximize the probability of such long-term benefits to participants and ripple effects to family members and others through household and other social networks within and beyond the school system.

## Conclusion

A theory-based, 5-lesson classroom curriculum was shown to significantly increase energy- and GHG-saving behaviors among adolescents in a school-based cluster-randomized controlled trial. The rigorous evaluation allows the effects to be attributed to the intervention. The greatest effects were found for hang drying instead of clothes dryer use and switching off home appliances and other energy-using devices. The effects have the potential to produce substantial population-wide savings in energy and GHG emissions if diffused to other schools and settings.

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