PEER-REVIEWED RESEARCH PAPER

Development of a Climate Change Education Program Using Knowledge of Behavioral Science Such as Nudges and Verification of its Effects in Decreasing CO_2 at Home

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Abstract

Climate change is a critical issue. However, the effects of climate change education have not been quantified. This paper investigates the contribution of education in curtailing climate change by measuring household energy consumption and behaviors. We developed an educational program incorporating the United Nation's Sustainable Developmental Goals, active learning, and behavioral science insights, including nudges and the stages of change model, and enrolled 2016 junior high and high school students throughout Japan. After excluding those who did not provide consent for their data to be used as well as outliers from the statistical data, finally 300 students were included in the analysis.

Each student recorded their home electricity and gas meter values and checked the implementation of 16 energy-saving behavior items. Implementation of the 16 items improved by 22.4 percentage points after the lessons. Decreases in electricity and gas usage were particularly notable following the third lesson. Average CO_2 emissions generated by electricity and gas decreased 3.7% (0.39 kg/day) per household. We found that conducting climate change education in junior and senior high schools contributed to decreasing household CO_2 emissions.

The developed climate change education program led to a 3.7% reduction in household CO_2 emissions, confirmed by meter readings, and the results of the questionnaire survey revealed changes in awareness and energy-saving behavior. If the developed program were widely introduced, it might contribute to CO_2 reduction at home.

KEYWORDS: **CLIMATE CHANGE EDUCATION, ENERGY-SAVING BEHAVIOR, CO_2 EMISSION REDUCTION, BEHAVIOR CHANGE, NUDGE**

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Introduction

Extreme weather due to climate change is a critical issue for humanity; the Framework Convention on Climate Change also points out the importance of education on climate change (United Nations, 1992). The impact of education on awareness and behavioral changes in Japan has been previously reported by the authors (Matsubaguchi & Mikami, 2015; Mikami, 2018; Mikami et al., 2010, 2015, 2019; Mikami & Nagao, 2011a, 2011b, 2012; Nagao et al., 2007; Nagao & Mikami, 2016). Similar studies have been conducted worldwide (Boudet et al., 2014, 2016; Aguirre-Bielschowsky et al., 2018; Ferrari-Lagos et al., 2019). However, the extent to which such education actually contributes to decreases in household CO_2 emissions has not been quantified because it requires study participants to read meter values at home and report them to the investigators. This paper investigates whether climate change education can contribute to reductions in household CO_2 emissions by measuring actual energy consumption and the implementation of energy-saving behaviors.

There are concerns that climate change induced global warming will lead to rising sea levels through seawater expansion and melting glaciers, and extreme weather events will become more frequent, damaging natural ecosystems, living environments, and agriculture. In response, the world took its first step toward a decarbonized society when the Paris Agreement came into effect in 2016 (United Nations, 2015).

Japan has an interim target of a 26% decrease in CO_2 emissions and other greenhouse gases by fiscal 2030 (as of the fiscal year 2013). However, to meet this target, the household sector would have to significantly decrease emissions by roughly 40% from fiscal 2013 levels (Ministry of the Environment, 2015).

The Italian government has made climate change and the United Nation's Sustainable Development Goals (SDGs) part of the compulsory curriculum for all public schools from 2020 and has decided to carry out training for teachers. On the global stage, Greta Thunberg's speech at the 24th Conference of the Parties to the United Nations Framework Convention on Climate Change has sparked a growing number of student-led strikes involving teachers and parents, and expectations for education are growing.

In Japan, the Act on the Promotion of Environmental Conservation Activities through Environmental Education, which came into full force on October 1, 2012, is promoting environmental education. However, even though references to environmental education are scattered throughout the Course of Study and textbooks stipulated by the Ministry of Education, Culture, Sports, Science and Technology, the learning content is not systemized, and there is a lack of systematicity and coordination among subjects and grades (Matsubaguchi & Mikami, 2015). Furthermore, the outcomes of such education are rarely reported, and most such reports are little more than qualitative assessments; in other words, more thorough research is needed (Mikami et al., 2015).

In the present study, we developed a climate change education program aimed at junior high and high school students in Japan. The program, which is incorporated in home economics classes, encourages energy-saving behavior and provides an opportunity to learn about environmentally friendly consumer behaviors. The program is designed such that the energy-saving impact of environmental education can be measured both quantitatively and qualitatively. To verify the overall effects, we measured household energy consumption as a quantitative indicator, and used implementation of energy-saving behaviors and surveys assessing motivation to take action as qualitative indicators. Using these measures, we evaluated the impact of education in terms of whether those receiving this education could reduce their household energy use and promote energy-saving behaviors. Accordingly, clarifying

the effects of climate change education through this program should provide evidence of the importance of climate change education.

This research formed part of the Ministry of Environment's Project to Promote Voluntary Measures in Households and Others Through Information Dissemination (Nudges) that Promote Low-Carbon Behavioral Changes launched in 2017 (Ministry of the Environment, 2017).

Research Methodology and Details

Developing a Climate Change Education Program

Our idea was to maximize the impact of climate change education. This program was developed by incorporating both the latest findings of behavioral science and the methods used in Japanese education so far, based on the Japanese education concept of fostering students' ability to think, make judgements, and express themselves. These acquired skills and knowledge are necessary for problem solving. Specifically, we adopted an active learning approach that involved the following behavioral science methodologies: nudge theory, which won its author, Richard H. Thaler, the 2017 Nobel Prize in Economics and has techniques for promoting voluntary choices of desirable behavior (Thaler, 2007; Thaler & Sunstein, 2008, 2009); the transtheoretical model, that is the behavior change stage model which was derived from studies on smoking cessation and improving health; and commitment, which is a behavioral planning method.

The intention of the *nudge* used in this program was not to regulate, teach, or guide as before, but to respect the freedom of choice of individuals, that is, not to prohibit choice, but to elicit a voluntary change in their behavior. There are several methods for nudging, but we adopted three points in particular. The first is the use of illustrations related to energy-saving behavior that can be understood without explanation. The illustrations appeared many times in the text and were printed as stickers that could be used as reminders at home. The second point is to show a total of 16 items—8 behaviors that involve changing device settings and 8 behaviors that involve daily actions—from among many energy-saving actions, and to provide a concrete image of the action to be taken. The text shows the specific setting method as well as photos and illustrations of the device. The third point is to recommend changing default settings, such as the temperature for heating and cooling devices, so that children can quickly feel the effects while measuring energy use. For example, by lowering the default temperature of the water heater, the energy saving effect can be expected to continue. Based on the above, we developed textbooks, digital teaching materials, and the abovementioned energy-saving action stickers.

We also intended for the program to provide practical education on SDGs, with a particular focus on *Goal 7: Affordable and clean energy*, *Goal 12: Responsible consumption and production*, *Goal 13: Climate action*, *Goal 14: Life below water*, and *Goal 15: Life on land*.

This study was approved by the Research Ethics Committee of our institution (Approval No. Ita H29-12, Ita H30-29).

Pilot Climate Change Education Program to Promote Energy-Saving Behavior

Participants

We recruited schools from throughout Japan to avoid bias toward any particular region and obtained the cooperation of seven junior high schools and six high schools. After excluding those who did not provide consent for their data to be used as well as outliers from the statistical data, finally 300 students were included in the analysis.

Program Design

The pilot energy-saving education program took place from April to July and September to November of 2017 and 2018, during mid-seasons that saw little seasonal differences. With a view toward its future nationwide rollout, teachers at the participating schools conducted the lessons during weekly home economics classes. We conducted a training session for all the teachers involved, in which we explained the program and the textbook and provided instruction about the learning contents and how to teach them. In addition, we prepared reference materials for the teachers, as discussed later. As shown in Table 1, 50-minute lessons were held once weekly, actual energy usage was recorded by the students at home, and energy-saving action behaviors were measured using questionnaire surveys.

Table 1 Learning flow

Step	Subtitle theme	Goals	Main learning activities
Step 1	Prior learning	Reading electricity, gas, and water meters	Students learn about various forms of energy used in the house; location of electricity, gas, and water meters; and how to read and record meter readings.
Step 2	Issue discovery	What is the relationship between global environmental issues and energy conservation?	Students become aware of environmental issues that result from climate change accompanying global warming. By conducting research to create a newspaper, they deepen their understanding of global environmental issues. They consolidate and implement measures within reach in their daily lives.
Step 3	Investigating and planning solutions	What energy-saving measures can students take themselves?	Students become aware if they are wasting energy and what arrangements enable them to conserve energy. They become aware of the importance of their energy-saving behavior and implement energy-saving behavior at home and school.
Step 4	Activities aimed at solutions	Experience and implement power-saving measures Note: One of the items listed in the right-hand column	Activities: • Electricity (power-saving experiment) • Gas (eco-cooking) • Water (water-saving experiment) • Overall (energy-saving behavior card game)
Step 5	Improving evaluation of practice activities	Make a declaration for a sustainable society	Publish newspaper created via previous research activities and deepen each other's knowledge and make personal commitment (declaration) to save energy. Look back on results of meter readings, and check how much household gas, power, and water consumption has declined by engaging in energy-saving behavior.
Step 6	Post learning	Look back on own lifestyle	Submit remaining materials including meter reading sheets and challenge letter from "Dr Energy-saving."

We hypothesized that the education program would elicit behavioral changes in the children that would influence their families and lead to reduced energy consumption during the program compared with that before the program as well as increase the number of energy-saving action items practiced in daily life.

The program consists of six steps, with each 50-minute class focusing on a different step. In addition, the students were asked to record the electricity, gas, and water meter readings and practice each lesson's energy-saving behaviors at home. Questionnaire surveys were conducted for each step in order to evaluate changes in motivation for engaging in energy-saving practices as well as 16 items of energy-saving behavior. The analyses of these surveys were comprehensively verified by combining these quantitative indicators and qualitative indicators.

Step 1 reviews what kind of energy is used at home and explains how to measure energy use. In this step, no attempt is made to alter the students' behavior toward energy consumption. Step 2 explains energy conservation, including the relationship between climate change and daily life as well as how energy savings can be realized by making simple adjustments to device

settings. In addition, students begin researching a topic that they will write about in the form of a newspaper article to be presented in Step 5. Step 3 involves learning multiple specific energy-saving behaviors and understanding eight items that are most effective in daily life. Step 4 provides four types of experiential learning depending on the school situation: a power-saving experiment, a water-saving experiment, eco-cooking, and playing energy-saving action card games.

Step 5 is the presentation of the newspaper article the students have written based on their own research. The aim of this step is to have the students think about actions to take in. Step 6 encourages the students to reflect on what they have learned through the program. The program flow is illustrated in Figure 1.

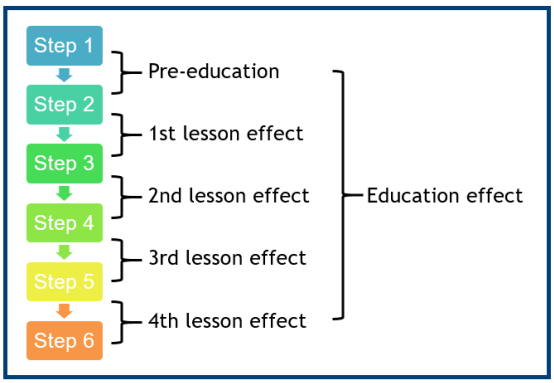

Figure 1 Project scheme

This program design is based on Japan's new course of study, which recommends that home economics classes be organized as follows:

1. discovery of problems in daily life
2. examination and planning of solutions,
3. practical activities for solving the problems,
4. evaluation/improvement of practical activities, and
5. practice at home or in the community.

These five areas correspond to Steps 2 to 6 of the developed program, respectively.

Furthermore, our program is designed from the viewpoint of the transtheoretical model. In this model behavioral change is considered to occur through each of the following stages: indifferent period, interest period, preparation period, execution period, and maintenance period. Our previous research (Mikami, Akaishi & Nagao, 2019) suggested that it is necessary to provide information suitable for each stage in order to elicit energy-saving behavior (Table 2).

Table 2 Support measures according to the transtheoretical model

Stage		Support measures
Precontemplation	Does not intend to act within the next 6 months	Provide information on the need for changing energy-saving behavior
Contemplation	Intends to start the behavior within the next 6 months	Provide information on methods and processes for changing energy-saving behavior
Reparation	Ready to act within the next 30 days	Setting energy-saving action goals and coaching for behavior change
Action	Has recently begun behavioral change and intends to continue	Coaching and feedback for sustaining energy-saving behavior
Maintenance	Sustained efforts for more than 6 months and intends to maintain effort going forward	Continuous provision of information and follow-up to sustain the transformation of energy-saving behavior

The educational course involves six steps, which are taught over 6 weeks in weekly home economics classes. The educational effects of each step are evaluated by questionnaire surveys after each class and by changes in electricity, gas, water meter readings recorded by the students at home.

Measuring Energy Use

The students learned how to take measurements from electricity and gas meters at home so that they could check the impacts of energy-saving behaviors. Students visually checked the values displayed on their home meters and recorded them on a worksheet. Electricity and gas consumption as well as the corresponding CO_2 emissions were estimated from these measurements. To analyze energy consumption data, we used the following screening criteria: availability of all measurement dates and measured values for electricity and gas; final measurement date within 2 weeks of the end of lessons; and positive consumption volume (as measured by current reading minus previous reading).

The upper and lower limits of the ratio to the previous reading were set at 1.5 × the interquartile range; based on these data, we excluded as outliers those participants whose final reading was in the upper or lower 1% of the distribution. Electricity and gas consumption were temperature-corrected for the post-lesson figures using the formulas shown in Figure 2, and we estimated the household energy consumption for those who did not receive energy-saving education (base figure). Using the ratio of the base figure and the measured figure ([measurement/base figure] − 1), outliers (5% above and below) were excluded from the data, taking into account differences in area and temperature fluctuations.

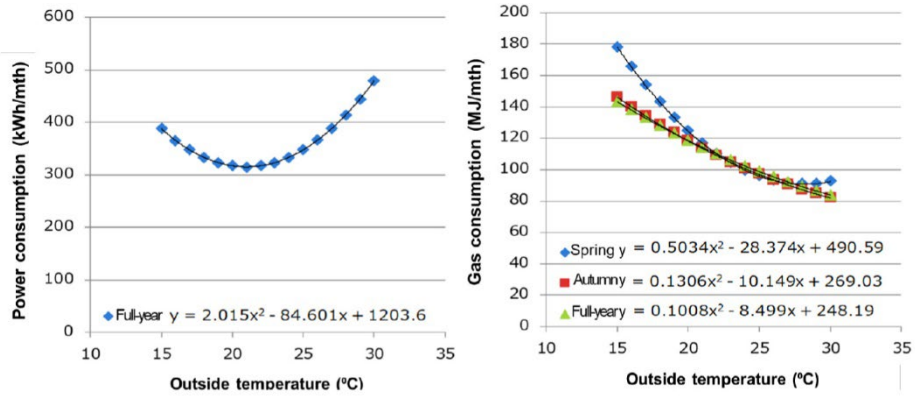

Figure 2 Approach to temperature correction (Kanto region)

Note: Based on a monthly household survey on energy use (*Family Income and Expenditure Survey* by the Ministry of Internal Affairs and Communications and the Statistics Bureau of Japan, 2018) covering 5 years (60 months) from 2012 to 2017 and temperature data from the Japan Meteorological Agency. Outside temperatures corresponding to regional classifications in the household survey were created using adjusted municipality temperatures with weighted average number of households per municipality. Energy usage is not available for city gas from the household survey, so this was calculated by dividing the amount of spending by the city gas price (for 1465.12 MJ) from the retail price statistics survey (Ministry of Internal Affairs and Communications).

Using the formulae below, we converted measured electricity and gas consumption into CO_2 emissions, which we displayed as overall household CO_2 emissions due to energy use.

$$CO_2 \text{ emissions (kg) from electricity} = \text{Electricity consumption (kWh)} \times 0.65^*$$

$$CO_2 \text{ emissions (kg) from gas} = \text{Gas consumption (m3)} \times 2.21^‡$$

* FY2017 average thermal power coefficient in the Plan for Global Warming Countermeasures (2016 cabinet decision)

‡ City gas (per m^3) 2.21 kg (CO_2/m^3): Calculated using the typical composition for Tokyo Gas's 13A city gas

Measuring Awareness of Energy-Saving Behavior and Impact of Behavioral Changes

To measure the practice of energy-saving behavior, we set 16 items in total: eight concerning changes to appliance settings (improving default settings) and eight everyday activities (improving habits). We chose items likely to generate results in a short time period and easy for junior high and high school students to carry out (Table 3), which could decrease household CO_2 emissions by roughly 20% compared with the case of no educational intervention.

Table 3 Changes to implementation rate

n = 300			**A**	**B***	**C‡**	**D**	**E**
			CO_2 decrease (kg /year/ household)	Before lessons (%)	After lessons (%)	(d = c - b) Change in percentage points (%)	(e = a × d) Estimated CO_2 decrease (kg/day/ household)
Appliance settings	1	Kitchen water heater on lowest setting	51	28.3	57	28.7	0.04
	2	Bath temperature setting lowered	19	54.3	78.3	24	0.01
	3	Shower temperature lowered	28	56	77.7	21.7	0.02
	4	Washing machine on eco-/water saving mode	3	37.7	68.7	31	0
	5	Power plug removed when not in use	73	38.7	71	32.3	0.06
	6	Fridge set to medium or weak	40	47.7	73.7	26	0.03
	7	TV set to energy-saving mode	99	25.7	52.3	26.7	0.07
	8	Room temperature set to 28°C and 20°C in winter	75	40.7	65	24.3	0.05
Everyday activities	9	Turn lights off when out of room	43	86	94.7	8.7	0.01
	10	TV off when not watching	37	79.7	93.3	13.7	0.01
	11	Using toilet half-flush button when appropriate	4	61	82	21	0
	12	Closing toilet lid	33	74	89.3	15.3	0.01
	13	Keeping showers under 5 minutes	120	22.7	56.3	33.7	0.11
	14	Ensuring bathtub lid is put back into position	39	64	79	15	0.02
	15	Only boiling water when needed	83	63.7	86.3	22.7	0.05
	16	Putting lids on cooking pots	18	77.7	92	14.3	0.01
Overall			**765**	**53.6**	**76**	**22.4**	**0.47**
Appliance settings			**388**	**41.1**	**68**	**26.8**	**0.29**
Everyday activities			**377**	**66.1**	**84.1**	**18**	**0.19**

*B = Number of students who answered that they were implementing behaviors before the educational program / 300 students

‡C = Number of students who answered that they were continuing to implement the learned behaviors after the educational program / 300 students

Throughout the program, during each lesson, the participants circled the energy-saving behaviors they were able to accomplish out of the 16 items. We measured changes in implementation before and after the energy-saving lessons and aggregated the results. In addition, we evaluated interest in environmental issues and implementation of energy-saving behavior, using a questionnaire survey with items rated on a five-point Likert scale. The effect of education was inferred from the ratio of the number of students who answered that they were implementing behaviors before the educational program to the number of students who answered that they were continuing to implement the learned behaviors after the educational program.

Results and Implications

The Developed Climate Change Education Program

This program aims at effective education and applying behavioral insights, developed as shown in Table 1. Lessons were held six times, once weekly in principle, in line with Steps 1–6.

Figure 3 shows the primary resource, the textbook developed for student use. We also developed the following materials: worksheets for recording household electricity and gas meter data; worksheets for students to make notes about their own energy-saving behavior; a newspaper article template for investigative learning with the aim of encouraging commitment; action plan sheets for retrospective learning using the behavioral planning method; stickers with pictures that reminded and encouraged students of voluntary energy-saving behavior; and reference materials for teachers, including lesson plans and digital teaching materials. This program encouraged data entry on the above-mentioned worksheets for not only measuring the effects of teaching but also for encouraging students to set their own hypothesis and verify the results of engaging in energy-saving behavior by visualizing energy use and behavior.

Figure 3 Textbook for students

The program used the transtheoretical model, which is often used for smoking cessation and improving dietary habits. Previous research has confirmed that it is difficult to generate educational outcomes when teaching individuals who are disinterested (Mikami et al., 2019), so the initial focus of the program was to improve environmental literacy and eliminate indifference as well as incorporate content that resonates at each step.

We also kept in mind the global education trend of active learning, and therefore included in-class group discussions, debates, group work, and investigative learning. To put into practice

the knowledge the students had acquired, the program also included experiential learning such as power-saving experiments, eco-cooking, and gamification.

Changes in CO_2 Emissions due to Education

Data on the households that were involved in the educational program are shown in Table 4.

Table 4 Participants' household status

		Number in study	Share (%)
Persons		300	100
Housing type	Detached house	189	63
	Complex	107	35.7
	No answer	4	1.3
Household size (persons)	2	8	2.7
	3	72	24
	4	135	45
	5	57	19
	≥6	22	7.3
	No answer	6	

Changes in CO_2 emissions from energy (electricity and gas)

Figure 4 shows the cumulative decreases in CO_2 emissions from electricity and gas consumption. A major change is apparent around the third lesson. We believe that this change is due to experiential learning. The rates of decrease in CO_2 emissions shown in Figure 5 were calculated as:

(measured value − base value) / base value

Without any instruction, the estimated value was 10.6 kg/day/household, but that value decreased to 10.2 kg/day/household in households with students who had taken one or more lessons in the course, a change of about 3.7%. The t-test confirmed statistically significant differences ($p < 0.01$) before and after teaching.

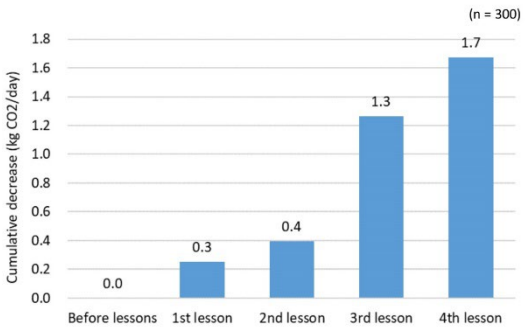

Figure 4 Cumulative decrease in CO_2 emissions from electricity and gas

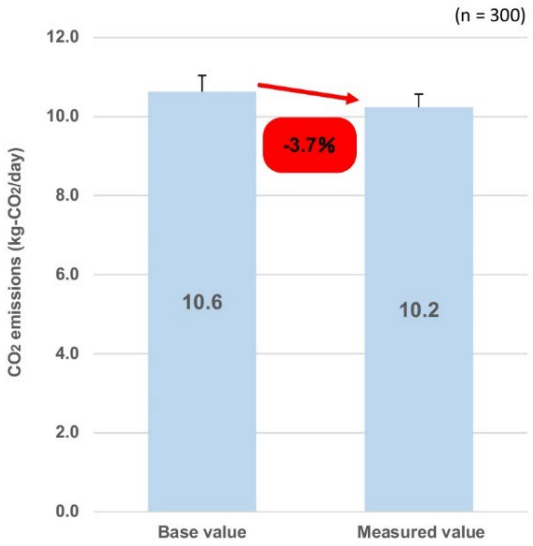

Figure 5 Change in household electricity and gas CO_2 emissions

Impact of Energy-Saving Education on Interest in Energy-Saving Behavior and Behavior Changes

We clarified changes in household electricity and gas consumption due to education. We also used a questionnaire survey to investigate which actions affected these changes and change in interest in environmental issues and awareness of carrying out eco-friendly energy-saving behavior. The results show changes in the practice rate of energy-saving behaviors and the changes in students as evidenced by the editorial postscript of the newspaper they created.

Energy-saving behavior implementation rates

As shown in Figure 6, interest in environmental issues improved from 54.5% before the lessons to 72.9% after the lessons. In line with the improvement in interest, behavioral implementation rates also improved as shown in Table 2, and for the 16 items overall, the average improvement was 53.6% to 76.0%. The implementation rate before the lessons was low for all categories concerning changes to appliance settings at 41.1% on average, and high for everyday activities at 66.1% on average. After the lessons, implementation rates improved to 68.0% and 84.1%, respectively.

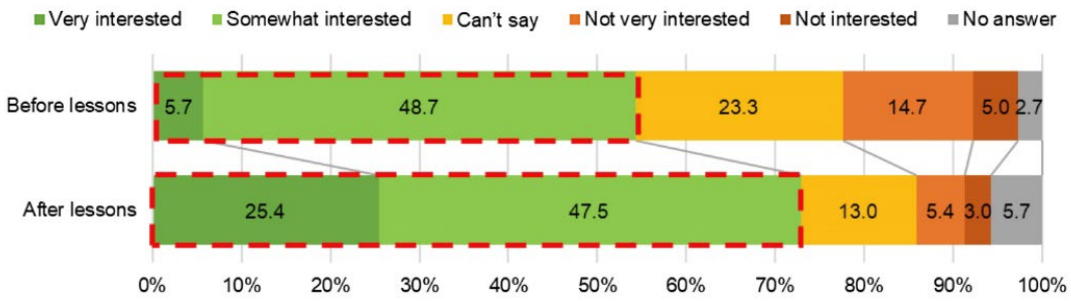

Figure 6 Changes to interest in energy conservation after lessons

Decreases in household CO_2 emissions were hypothesized from implementation of set behaviors. Based on improvements in implementation rates, decreases presumed to be due to the lessons averaged 0.47 kg/day/household. Although this is nothing more than an assumption, Figure 5

shows measured decreases of 0.39 kg/day/household, suggesting that individual changes in behavior resulted in changes to the numbers.

Considering the items in more detail, the implementation rate of three items was below 30% before the lessons:

1. Kitchen water heater on lowest setting

7. TV on energy-saving mode, and

13. Keeping showers to under 5 minutes.

Implementation rates climbed over the course of the lessons to about 50%. Particularly for energy-saving behavior involving changing appliance settings, once settings are changed, appliances can be used as is, which has good prospects for results. However, in some instances, the participants were unable to change their behavior for reasons such as not knowing how to set the device, inability of the device to be set, and opposition of other family members to energy-saving behaviors, including those related to water heaters and TVs. It takes time to change household behavior as well, so society first needs equipment that enables consumers to save energy easily, starting at the appliance-manufacturing stage. Furthermore, it is necessary to promote energy-saving behavior through education.

For seven of the items involving everyday activities (excluding *13. Keeping showers to under 5 minutes*), implementation rates were already high before the lessons, at over 60%, and rose to over 80% after the lessons. The editor's postscripts in the newspaper assignments (described below) show that through the education program, the students came to understand the monetary savings and benefits of saving energy, and explaining the reasons led to understanding of actions and the desire to implement them, suggesting that the students' awareness of energy-saving behavior in their daily lives.

Energy-saving awareness and behavioral change as revealed by analyzing editor's postscripts in the newspaper assignment

In addition to energy-use data and energy-saving behavior implementation rates, to shed light on understanding and desire to implement energy-saving behavior, we analyzed and extracted the most frequently used vocabulary from the free description editor's postscripts written after the newspaper writing assignment (n = 300). In the transtheoretical model, behavioral change requires moving through the pre-contemplation, contemplation, preparation, action, and maintenance periods. Research to date has shown that individuals move from cognition and understanding through improved awareness to improved behavior during these stages (Akamatsu & Nagahashi, 2008; Akamatsu & Takemi, 2007; Mikami et al., 2019; Prochaska & Norcross, 2007; Takemi & Akamatsu, 2013).

Analysis of the results revealed that the most frequently occurring verbs moved from *know* and *understand* (related to cognition and understanding), through to *being aware of* and *keeping in mind* (improving awareness), to *can do* and *do* (improving behavior).

Figure 7 shows excerpts of comments related to energy-saving behavior. We confirmed that through the newspaper assignment, the students had the opportunity to become aware of global environmental issues such as global warming, and thus take measures for the environment, and implement actions via an eco-declaration.

A lot of people told me to save energy, and I used to wonder why, but after reading and investigating, I learned that it was easy to do at home. I want to look for things I can do myself at home, where I can take initiative.
Up till now I had no interest in energy conservation or environmental problems. People in my family were worse than me and left the lights on and wasted a lot of water, things I did not feel good about. I didn't say anything because I thought it was not the place of someone like me who knew nothing about energy-saving, money, or the environment. However, through this newspaper, I learned a lot of things. I came to think that in the future it would be good if I could change the attitudes of not just myself, but my family, and people around me.
I thought I was taking showers in under 5 minutes when I measured the time to see if I could save, but I was surprised to find I was taking longer. Later, I was forgetting less and less often to turn off the lights on the stairs, which I sometimes forgot to do, and I became more aware of saving energy. I thought that we should do as much as we can.
After taking these lessons, I learned how much energy I had usually wasted. These lessons were extremely good for me. I think that global warming is progressing rapidly, so it is important for each of us individually in cooperation with our families to be aware of saving energy in our activities. In my lifestyle from now on I want to use the experiences I learned in the classes

Figure 7 Excerpts of free reflections on energy-saving behavior in the newspaper editorial postscript comments

Conclusion

In this research, we developed a climate change education program aimed at junior and senior high school students (aged 13–18 years) that is easy to adopt in the classroom. We evaluated the energy-savings impact of the lessons quantitatively and qualitatively to investigate what kind of contribution the program could make to Japan's energy conservation education and elucidated the following.

We measured actual household energy consumption using electricity and gas meter readings. We confirmed the impact of this climate change education on decreasing the consumption of electricity and gas. In particular, decreases were large from the third lesson, which involved experiential learning. Decreases in CO_2 emissions from electricity and gas consumption resulted in lower emissions of roughly 3.7% or 0.39 kg/day/household.

We also investigated interest in environmental issues and implementation rates of energy-saving behaviors. Interest in environmental issues climbed by 18.5 percentage points after the lessons and the implementation rates in 16 energy-saving behaviors rose by 22.4 percentage points on average. There were some items where implementation rates remained low after the program, but the commonly cited reasons were that the student did not know how to change either device settings or negative household opinions toward energy-saving behavior.

Classroom lessons included a newspaper writing assignment. Analyzing the commentary in the editor's notes, we found words that indicated improvements in attitudes such as *being aware of* and *keeping in mind* and improvements in behavior such as *will use*, *can*, and *continue*.

We found that conducting climate change education in junior and senior high schools promoted changes in awareness and behavior and contributed to decreases in household CO_2 emissions.

In the future, as we move toward a decarbonized society, we would like to consider the optimal approach to introducing such programs in Japanese education settings and investigate how to promote the dissemination of climate change education based on the results of this paper.

Acknowledgements

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