LOOK ACADEMIC PUBLISHERS
OPEN ACCESS

INTERNATIONAL JOURNAL OF ENVIRONMENTAL & SCIENCE EDUCATION
2017, VOL. 12, NO. 5, 1067-1095

Investigating energy literacy and its structural model for lower secondary students in Japan

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ABSTRACT

Energy literacy is indispensable for a sustainable society, which is fostered and improved by formal and informal energy education. To achieve the goal of energy education, which develops a well-informed public with positive attitudes toward energy conservation and the ability to make appropriate decisions regarding future energy choices, we must understand the status of students' energy literacy and its conceptual structure. By employing and modifying the energy literacy framework and instrument developed by DeWaters & Powers (2013), energy literacy and its structural model for students in Japan were investigated through a survey for 1316 lower secondary students (ages 13–15) in 2014. It was found that female students and students who have family discussions about energy-related issues scored higher than their counterparts. Students in Fukushima scored lower than those in Tokyo and Kyoto/Nagasaki. The energy literacy structure model was described by six predictors by structure equation modeling, where energy-saving behavior was predicted by both the awareness of consequences and the ascription of responsibility. Both the awareness of consequences and the ascription of responsibility were predicted by basic energy knowledge through the cognition of environmental issues. The prediction of energy-saving behavior by the awareness of consequences indicates the role of bonding between the relevant knowledge on energy and the environmental issues and energy-saving behavior. A moderation analysis found that (1) the effect of the cognition of environmental issues on responsibility depends on gender, and the magnitude of its effect did not necessarily depend on the amount of knowledge; (2) the indirect effect of responsibility toward energy-related issues on energy-saving behavior through energy-use conscious behavior seems to decrease with grade progression; and (3) the indirect effect of the awareness of consequences on energy-saving behavior through energy-use conscious behavior depends on the region.

KEYWORDS
Energy literacy, Energy literacy structure model, Moderation analysis, Lower secondary school students in Japan

ARTICLE HISTORY
Received 17 January 2017
Revised 1 June 2017
Accepted 12 June 2017

Introduction

Energy is indispensable for human activities and a fundamental resource for maintaining and developing our societies. The overconsumption of energy to satisfy human desires has, however, triggered critical issues of resource

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depletion, greenhouse gas emissions, and global climate change. The United Nations adopted the Paris agreement, which requires the widest cooperation by all countries and their participation in an effective and appropriate international effort to reduce global greenhouse gas emissions. Human societies must recognize that we are facing an urgent and potentially irreversible threat caused by the adverse effects of climate change (COP21). These environmental problems are primarily caused by energy production and consumption (Farhar, 1994). Thus, the improvement in public awareness of energy conservation, appropriate energy choices, and energy problem solving is an urgent matter. Namely, the energy literacy of a public citizen is extremely important for evaluating the energy policy presented by a government "faced with defining new directions and values for energy development, energy consumption, lifestyles, and global environmental protection" (DeWaters & Powers, 2011).

Energy literacy is not just knowledge. An energy-literate individual is characterized as one who is cognizant and knowledgeable; understands energy use in daily life, the impact of energy overconsumption on the society and environment, and the need for energy conservation and alternative energy resource development; can make appropriate energy choices and decisions; and can take actions reflecting one's skills and action for a sustainable society (Barrow & Morrisey, 1989; DeWaters & Powers, 2013). Thus, it can be argued that energy literacy is a common ability that is fostered by energy education to overcome energy challenges in the world.

Since 2002, The Japan Science Foundation (JSF) has undertaken the Energy Education Model Schools Project commissioned by the Ministry of Economy, Trade and Industry Agency for Natural Resources and Energy (METI, 2014). The project administered a school appointment system to learn energy security, global warming, energy resource diversity, and energy conservation for our future. More than 500 schools including elementary to high school have been encouraged by the project as a role model of energy education practice. The Japan Association of Energy and Environmental Education (JAEEE) established in 2005 has taken leadership in ensuring cooperation among educators, researchers, companies, and the relevant authorities of energy and environmental (E/E) education and in promoting the development of the education materials and practical methods. A variety of energy education practices have been accumulated by teachers in recent years. However, neither an energy education program nor a common evaluation measurement for energy education achievement, which focuses on improving students' energy literacy including real-world and real-time energy-related issues relevant to their daily life, has been presented by the official curriculum guidelines of the Ministry of Education, Culture, Sports, Science and Technology (MEXT). Therefore, energy education in Japan relies on the contributions of teachers who devise their own energy education based on the given official curriculum. To achieve the goal of energy education that develops a well-informed public with positive attitudes and behavior toward energy-related issues (Lawrenz, 1988), we must understand the status of students' energy literacy and its conceptual structure.

Literature review

Numerous studies have contributed to the understanding of people's knowledge, attitudes, and behavior about energy-related issues. Although people are concerned about E/E issues and want to contribute to problem solving themselves, their basic scientific energy-related knowledge is insufficient (e.g., Barrow & Morrisey, 1989; Bittle, Rochkind & Ott, 2009; Curry, Ansolabehere & Herzog, 2007; Farhar, 1996; Gambro & Switzky, 1996; Herrmann-abell & Deboer, 2011; Holmes, 1978; NEETF, 2005; Opitz, Harms, Neumann, Kowalzik & Frank, 2015). A knowledge deficit and misconceptions about energy become a barrier when people seek solutions to global warming, and it may lead to inappropriate energy choices (Curry et al., 2007; Georgia, Energy & Gas, 2009).

Frequently, findings indicate gender differences in which males score higher in the knowledge of energy-related issues than females (e.g., Barrow & Morrisey, 1989: Chapin, 1982, Chen, S., Chou, Yen & Chao, 2015). Females tend to represent positive attitudes to energy issues and conservation than males (e.g., Ayers, 1976; Barrow & Morrisey, 1987, 1989; Chen, S. et al., 2015; DeWaters & Powers, 2011; Dwyer, 2011; Lawrenz & Dantchik, 1985). In contrast, it has been claimed that the number of science classes taken contributed to the difference in the students' levels of knowledge about environmental issues related to energy (Gambro & Swuitzky, 1999). Namely, gender differences may be considered a byproduct of the disparity of literacy and interests in scientific issues (Hayes, 2001; Khun, 1979).

Barrow and Morrisey (1987, 1989) found that the efforts of implementing energy education based on energy crisis experience would cause a disparity in the knowledge and attitudes of energy-related issues of ninth graders by a geographical comparison between the US and Canada. Another geographical comparison survey in the Ehime prefecture in Japan found that students who live near the Ikata nuclear power plant indicated a higher motivation for learning about energy. They were more knowledgeable about power generation and alternative energy. Moreover, they tended to think of energy associated with generation, whereas students who live far from the nuclear power plant tend to think of energy by the contents of school science classes (Fukuyama, 2008). More experience with energy would affect students' motivation toward energy issues and the contents of the energy education provided by a teacher.

A study of students in elementary, middle, and secondary schools in Japan indicated that students' actions towards E/E issues were associated with their family behaviors (Tanabe & Kado, 2006). Pe'er, Goldman & Yavetz (2007) also suggested that the environmental knowledge and attitudes of college students in Israel are positively related to their mothers' educational level. Furthermore, effective energy education programs improve students' attitudes and energy conservation behavior and change their parents' attitudes and behavior owing to the spillover effects of the students' education (Craig & Allen, 2015; Hiramatsu, Kurisu, Nakamura, Teraki & Hanaki, 2014; Zografakis, Menegaki & Tsagarakis, 2008). The interaction effects among students, parents, teachers, or other adults could promote their energy-saving behavior, and students disseminated what they learn into their homes. The synergistic effect of students and family is one of the important factors for understanding students' energy literacy.

For a comparative energy literacy study, DeWaters et al. (2008, 2013, 2013a) have established an energy literacy framework and developed an instrument that consists of energy-related knowledge, attitudes, and behavior that can measure by using a written closed-item questionnaire for a practical classroom application. Utilizing this instrument, a study reported that secondary students in New York State (US) were concerned about energy problems yet discouragingly low in the cognitive domain, which implies that students may lack the knowledge and skills required to contribute effectively toward energy-related solutions. Moreover, the intercorrelation between behaviors and attitudes rather than knowledge suggests the need for education that improves energy literacy by impacting students' attitudes and behaviors as well as content knowledge (DeWaters & Powers, 2011).

In response to this study, several studies have adopted the work of DeWaters et al. to evaluate students' energy literacy in their own countries. Students in Taiwan scored over 60% correct on a cognitive subscale, which is better than the students in New York State. Moreover, their energy-saving behavior was more closely associated with attitudes than other variables. However, their finding of a notable discrepancy between attitudes and behavior was indicated. Namely, there might not be a correspondence between what students say they should do and how they actually behave (Lee, Lee, Altschuld & Pan, 2015). In another comparative study of secondary students in Malaysia, in spite of the government promotion of energy education in formal (Ministry of Education Malaysia, 2002) and informal (KeTTHA 2009) education, the energy literacy of students was discouragingly low. The results emphasize the need for improved energy education programs in Malaysian public schools with broader coverage of topics related to current events and practical issues such as energy use in everyday life (Lay, Khoo, Treagust & Chandrasegaran, 2013; Karpudewan, Ponniah & Ahmad, 2016). Chen, S. et al. (2015) conducted a confirmatory factor analysis to investigate the relationships among energy-related knowledge, attitudes, self-efficacy, and influences of family behavior toward the personal behavior of their son(s)/daughter(s) in high school in Taiwan by structural equation modeling (SEM). They found that how family members perform for energy saving affected students' positive behavior for energy saving the most. Conversely, a negative relation between knowledge and personal behavior was evidently observed.

Although we can compare the level of energy literacy components, the relationships between knowledge, attitudes, and behavior are complicated; in particular, little correlation between knowledge and behavior has frequently been reported by energy literacy studies (e.g., Ajzen, Joyce, Sheikh & Cote, 2011; Chen, S. et al., 2015; Craig & Allen, 2015; DeWaters & Powers, 2011; Hu, Horng, Teng & Yen, 2013; Jurin & Fox-Parrish, 2008; Lee et al., 2015). Evidence from a number of studies has supported the relationship between attitudes and behavior (e.g., Hines, Hungerford & Tomera, 1987; Hungerford & Volk, 1990; Schultz, 2001; Stern, 2000; Teksoz, Sahin & Tekkaya-Oztekin, 2011). However, the dissonance between knowledge and behavior has been discussed in pro-environmental behavioral studies; causal models that link knowledge and attitude to behavior have not been yet supported (e.g., Hu et al. 2013; Jensen, 2008; Kollmuss & Agyeman, 2002; Teksoz et al., 2011). Even though a person has significant knowledge of energy-related issues, he/she would not necessarily perform energy-saving behaviors or participate in actions to facilitate a more sustainable energy-related future (e.g., Chen, S. et al., 2015; Craig & Allen, 2015; DeWaters & Powers, 2013; Hu et al., 2013; Lee et al., 2015).

Social psychology studies have focused on attitudes and the formation of behaviors for many decades. The Theory of Planned Behavior (TPB) (Ajzen, 1991), extended from the Theory of Reasoned Action (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975), observes an individual's behavior, which is predicted by a behavioral intention formed by attitudes toward behavior, subjective norms, and perceived behavioral control (Ajzen, 2006). One traditional linear model of responsible environmental behavior (Hungerford & Volk, 1990) suggests that increasing knowledge would lead to environmental awareness and attitudes, which derive more positive pro-environmental behaviors. Although a behavioral change requires knowledge contributions to change attitudes toward behavior (Hines et al., 1987; Kollmuss & Agyeman, 2002; Roy, Dowd, Muller, Pal & Prata, 2012), the relations between knowledge, attitude, and behavior have not been supported by simple linear causal models in the field of environmental attitudes and behaviors (DeWates and Powers, 2011). Thus, in this work, we assume that attitude plays a role between knowledge and behavior from the results of an intercorrelation (e.g., Chen, S. et al., 2015; DeWates and Powers, 2011; Lee et al., 2015).

Value-Belief-Norm (VBN) Theory (Stern, Dietz, Abel, Guagnano & Kalof, 1999) is principally founded on Schwartz's Norm Activation Theory (NAT) (1977), which focuses on a personal norm activating as a determinant of a given behavior. VBN Theory assumes a causal model linking the assumptions of the NAT that a person's general ecological worldview and environmental values are linked to a person's conservation behavior, which is predicted by personal norms, the ascription of responsibility, and the awareness of consequences. The application of these theoretical models and predictors gives us a clue to explore the complex relationships among energy literacy components.

As Lawrenz & Dantchik (1985) noted that the given time for energy education is limited in the busy school curriculum, energy education should be presented in the most effective manner possible. To do so, we must understand the causal structure of students' energy-relevant knowledge, attitude, and behavior as well.

Purpose

We aimed to investigate the energy literacy of students in Japan and propose its structure model by SEM through a common framework and the instrument developed by DeWaters & Powers (2011, 2013, 2013a). Moreover, the interaction effects of gender, grade, regions, and the presence of family discussion on energy-related issues are further analyzed in conjunction with energy literacy.

Materials and Method

Survey questionnaire

An energy literacy assessment questionnaire based on the Energy Literacy Survey for Middle School, Clarkson University (DeWaters, 2013b) was developed and modified. It was translated into Japanese wording, reformulated to suit domestic energy circumstances, and consisted of 73 items of three subscales of cognitive, attitudes, and behavior based on the Instrument Development Framework of DeWaters & Powers (2013). The overall question items have been previously reported in the Journal of Energy and Environmental Education (Akitsu, Ishihara, Okumura & Yamasue, 2016). Additional question items to DeWaters' original instrument were administered by referring to surveys of the awareness of energy, radiation, and environment in Japan (Fukutoku, 2009, 2009a; Fukuyama, 2008; Hashiba, 2010; Cabinet Office, Government of Japan, 2005; Tanabe & Kado, 2006) (Appendix). The cognitive subscale was composed of 43 items including energy self-sufficiency, radiation, and nuclear power. The affective and behavioral subscales consisted of 19 and 11 items, respectively. Four question items of energy-related self-efficacy, which explain a person's beliefs about his/her contributions toward solving energy-related problems (Bandura 1997, DeWaters & Powers 2011), were embedded within the affective subscale. A self-rating question that asks students about the presence of family discussion on energy-related issues was provided to examine the relation between students' energy literacy and family influence.

Sample

In March 2014, six lower secondary schools in Fukushima (one school), Tokyo (two schools), Kyoto (two schools), and Nagasaki (one school) participated in this survey, and the questionnaire was carried out in the classroom by each teacher. In total, 1316 valid responses without missing values (64% out of a response rate of 86%) from students in the 7th, 8th, and 9th grades (ages 13–15) were analyzed. Because of the participation of two private girls' schools, the gender distribution of the survey respondents was 36% male and 64% female.

Data analysis

The cognitive subscale employed five-option multiple-choice questions, and both the affective and behavioral subscales administered a five-point Likert-type response scale with bipolar indices (e.g., strongly agree to strongly disagree). Item responses were converted into numerical scores in the same way as the investigation of secondary students in New York State (US) by DeWaters & Powers (2011). The cognitive items were allocated one point for each correct response and zero points for each incorrect response. The five-point Likert-type response for the affective and behavioral subscales was converted into numerical scores from one point (least preferred responses) to five points (most preferred responses) according to a predetermined preferable answer in this study. The total scores for each subscale were converted into a percentage of the maximum attainable scores as a common scale for a simply comparison among the three subscales.

Taking into account the circumstances of students in Fukushima, we assessed the energy literacy between regions divided into three groups: Fukushima, Tokyo (somewhat close to Fukushima), and the western region (Kyoto and Nagasaki) far from the radioactively contaminated area. The students in Fukushima have been facing difficulties in their daily lives and educational environment since the multiple disasters of the Great East Japan Earthquake and Tsunami and the severe accident at the Fukushima Dai-Ichi nuclear power plant, Tokyo Electric Power Co. on March 11, 2011.

Samples were dichotomized into positive and negative response groups to the presence of family discussion on energy-related issues to examine the influence of family on student's energy literacy. Students who chose the positive two scales about family discussion were allocated to a positive group (17% overall), and those who chose the negative two scales were allocated to a negative group (54% overall). A neutral group who chose option three (29%, $N = 385$) was combined with the negative group to distinguish the effect of the positive group from others.

The mean values of the subscales between subgroups were compared by a nonparametric statistical analysis using Mann–Whitney U test and Tukey's honestly significant difference (HSD) for multiple comparisons. The correlations between the cognitive, affective, and behavioral subscales were evaluated with the nonparametric Spearman's rank correlation (ρ).

Energy literacy model by structural equation modeling (SEM)

SEM usually takes a hypothesis model verification approach; in this study, however, we employed a factor analysis approach to explore the energy literacy components utilizing our results from the energy literacy assessment. When a researcher does not have a substantive theoretical model and extracts the latent variables used in SEM, an "exploratory factor analysis (EFA) can contribute to a useful heuristic strategy for model specification before cross-validation with confirmatory factor analysis" (Gerbing & Hamilton 1996).

An EFA was carried out for the three subscales using the maximum-likelihood method and Promax rotation. We determined the number of factors by eigenvalue attenuation and proper interpretation of the criteria that the boundary value of the factor score was set larger than 0.35 and the minimum two observed variables were used to define each latent variable. As a result, three factors consisting of 14 observed variables for the cognitive subscale, five factors of 17 observed variables for the affective subscale, and three factors of 11 observed variables for the behavior subscale were set for exploring the energy literacy model. Forty-two variables were computed by EFA again. Finally, we adopted six latent variables that consist of two cognitive, two affective, and two behavioral components to configure the energy literacy model.

SEM in maximum-likelihood estimation was employed to understand the patterns of correlation/covariance among a set of variables and to explain as much of their variance as possible with the proposed model. The concept of the energy literacy model employed the relationship between attitudes and behavior in the TPB (Ajzen, 1991) and the associations between environmental concerns, the awareness of consequences for valued objects, and the ascription of responsibility for reducing threats (Schwartz, 1977) in VBN Theory (Stern et al., 1999). To evaluate the model fitness, we employed the goodness-of-fit index (GFI), the adjusted goodness-of-fit index (AGFI), the standardized root mean squared residual (SRMR), the root mean squared error of approximation (RMSEA), the normed fit index (NFI), the comparative fit index (CFI), and the Akaike information criterion (AIC) to estimate the validity of each model for selection. The expected values for the good model-fit interpretation are 0.9 or more for the GFI, AGFI, NFI, and CFI and less than 0.05 for the SRMR and RMSEA. A statistical analysis was conducted at the 0.05 significance level for a two-tailed test and performed using IBM® SPSS® Amos™ Ver. 23.

To determine whether the boundary conditions affect the strength or direction of the causal effect of a predictor on an outcome, we employed a moderation analysis. Here, the moderators of gender, grade, region, and the presence of family discussion of energy-related issues were tested to determine whether they would affect the energy literacy structure by using a regression-based path analysis with PROCESS for SPSS, The Ohio State University, Release 2.13.2 for estimating and probing the interaction and conditional direct and indirect effects (Hayes, 2013, 2013a, 2014, 2015).

Results

Energy literacy assessment

Overall

The performance summaries for the cognitive, affective, and behavioral subscales are presented in Table 1. Each subscale appears to have internal consistency by Cronbach's alpha values ranging from 0.66 to 0.78, which satisfied the adopted criteria for internal reliability in educational assessment (Morioka, 2001; Zaiontz, 2016). The subscales were discriminated by the highest and lowest 27%-scoring groups. The discrimination index indicates how well the question item can discriminate between the high and low performance of respondents. The consensus of the discrimination index is less than 0.2 and should be revised (Ebel, 1979; Benson & Clark, 1982; Buffum et al., 2015), and the question items with the lowest discrimination index below 0.15 should be eliminated (Cunnningham, 1997). In this study, the discrimination indices of the three subscales were acceptable (ranging from 0.17 to 0.27). The energy literacy level of the lower secondary school students in Japan exhibited a similar tendency to the US middle school students' results (DeWaters & Powers, 2011). The students in Japan were significantly higher than the US regarding behavioral aspects (Japan 67%, US 66%; $p < .005$). However, the US students scored significantly higher than Japanese students on the affective and self-efficacy subscales (affective: Japan 69%, US 73%; self-efficacy: Japan 69%, US 72%; $p < .001$). Students in Japan still scored insufficiently on the cognitive subscale (39%, average of item difficulty) toward the ideal difficulty level for five-response multiple-choice items regarding the discrimination potential, which is 70% (Univ. of Washington, 2005).

Group comparison

However, several studies found that males achieved relatively superior scores to females in E/E-related knowledge (e.g., Barrow & Morrisey, 1989; Chen, K., Liu & Chen, 2015; Gambro & Switzky, 1999; Lay et al., 2013; Lee et al., 2015), our results indicated that females scored higher than males on the cognitive subscale (males 38%, females 40%, $p < .05$). Moreover, females showed significantly greater values than males regarding self-efficacy (males 67%, females 70%, $p < .000$) (e.g., DeWaters & Powers, 2011); however, there was no significant difference between gender on the affective or behavioral subscales (e.g., Lee et al., 2015).

In a comparison of the grades, the 8th and 9th grades scored significantly higher than the 7th grade on the cognitive subscale (40%, $p < .05$; 41%, $p < .005$;

37%), and the 9th grade scored higher than the 7th grade on the affective subscale (70%, 68%, $p < .05$).

The disparity in the energy literacy between Fukushima and Tokyo was significant. Fukushima showed the lowest mean values on all subscales among the regions we surveyed.

The positive respondents for the presence of family discussion of energy-related issues scored significantly higher than their counterparts on all subscales.

Table 1. Energy Literacy Survey Results of Overall and Group Comparison of Gender, Regions, and the Presence of Family Discussion on Energy-Related Issues of Lower Secondary Students in Japan

		Cognitive		Affective		Self-efficacy[a]		Behavior	
	N	Mean (%)	SD (%)	Mean (%)	SD (%)	Mean (%)	SD (%)	Mean (%)	SD (%)
Overall	1316	39.53	14.32	69.02	7.51	68.89	12.67	66.86	10.61
Reliability[b]		0.78		0.66		-		0.68	
Standard error of measurement (%)[c]		6.66		4.39		-		5.97	
Average item difficulty		0.40		-		-		-	
Average discrimination index		0.25		0.17		0.27		0.24	
Gender									
Male	477	38.42	15.36	68.45	7.72	66.98	12.79	66.38	10.62
Female	839	40.16 *	13.66	69.35	7.37	69.98 †	12.47	67.14	10.59
Grade									
7th grade	382	37.48	12.75	68.34	7.40	68.23	12.46	66.18	10.63
8th grade	515	40.10 *	14.48	68.82	7.36	68.34	12.28	66.71	10.43
9th grade	419	40.70 ***	15.29	69.89 *	7.71	70.18	13.24	67.66	10.77
Fukushima, Tokyo, and the western regions (Kyoto & Nagasaki)									
Fukushima	405	35.19	12.73	67.32	7.17	67.48	11.17	65.84	9.87
Tokyo	444	41.37 †	14.75	69.95 †	7.47	69.71 *	12.75	67.90 *	10.69
Kyoto & Nagasaki	467	41.56 †	14.42	69.61 †	7.59	69.35	13.70	66.77	11.06
The presence of family discussion on energy-related issues									
Positive	223	43.26 †	14.98	73.00 †	6.96	75.25 †	11.41	72.87 †	9.91
Neutral & Negative	1093	38.77	14.07	68.21	7.36	67.60	12.52	65.64	10.33

[a] Four self-efficacy items embedded within the affective subscale.
[b] Cronbach's alpha value. Self-efficacy items embedded within affective subscale are not calculated.
[c] For instruments comprised of multiple subscales, the standard error of measurement for each subscale should be equal to or less than 7.5% (DeWaters and Powers, 2011; Qaqish, 2005). Not calculated self-efficacy items within affective subscale.
Probability of the statistical differences of mean scores between subgroups was calculated with Mann-Whitney U test and Tukey-Kramer method. Results indicate * $p < .05$, *** < .005, † < .001, two-tailed test.

Relationships between the cognitive, affective, and behavioral domains

The correlation coefficients of Spearman's rank correlation between each subscale are given, and all were positive and significant ($p < .01$) (Table 2). As previous studies have reported, this study also indicated that the affective subscale was more closely correlated to the behavioral subscale than the cognitive subscale and that there was little correlation between knowledge and behavior (e.g., Chen, S. et al., 2015; DeWaters & Powers, 2011; Lee et al., 2015). The significant difference between Japan and the US for the intercorrelation between the attitude and behavior subscales may have been produced by the fact that the US scored higher than Japan on the affective subscale and self-efficacy ($r = 0.54$, US average of intercorrelations of the middle and the secondary students; $r = 0.46$, Japan; $p < .005$) (Akitsu et al., 2016; DeWaters & Powers, 2011).

Table 2. Intercorrelations between Cognitive, Affective, and Behavioral Scores (N = 1316)

Intercorrelations between	*r*
Affective vs. behavioral subscale	0.465 **
Cognitive vs. affective subscale	0.432 **
Cognitive vs. behavioral subscale	0.145 **

The correlation coefficients are significant at the 1% level, two-tailed test.

Energy literacy structure model

Components of the energy literacy model

Employing our results from the energy literacy assessment and its factor loading, 32% of the raw data contributed to the interpretation of the energy literacy structure model. Cronbach's alpha values for the internal consistency of factors were in the range of 0.52–0.70. We adopted these values by conducting a confirmatory factor analysis to "specify a certain number of factors, which factors are correlated, and which observed variables measure each factor" (Schumacker & Lomax, 2010) to explore the energy literacy structure model. Six latent variables were extracted and denoted as basic energy knowledge (BEK), cognition of environmental issues (CEI), awareness of consequences (AC), ascription of responsibility (AR), energy-use conscious behavior (ECB), and energy-saving behavior (ESB) (Table 3). The means, standard deviations, and factor loadings of the components measured by 25 observed variables are summarized in Table 4. Furthermore, the mean values, standard deviations, and correlation coefficients among the six latent variables are presented in Table 5. The fitness indices, 0.957 for the GFI and 0.934 for the AGFI, were satisfied for values larger than 0.900; the SRMR of 0.056 and the RMSEA 0.053 were acceptable.

Table 3. Six Latent Variables and Their Abbreviations for Energy Literacy Model

Domain	Latent variables	Abb.
Knowledge	Basic Energy Knowledge	BEK
	Cognition of Environmental Issues	CEI
Attitude	Awareness of Consequences	AC
	Ascription of Responsibility	AR
Behavior	Energy-Use Conscious Behavior	ECB
	Energy-Saving Behavior	ESB

Table 4. Means, Standard Deviation, and Factor Loadings of Components of Energy Literacy Structure

	Question Items	Mean (%)	*SD*	BEK	AC	ECB	AR	ESB	CEI
F1: Basic Energy Knowledge (BEK) (α = 0.70 *)									
68c **	The meaning of 35% efficient electric power plant	35.9	0.48	**0.581**	-0.034	-0.016	0.045	0.011	-0.076
75c	The oil import trend in Japan	45.4	0.49	**0.538**	0.079	-0.072	0.032	-0.005	-0.055
72c	Wrong idea of electric car can be useful instead of running out of fossil fuels	36.2	0.48	**0.480**	0.001	0.024	-0.060	-0.001	0.011
74c	Environmental impact by developing energy sources	40.4	0.49	**0.456**	-0.004	0.022	0.032	0.037	-0.095
60c	The least harmful energy-related activities to human health and the environment	58.5	0.49	**0.448**	-0.058	0.105	-0.011	-0.045	0.339
55c	Two things determine the amount of electricity consume	44.3	0.50	**0.429**	0.025	-0.015	0.012	-0.016	0.064
71c	The way of energy consumption reduction	66.3	0.47	**0.381**	-0.004	0.009	0.009	0.006	0.142
F2: Awareness of Consequences (AC) (α = 0.69)									
16a	Japanese people should save energy more	77.1	0.98	-0.017	**0.705**	-0.028	0.034	-0.015	-0.056
18a	Intention to contribute energy conservation if I know how	73.3	1.03	0.014	**0.542**	0.225	0.097	0.025	-0.036
10a	Energy saving is important	89.0	0.82	0.022	**0.529**	-0.199	-0.019	0.167	0.125
12a	Strong government regulation on car CO_2 emission	68.4	1.00	0.008	**0.509**	0.065	-0.082	0.029	-0.075
9a	Labels showing resources used	60.3	1.01	0.010	**0.379**	0.314	-0.013	-0.100	-0.055
F3: Energy-use conscious Behavior (ECB) (α = 0.57)									
24b	Many of my everyday decisions affected by own thoughts on energy use	46.7	1.02	0.037	0.064	**0.661**	-0.044	-0.117	-0.045
25b	Buy fewer things in order to save energy	50.7	0.98	-0.062	0.024	**0.557**	-0.085	0.046	0.184
35b	Encourage family to buy compact fluorescent light bulbs	52.6	1.17	0.063	-0.088	**0.384**	0.009	0.375	-0.187
F4: Ascription of Responsibility (AR) (α = 0.61)									
15a	No worries about saving energy, because new technologies solve the energy problems (R)***	73.1	0.94	0.027	0.043	-0.046	**0.621**	-0.038	0.006
13se	No worries about turning the lights off in the classroom, because the school pays for the electricity (R)	78.8	1.10	-0.086	-0.048	0.143	**0.539**	0.061	0.207
17a	Law protecting the natural environment should be made less strict in order to allow more energy to be produced (R)	69.3	0.94	0.064	-0.071	-0.096	**0.504**	-0.005	-0.038
7se	My energy use contributes no difference to energy problems facing our nation (R)	70.1	0.96	0.021	0.051	-0.110	**0.433**	-0.019	-0.091

F5: Energy-saving Behavior (ESB) (α = 0.55)									
31b	Family buys energy efficient compact fluorescent light bulbs	71.1	1.12	0.057	-0.022	0.042	-0.010	**0.571**	-0.127
30b	Turning off lights and computers	83.6	1.09	-0.114	0.056	-0.087	-0.045	**0.462**	0.243
26b	Separation and recycling of waste	78.7	1.08	0.064	0.059	-0.061	-0.026	**0.449**	0.047
34b	Minimizing the room temperature	70.9	1.14	-0.052	0.036	0.152	0.076	**0.363**	0.053
F6: Cognition of Environmental Issues (CEI) (α = 0.52)									
42c	The best reason to buy an ENERGY-EFFICIENT MARK appliance	83.1	0.38	0.079	-0.076	0.014	0.005	0.022	**0.562**
47c	Global warming by CO_2 emission increasing	69.1	0.46	0.359	0.011	-0.008	-0.026	0.025	**0.385**
			Contribution (%)	14.65	8.65	3.50	2.09	1.95	1.27
			Cumulative contribution (%)	14.65	23.30	26.80	28.89	30.85	32.12

Some phraseology were adopted from Chen, S. et al., (2015).
* Internal consistency, Cronbach' alpha value.
** a (affective), b (behavior), c (cognitive), and se (self-efficacy) are marked with question number.
*** (R) reverse items were converted reverse score.

Table 5. Factor Correlation Matrix Extracted by Maximum-Likelihood Method, Promax Rotated with Normalization of Kaiser

N = 1316	Mean (%)	SD	BEK	AC	ECB	AR	ESB
BEK (c)	46.7	0.29					
AC (a)	73.6	0.13	.23 **				
ECB (b)	50.0	0.16	-.12 **	.22 **			
AR (a)	72.8	0.13	.48 **	.48 **	-.06 **		
ESB (b)	76.1	0.14	.16 **	.55 **	.37 **	.39 **	
CEI (c)	76.1	0.35	.51 **	.38 **	-.27 **	.52 **	.27 **

(a): affective, (b): behavior, and (c): cognitive are marked to each factor.
Coefficients are significant at the 1% level, two-tailed test.

Energy literacy structure model

To improve the structure model statistically, modification indices and model fitness indices were considered. Applying the concepts of the TPB and VBN Theory, our energy literacy structure model is depicted in Fig. 1 with standardized estimates (β). All paths in the model were significant, and acceptable values of the model fitness indices were obtained: GFI = .947, AGFI = .936, SRMR = .048, RMSEA = .042, NFI = .847, and CFI = .888.

According to this model, energy literacy was interpreted as that ESB is predicted by AC and AR and that both AC and AR are predicted by BEK through CEI. The affective components (AC and AR) perform the role of bonding between the cognitive (BEK and CEI) and behavioral (ECB and ESB) components. Although the recent study by Ajzen et al. (2011) reported that environmental knowledge had no effect on energy conservation from an evaluation with the TPB, we observed that students with a higher score of knowledge (BEK and CEI) indicated positive ESB mediated by the awareness of potential adverse consequences of energy-related issues (AC). Furthermore, students who had a higher score of knowledge of energy and environment indicated stronger AR (standardized coefficient $\beta_3 = 0.55$) than AC ($\beta_2 = 0.31$). However, the negative estimated value of AR on ESB was mediated by ECB ($\beta_6 \times \beta_9$ = -0.45 × 0.44), while the indirect effect of AC on ESB through ECB was positive ($\beta_5 \times \beta_9$ = 0.61 × 0.44).

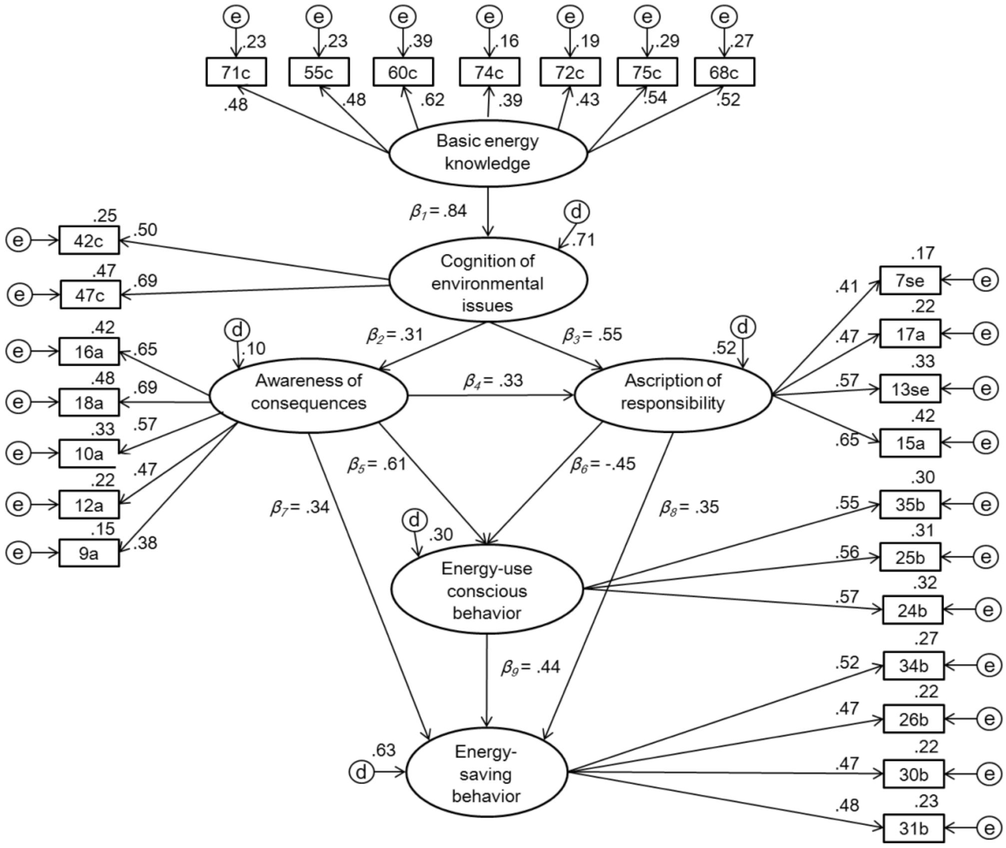

Figure 1. Standardized estimates of energy literacy structural equation model of students of the lower secondary school in Japan.

Moderation analysis of the energy literacy model

According to a moderation analysis for a regression-based approach (Hayes, 2013a), we examined whether the mediation model that X affects Y through M depends on W (gender, grade, region, and the presence of family discussion about energy-related issues). Fig. 2, panel A shows the model concept in which all three of the paths are moderated by W. Its statistical diagram is presented in Fig. 2, panel B. The effects for M and Y are calculated as follows:

$$M = i_M + a_1 X + a_2 W + a_3 XW + e_M \quad (1)$$

$$Y = i_Y + c'_1 X + c'_2 W + c'_3 XW + b_1 M + b_2 MW + e_Y \quad (2)$$

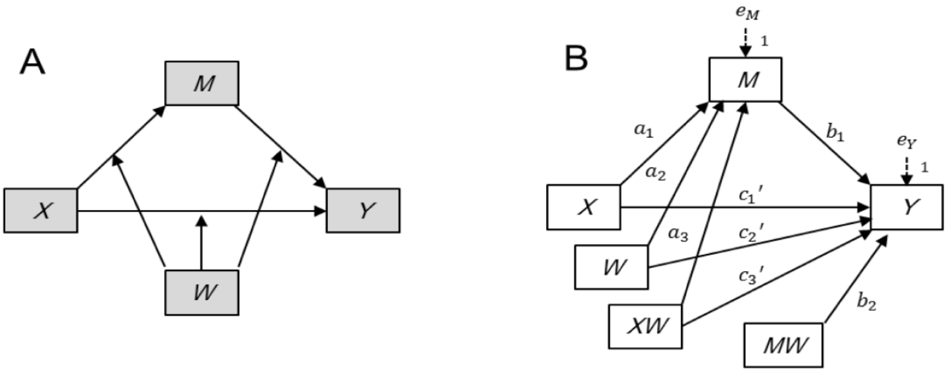

Figure 2. A conceptual (panel A) and statistical (panel B) diagram representing a simple mediation model with all three paths moderated by a common moderator (adopted Hayes 2013a, p. 410).

A conditional indirect effect of X on Y through M and a conditional direct effect of X on Y are calculated with the following equations:

Conditional indirect effect of X on Y through $M = (a_1 + a_3W)(b_1 + b_2W)$ (3)

Conditional direct effect of X on $Y = c'_1 + c'_3W$ (4)

The difference between the conditional indirect effect of X on Y through M when $W = \omega_1$ and when $W = \omega_2$ is expressed as

$$(a_1 + a_3\omega_1)(b_1 + b_2\omega_1) - (a_1 + a_3\omega_2)(b_1 + b_2\omega_2)$$
$$= a_1b_2(\omega_1 - \omega_2) + a_3b_1(\omega_1 - \omega_2) + a_3b_2(\omega_1^2 - \omega_2^2) \quad (5)$$

In the case where the moderator W is dichotomous and coded 1 and 0, the index of moderated mediation corresponds to the difference between the indirect effects in the two subgroups. In the first and second stages of the mediation model when W is coded 1 (e.g., male) and 0 (e.g., female), the weight for W based on Eq. 5 is simplified to $a_1b_2 + a_3b_1 + a_3b_2$, which is the *index of moderated mediation* (see Hayes 2013a, p. 411).

Our moderators are coded one for male, Tokyo, response “Yes” to the family discussion and coded zero for female, Fukushima, response “No” to the family discussion. The parameters were estimated using ordinary least squares (OLS) regression, and the mean of variables that are used to configure the mediation model are centered beforehand (Hayes, 2015).

We investigated five mediation models (Table 6). As a result, we found an interaction by gender in (1) CEI on AR through AC, by region in (4) AC on ESB through ECB, and by grade in (5) AR on ESB through ECB. There was no interaction by the presence of family discussion of energy-related issues in the energy literacy model.

Table 6. Mediation Models for Investigating the Effect of Moderators

Model	Cause (*X*)	Outcome (*Y*)	Mediator (*M*)	Moderator(*W*)
1	CEI	AR	AC	gender
2	AC	ECB	AR	n.s.
3	AC	ESB	AR	n.s.
4	AC	ESB	ECB	region
5	AR	ESB	ECB	grade

CEI: Cognition of environmental issues, AC: Awareness of consequences, AR: Ascription of responsibility, ECB: Energy-use conscious behavior, ESB: Energy saving behavior

Table 7 presents the estimated regression coefficients of AC and AR in the moderated mediation model by gender. Students with relatively higher CEI expressed higher AC ($a_1 = 0.063$, 95% $CI = 0.043$ to 0.083, $p < .000$). Moreover, holding CEI constant, the effect of AC on AR depends on gender ($b_2 = -0.136$, 95% $CI = -0.240$ to -0.031, $p < .05$). For the reason that "the evidence of moderation of one of the paths in a mediation model is sufficient to claim moderated mediation" (Hayes, 2015), this analysis supports the conclusion that the indirect effect of CEI on AR through AC depends on gender. In this case, however, the 95% bootstrap confidence intervals for 10,000 resamples includes zero (-0.024 to 0.002). Thus, we cannot define that the indirect effect of the cognition of environmental issues on the ascription of responsibility through the awareness of consequences depends on gender since the confidence interval of the index of moderated mediation includes zero.

Table 7. Unstandardized OLS Regression Coefficients with Confidence Intervals Estimating Awareness of Consequences (AC) and Ascription of Responsibility (AR) in the Moderated Mediation by Gender. Variables are Mean Centered

		AC (*M*)					AR (*Y*)			
		Coeff.	SE	95% CI	*p*		Coeff.	SE	95% CI	*p*
CEI (*X*)	a_1 →	.063	.010	.043, .083	†	c'_1 →	.116	.010	.096, .135	†
AC (*M*)						b_1 →	.248	.027	.196, .300	†
Gender (*W*)	a_2 →	-.021	.001	-.035, -.006	**	c'_2 →	-.018	.007	-.032, -.005	**
$X \times W$	a_3 →	-.012	.021	.558, -.053	.558	c'_3 →	.040	.020	.001, .079	*
$M \times W$						b_2 →	-.136	.053	-.240, -.031	*
Constant	i_M →	-.000	.004	-.007, .007	.962	i_Y →	.728	.003	.722, .735	†
		$R^2 = 0.036$ $F(1, 1312) = 16.38$, $p < .000$					$R^2 = 0.186$ $F(5, 1310) = 59.922$, $p < .000$			

* $p < .05$, ** < .01, † < .001

Table 8 presents the estimated regression coefficients of ECB and ESB in the moderated mediation model by grade. Students with relatively higher AR expressed less ECB ($a_1 = -0.079$, 95% $CI = -0.142$ to -0.017, $p < .05$). Moreover, holding AR constant, the effect of ECB on ESB depends on grade ($b_2 = -0.063$, 95% $CI = -0.123$ to -0.004, $p < .05$). Although there was no significant difference for the 7th grade by 95% bootstrap confidence intervals for 10,000 resamples

(b_{7th} = -0.014, t(1310), 95% CI = -0.054 to 0.025), there were significant differences for the 8th and 9th grades (8th grade b_{8th} = -0.024, t(1310), 95% CI = -0.049 to -0.000; 9th grade b_{9th} = -0.030, t(1310), 95% CI = -0.061 to -0.004). The conditional indirect effect of the ascription of responsibility on energy-saving behavior through energy-use conscious behavior seems to decrease with grade progression.

Table 8. Unstandardized OLS Regression Coefficients with Confidence Intervals Estimating Energy-Use Conscious Behavior (ECB) and Energy-saving Behavior (ESB) in the Moderated Mediation by Grade. Variables are Mean Centered

			ECB (*M*)						ESB (*Y*)			
			Coeff.	SE	95% CI	*p*			Coeff.	SE	95% CI	*p*
AR (*X*)	a_1	→	-.079	.032	-.142, -.017	*	c'_1	→	.301	.027	.248, .355	†
ECB (*M*)							b_1	→	.305	.024	.259, .352	†
Grade (*W*)	a_2	→	.010	.006	-.001, .020	.085	c'_2	→	-.003	.005	-.012, .006	.543
X X *W*	a_3	→	-.050	.041	-.131, .031	.226	c'_3	→	.001	.035	-.068, .071	.969
M X *W*							b_2	→	-.063	.030	-.123, -.004	*
Constant	i_M	→	-.000	.004	-.009, .008	.974	i_Y	→	.761	.004	.754, .769	†
			R^2 = 0.009 F(3, 1312) = 3.740, p < .0.05						R^2 = 0.173 F(5, 1310) = 54.600, p < .000			

* p < .05, † < .001

Table 9 presents the estimated regression coefficients of ECB and ESB in the moderated mediation model by region. Students with relatively higher AC expressed higher ECB (a_1 = 0.345, 95% CI = 0.268 to 0.422, p < .001). Furthermore, this direct effect depends on the region: Fukushima and Tokyo (a_3 = 0.280, 95% CI = 0.126 to 0.434, p < .001). Therefore, this model is a moderated mediation model. Regarding the conditional direct effect of AC on ESB for the region, it was significant at the values of Fukushima (b_{FUKd} = 0.414, t(843), 95% CI = 0.316 to 0.513, p < .000) and Tokyo (b_{TKYd} = 0.374, t(843), 95% CI = 0.279 to 0.468, p < .000). Holding AC constant, the effect of ECB on ESB does not significantly depend on the region (b_2 = 0.062, 95% CI = -0.053 to 0.176, p = 0.291). However, for the conditional indirect effect of AC on ESB through ECB for the region, there was a significant difference at the values of Fukushima (b_{FUKi} = 0.030, t(843), 95% CI = 0.008 to 0.069) and Tokyo (b_{TKYi} = 0.102, t(843), 95% CI = 0.061 to 0.153). The 95% bootstrap confidence intervals for 10,000 resamples did not include zero (0.018 to 0.127). Thus, we can conclude that the conditional indirect effect of the awareness of consequences on energy-saving behavior through energy-use conscious behavior depends on the region, which is significantly stronger for Tokyo than Fukushima.

Table 9. Unstandardized OLS Regression Coefficients with Confidence Intervals Estimating Energy-Use Conscious Behavior (ECB) and Energy-saving Behavior (ESB) in the Moderated Mediation by Regions (Fukushima and Tokyo N = 849). Variables are Mean Centered

		ECB (*M*)					ESB (*Y*)			
		Coeff.	SE	95% CI	*p*		Coeff.	SE	95% CI	*p*
AC (*X*)	a_1 →	.345	.039	.268, .422	†	c'_1 →	.393	.035	.325, .461	†
ECB (*M*)						b_1 →	.183	.029	.126, .241	†
Regions (*W*)	a_2 →	-.018	.010	-.038, .001	.068	c'_2 →	.027	.009	.010, .043	***
X X *W*	a_3 →	.280	.079	.126, .434	†	c'_3 →	-.041	.070	-.177, .096	.559
M X *W*						b_2 →	.062	.058	-.053, .176	.291
Constant	i_M →	-.002	.005	-.012, .008	.666	i_Y →	.763	.004	.755, .771	†
		R^2 = 0.102 $F(3, 845) = 31.990$, $p < .000$					R^2 = 0.234 $F(5, 843) = 51.445$, $p < .000$			

* $p < .05$, *** < .005, † < .001

Discussion

Relation between knowledge and responsibility

Female students achieved higher mean values than males for three factors: cognition of environmental issues, awareness of consequences, and ascription of responsibility (CEI: males 72%, females 78%, $p < .01$; AC: males 72%, females 74%, $p < .005$; AR: males 71%, females 74%, $p < .000$) and reported a strong estimate of CEI to AR than males (unstandardized coefficient of males $B_m = 0.75$, females $B_f = 1.42$, $p < .01$). One possible reason for the females' better cognitive performance may be that one of the private girls' junior high schools has excellent academic performance in the Kansai area (western Japan) and participated in this survey. Although this girls' school has not implemented energy education, the students achieved the highest mean score on the cognitive subscale among six schools (44.3%, overall mean value is 39.5%, Table 1), and there was a significant difference on the cognitive subscale between the overall mean and five schools excluding the girls' school (overall: 39.5%, without girls' school: 37.9%, $p < .01$). Thus, the students of the private girls' school may have raised the overall females' performance in the cognitive domain to be greater than that of male students. However, this school does not affect the attitude and behavioral subscales and has little effect on the energy literacy structural model (the model fitness indices for the energy literacy model when the girls' school (N = 330) was eliminated: GFI = .941, AGFI = .928, SRMR = .050, RMSEA = .042, NFI = .823, and CFI = .879).

The moderation analysis found that the conditional direct effect of CEI predicted a stronger AR for males than females (males $b_m = 0.14$, $t(1310) = 9.30$, $p < .000$; females $b_f = 0.10$, $t(1310) = 7.83$, $p < .000$). On the other hand, when the girls' school was eliminated, the coefficient of interaction was not significant (p = .065), and the conditional direct effect of CEI predicted a stronger AR for males than females (males $b_m = 0.14$, $t(986) = 9.45$, $p < .000$; females $b_f = 0.10$, $t(986) = 6.43$, $p < .000$).

Although Gambro and Switzky (1999) suggested that the number of science classes taken would contribute to the level of high school students' knowledge about environmental issues, there is no difference in the number of science class taken among genders in the compulsory education curriculum in lower secondary schools in Japan. Comparing each observed variable in CEI and AR by gender, females scored significantly higher than males for three question items: No. 42 (the best reason to buy an appliance labeled "energy efficient" $p < .005$), No. 7 (My energy-use contributes no difference to energy problems, $p < .000$), and No. 15 (No worries about saving energy because new technologies solve the problems, $p < .05$), but others were not significant (Reason for global warming; Easing strict laws for environmental protection; No worries about turning off the lights in the classroom). Since the results cannot find a characteristic tendency among genders, it is difficult to assume the reason for the males' effect in the moderated mediation model with limited information. However, it is noted that an interaction between the cognition of environmental issues and gender on the ascription of responsibility was found. Moreover, in this case, the magnitude of the effect of gender did not necessarily depend on the amount of knowledge of E/E issues.

Relation between responsibility and energy-saving behavior

We found a negative effect of the ascription of responsibility on energy-saving behavior through energy-use conscious behavior in the energy literacy model. Even though students feel responsibility to energy saving on a conceptual basis, if an individual may not know or understand that his/her behavior contributes to solve some of the global E/E problems, he/she may ignore or underestimate energy-use consciousness in everyday life. In fact, only 49% students opposed the idea of question item No. 7 in AR, which is "My energy use contributes no difference to energy problems facing our nation." The relation between the ascription of responsibility and energy-use conscious behavior may become positive when it is consistent with social norms and pressures, and students feel responsible for and are aware of the adverse consequences for future society (van Riper & Kyle, 2014). It may be said that lower secondary students in Japan do not necessarily recognize the needs for urgency and importance in addressing global E/E issues.

In this mediation model, we also found that the lower grades predicted ESB by ECB stronger than 9th graders (unstandardized coefficient of ECB to ESB: 7th grade 1.29, 8th grade 0.57, 9th grade 0.38; $p < .01$). This was supported by a moderation analysis that the conditional indirect effect of the ascription of responsibility on energy-saving behavior through energy-use conscious behavior seems to decrease with grade progression. When the girls' school of excellent performance was eliminated, the coefficient of interaction was not significant ($p = .317$), and the conditional indirect effect of AR predicted a stronger negative ESB through ECB for the 9th graders compared to the 8th graders (8th grade: $b_{8th} = -0.034$, $t(986)$, 95% $CI = -0.064$ to -0.007; 9th grade: $b_{9th} = -0.046$, $t(986)$, 95% $CI = -0.084$ to -0.015). It is noted that the students who indicated a higher responsibility would perform energy saving somewhat unconsciously. It might be said the habit of energy-saving behavior, which is often formed partially by home or school discipline or unconscious actions for energy conservation (Van Raaij & Verhallen, 1983), such as turning off lights in unoccupied rooms or turning off the water while showering during shampooing. Habits also play an important role in daily energy use (Hayabuchi, 2008; Lutzenhiser, 1993); however, a habitual behavior is difficult to change (Van Raaij & Verhallen, 1983). Hence, it would be better to form proper energy conservation habits during childhood.

The reason why the indirect effect of the ascription of responsibility on energy-saving behavior through energy-use conscious behavior decreases with grade progression can be considered that as students grow, a habit is more fixed in everyday life and they use energy unconsciously. Despite the fact that Japan has a low self-sufficiency regarding natural resources and energy, only 13% of students know that Japan is almost 100% dependent on imported energy resources and so do 15% of adults according to a JAERO survey (2017, p. 67). Furthermore, only 39% of adults worry about the depletion of fossil resources or oil shock (JAERO, p. 115). This is because we have hardly experienced serious energy-related difficulties, even though most nuclear power plants have been shut down since the nuclear accident in Fukushima, 2011. The regional electricity supply is stable, has few blackouts, is quickly back up, and is always restored to support our daily lives. Therefore, even if the student feels responsible for an E/E problem, they can perform a pro-environmental habitual behavior without specific consciousness for energy use. Gradually, this tendency would become trivial with grade progression because the students' interests will diversify toward the future.

Although it is difficult to maintain consciousness about energy use in daily life, as Zografakis et al. (2008) proposed that energy awareness is formed during childhood, family discussion about energy-related issues is more likely to impact students' energy literacy (see Table 1). Therefore, the earlier implementation of energy education regardless formal or informal, which improves students' awareness and values for solving energy-related issues and leads to favorable habits for energy conservation, would be recommended.

Relations between knowledge, awareness of consequences, and energy-saving behavior

Despite the fact that knowledge relevant to E/E issues may be a critical component for deriving personal values, beliefs, attitudes toward energy-saving behavior and making a favorable decision for energy-related issues, the lack of a correlation between knowledge and behavior has been frequently reported (e.g., Ajzen et al., 2011; Chen, S. et al., 2015; DeWaters & Powers, 2011; Hu et al., 2013; Lee et al., 2013). In the TPB, the most substantial information about behavioral determinants is contained in a person's behavioral, normative, and control beliefs (Ajzen, 2011a). Knowledge is one of the background factors that may impact the beliefs people hold, and it is expected to affect the intent to act and behavior indirectly (Ajzen, 2011a, 2017). The VBN Theory assumes the relations between a person's values, environmental beliefs, and behavior, which is directly determined by personal norms to be activated by the ascription of responsibility and the awareness of consequences (Klöckner, 2013). If it can be considered that knowledge impacts one's values, which in turn forms one's beliefs, "energy-use conscious behavior" in the energy literacy model might be discussed as a behavior with personal norms activated by the awareness of consequences. On the basis of this idea, our energy literacy model can support the fact that E/E knowledge predicts energy-saving behavior through energy-use conscious behavior by being concerned about the adverse consequences of ongoing energy-related problems.

Even though indirect experiences such as school learning about E/E issues do not impact behavior directly (Kollmuss & Agyeman 2002; Rajecki, 1982), behavioral change requires knowledge contributions to modify values and beliefs to behavior (Hines et al., 1987; Kollmuss & Agyeman, 2002; Roy et al., 2012). Knowledge about the adverse consequences of ongoing energy-related problems may touch students' emotions, stimulate resonance, and inspire and foster their understanding of E/E issues (Anable, Lane & Kelay, 2006). A corpus of knowledge, which was identified by Anable et al.—the facts of the issue, the causes and effects of the issue, its urgency and importance, and the individual contribution to a behavioral change—may be effective for improving students' awareness of the current E/E situation. Furthermore, "knowledge of the impact of behavioral changes" is also needed to learn the basic principles of energy to make rational behavioral choices (Cotton, Miller, Winter, Bailey & Sterling, 2015).

Relation between region and energy-saving behavior

We found a conditional indirect effect of the awareness of consequences on energy-saving behavior through energy-use conscious behavior for the region (Fukushima and Tokyo). Although identifying the cause of the decrease in the interaction effect for Fukushima might be difficult, at least two points of view can be discussed. First, regarding the National Educational Achievement Test in Japan, Fukushima represented the lowest performance among regions where we conducted the energy literacy assessment, and it has not varied since the year before the disasters (MEMORVA, 2010-2015). In fact, students in Fukushima scored significantly less than students in Tokyo on all subscales (see Table 1). Second, an economically, socially, and educationally disadvantaged region may lower the level of community environmental activeness (Parisi, Taquino, Grice & Gill, 2004). After the Great East Japan Earthquake and Tsunami and the nuclear power plant accident occurred in March 2011, a large number of people moved in and out of Koriyama City where the school was located to evacuate from the radioactively contaminated area. Although this phenomenon has converged since 2013, the population of person's ages 13 to 15 in Koriyama has been decreasing compared with the year before the disasters (Koriyama City, 2015, 2015a). Although Koriyama City was not designated as an evacuation zone due to radioactive contamination, students' circumstances were dramatically changed by the evacuees from the disasters and the nuclear accident. We should take account of the deterioration in educational circumstances through serious social situations and students' unstable and inconvenient everyday lives.

On the other hand, students in Tokyo experienced planned power outages after the disasters to avoid massive blackouts in its service area, which affect economic and industrial activities as well as various aspects of daily lives. Energy and power savings were often discussed in mass media and schools and at home. In fact, the planned power outage in the early morning of March 14 was postponed owing to the prospect of lower-than-expected demand due to people's electricity saving (JAPAN TODAY, 2011). As an intriguing fact to support this, over 90% of the participants in this survey reported that their parents had talked about the discipline of energy and power savings before graduating elementary school. Although we could not find an interaction effect for family discussion about energy-related issues in the energy literacy model, it cannot be denied that it may implicitly have turned into a regional effect for Tokyo, where students experienced strict energy saving for the planned blackouts. Some possible reasons for the differences between the students in Fukushima and Tokyo can be discussed, which are the disadvantages in daily life due to the natural disasters and nuclear accident, the low academic performance in Fukushima, and the extraordinary experience of energy savings in Tokyo.

According to a recent study in Taiwan, secondary students in a southern region that frequently experiences natural disasters scored higher on energy-conservation-related attitudes and practices than students in a northern urban area that does not directly suffer from environmental disasters in an advanced infrastructure (Chen, K. et al., 2015). Such direct experiences have a stronger impact on people's behavior than indirect experiences (Rajecki, 1982), and personal experiences could foster a student's long-term environmental concerns (Chawla, 1999). Moreover, the impact of natural disasters can be employed as teaching materials in schools since students may be aware of E/E issues more closely. In fact, the students of six high schools in Fukushima published their research about the measurement and comparison of individual external doses of high school students living in Japan, France, Poland, and Belarus. They found that the individual external doses in areas where people are allowed to live in Fukushima prefecture and Belarus are within the range of the estimated annual doses of the terrestrial background radiation level of other regions they surveyed (Adachi et al., 2016). Although there must be hardships for students in Fukushima, their personal experiences, proper teaching materials, and timely educational approaches would help to enhance students' awareness of E/E issues.

The Information Center for Energy and Environment Education (Japan) presents the aim of energy environmental education: developing an in-depth understanding of E/E issues through various activities relevant to energy and the environment and cultivating and fostering fundamental knowledge, skills, awareness to contribute to solving energy-related issues with proactive attitudes and appropriate actions (ICEEE, 2013). To foster students' energy literacy within a limited given time for energy education, our energy literacy model is effective for developing energy education content that take account of a student's conceptual structure of energy-relevant knowledge, attitudes, and energy-saving behavior.

Limitations

There are at least three limitations that should be acknowledged in this study. First, only one-third of the observed variables out of all variables were extracted by a factor analysis to constitute the energy literacy model. Other predictors in TPB and VBN Theory, i.e., the subjective norms, perceived behavioral control, personal norms, and new ecological paradigm for exploring a world view or the value of the environment (Dunlap, Van Liere, Mertig, & Jones, 2000; Stern et al., 1995, 1999) were not distinguished in this study. To specify the causal structure of energy literacy more realistically and practically, it is also necessary to focus on normative factors. Second, our results do not assume that energy education has been applied to all students equally. As mentioned in the introduction, an interdisciplinary holistic energy education curriculum has yet not been made compulsory in Japan. Therefore, we did not compare the contents and frequency of energy education. Last, this survey has been accomplished by the contribution of teachers who appreciated that energy literacy assessment is important in spite of the controversy over nuclear energy since the severe nuclear accident occurred. To clarify the relationship between the attributes and energy literacy, further investigation will be required.

Conclusion

By employing and modifying the energy literacy framework and instrument developed by DeWaters & Powers (2013), energy literacy and its conceptual structure model of students in Japan were investigated through a survey of 1316 lower secondary students (ages 13–15) in 2014.

An energy literacy assessment indicated that female students scored higher than males on the cognitive and self-efficacy subscales. The 8th and 9th graders scored higher than the 7th graders on the cognitive subscale, and on the affective subscale, the 9th graders scored higher than the 7th graders. There was no significant difference on behavioral subscale. From a regional comparison, students in Fukushima scored the lowest on all subscales among the surveyed regions: Tokyo and the western regions (Kyoto and Nagasaki). Students who have a discussion of energy-related issues with their family scored significantly higher than their counterparts on all subscales. The intercorrelation between the affective and behavioral subscales was rather close, whereas there was little correlation between knowledge and behavior.

Referring to the TPB and VBN Theory, we examined an energy literacy structure model. Six predictors were extracted to interpret the energy literacy structure model, where "energy-saving behavior" is predicted by both "awareness of consequences" and "ascription of responsibility," which are supported by "cognition of environmental issues" based on "basic energy knowledge." The relatively higher knowledge of energy and the environment predicted a strong positive effect on "ascription of responsibility" than "awareness of consequences." However, it is interesting that the negative effect of "ascription of responsibility" on "energy-saving behavior" mediated by "energy-use conscious behavior" was observed. Even though students feel responsibility to energy saving on a conceptual basis, they are likely to ignore or underestimate energy-use consciousness in daily life if they do not know that the contributions of their behaviors are important and urgent to solve energy and environmental issues. In contrast, the positive effect of "awareness of consequences" predicts "energy-saving behavior" through "energy-use conscious behavior." Thus, "awareness of consequences" plays the role of bonding between energy-relevant knowledge and energy-saving behavior. A moderation analysis found that (1) the direct effect of the cognition of environmental issues on responsibility depends on the gender, and the magnitude of its effect did not necessarily depend on the amount of knowledge; (2) the indirect effect of responsibility toward energy-related issues on energy-saving behavior through energy-use conscious behavior seems to decrease with grade progression; and (3) the indirect effect of the awareness of consequences on energy-saving behavior through energy-use conscious behavior depends on the region.

Acknowledgments

The authors would like to express deep appreciation to school teachers, students and others who cooperated with this survey, and especially, to Dr. J. E. DeWaters who provided the invaluable data, papers, and advices for this study.

Disclosure statement

The Authors reported that no competing financial interest.

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Appendix

18 Additional Question Items to DeWaters' Instrument (2013b)

Cognitive subscale	
43	The percentage of our energy consumption depends on imported energy resources
46	Correct description about methane hydrate development in our country
47 *	Correct description about the CO_2 emission increasing which causes global warming
51	Incorrect description about radiation
52	The sector that consume oil MOST in Japan
59	Correct description about explanation of energy
61	Correct meaning about oil depletion
65	Incorrect description about nuclear power plant operating safely
69	Correct description about energy resources development alternative to fossil fuels
73	Appropriate description about energy choice in Japan
74 *	The MOST appropriate description about the environmental impact by energy resource development and use
75 *	Correct description about petroleum that Japan consumes most
76	Appropriate description about abandoning nuclear power in Japan
77	Appropriate description about renewable and nonrenewable energy
Affective subscale	
14	Reality of daily life burden by strict energy saving
23	Need for the Energy-best-mix policy including development of both nuclear power and renewable energy for Japan which is energy insufficient country
Behavior subscale	
29	Change own idea if I understand the energy choice for sustainable society
32	Agree to the policy balanced among economic and industrial activity and renewable energy development

* Variables which were extracted by factor analysis for energy literacy model