



## An Integrated Model Approach: Exploring the Energy Literacy and Values of Lower Secondary Students in Japan \*

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**Abstract:** Energy literacy is a minimum required capacity for developing a sustainable society that participates in and discusses on energy and environmental (EE) issues. Understanding the energy literacy structure is of significant importance for providing effective energy education to promote people's awareness of EE issues. In this article, an energy literacy structural model integrated with the Theory of Planned Behavior and Value-Belief-Norm Theory was investigated for 1070 lower secondary students (ages 13-15) in Japan. Structural equation modeling uncovered that the awareness of consequences is the most powerful predictor for the causality between basic energy knowledge and energy-saving behavior through the attitude toward the energy-saving behavior. A conditional process analysis elucidated that (1) the conditional effect of basic energy knowledge on the awareness of consequences depends on scientific literacy, critical thinking ability, and environmental worldview, and (2) the conditional direct and indirect effects in the mediation model of awareness of consequences on the attitude toward energy-saving behavior through the ascription of responsibility depend on environmental worldview or values and family discussion of energy-related issues. The energy literacy model proposed provides a theoretical contribution to the development of an effective energy education program.

**Keywords:** *Theory of planned behavior, value-belief-norm theory, structural equation modeling, conditional process analysis.*

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### Introduction

It is necessary for human society to perceive the irreversible threat of climate change and make efforts to reduce greenhouse gases emissions through international cooperation (COP21). A solution to the energy and environmental (EE) issues depends on technology development, policy administration, and public participation. One of the greatest potential resources for meeting the global energy challenges is the citizens' energy literacy (DeWaters and Powers, 2011; DOE). DeWaters & Powers (2007, 2013) have defined energy literacy in terms of three domains: cognitive (knowledge), affective (attitudes and values), and behavioral. It is hypothesized that energy-literate citizens choose appropriate energy-related behaviors in daily life to pursue a more sustainable society.

Energy literacy is fostered and improved by formal and informal energy education (DOE). Energy education aims at cultivating a well-informed public with positive attitudes and behaviors toward global EE issues. To fulfill the goal of energy education, the status of people's knowledge, attitudes, and behavior that are relevant to the EE issues is of paramount importance. Many studies on energy literacy have reported little correlation between EE knowledge and energy-saving behavior (e.g., Ajzen, Joyce, Sheikh & Cote, 2011; Chen, Chou, Yen & Chao, 2015; Craig & Allen, 2015; DeWaters & Powers, 2011; Hu, Horng, Teng & Yen, 2013; Jurin & Fox-Parrish, 2008; Lee, Lee, Altschuld & Pan, 2015). The amount of knowledge does not alone lead to the altering of people's behaviors and lifestyles toward energy-saving, nor does it affect the attitude-behavioral consistency (e.g., Gifford & Nilsson, 2014; Leeuw, Valois, Ajzen & Schmidt, 2015; Ntona, Arabatzis & Kyriakopoulos, 2015; Stern, 2011).

However, knowledge is an important factor in overcoming psychological barriers, such as ignorance and misinformation, and making decisions to act. Its role is potentially complex, but necessary for successful action (e.g., Duerden & Witt, 2010; Frick, Kaiser, & Wilson, 2004; Gifford & Nilsson, 2014; Kaiser & Fuhrer, 2003; Levine & Strube, 2012; Ronis & Kaiser, 1989). Even if relevant EE knowledge does not directly affect a specific energy-saving behavior, it may implicitly facilitate a given behavior through mediators, such as beliefs or confidence (Ronis & Kaiser, 1989). Earlier studies suggested that a large amount of knowledge induces pro-environmental intentions and behaviors (e.g., Davidson, Yantis, Norwood, & Montano, 1985; Kallgren & Wood, 1986). Hungerford & Volk (1990) assumed a simple linear model in which increasing knowledge induces positive pro-environmental behavior by activating a person's

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awareness and responsibility toward environmental issues. Many researchers have claimed that this simple linear model is insufficient, and more complex relationships between knowledge and behavior have been discussed (e.g., Hu et al., 2013; Jensen, 2008; Kollmuss & Agyeman, 2002; Teksoz, Sahin, & Tekkaya-Oztekin, 2011). Fabrigar, Petty, Smith & Crites (2006) have discussed that, while the amount of knowledge does not affect attitude-behavioral consistency, people consider the relevance of the dimensional complexity of the knowledge that underlies their attitudes and behavior before deciding to act. Because people's attitudes, intentions, and behaviors are consistent with their beliefs, which reflect the information that they hold, knowledge is one of the background factors that influences a person's beliefs (Ajzen, 2011). Although knowledge plays an inevitable role in energy literacy, the informative causality between knowledge and behavior has not been uncovered.

To improve the understanding of the relationship among knowledge, attitudes, and behaviors in energy literacy and to identify the elements that should be emphasized in energy education, the conceptual structure of energy literacy should be examined. Recently, authors have constructed an energy literacy conceptual model for lower secondary students in Japan by employing an exploratory factor analysis (EFA) approach based on the Theory of Planned Behavior (TPB: Ajzen, 1991, 2006) and the Value-Belief-Norm Theory (VBN: Stern, Dietz, Abel, Guagnano, & Kalof, 1999; Stern, 2000), and investigated the relationship between knowledge and behavior (Akitsu, Ishihara, Okumura & Yamasue, 2017). It has been discovered that basic EE knowledge predicts energy-saving behavior by mediating the awareness of adverse consequences of toward values or valued objects. An EFA can contribute to the formulation of a useful strategy for model specification in cases in which a substantive theoretical model has not been defined. The energy literacy conceptual model that was developed in previous work requires further investigation to explore the relation between students' behavioral intentions and their EE knowledge, by incorporating attitude-behavioral factors, belief and normative factors. It is expected that these factors, which are not extracted by the EFA, can be clearly assessed by employing a hypothesis model approach. The hypothesis model approach can be adapted from both the TPB and VBN, which have been verified in social psychology studies in last decades. Thus, it is of paramount importance to construct the energy literacy structural model by employing the hypothesis model approach.

Finally, it is often of significant interest to determine whether a constant causal effect is maintained across different groups, contexts, and values of the independent variable (Preacher, Rucker & Hayes, 2007). By employing a conditional process analysis, this paper examines six attributes, which are gender, school year grade, energy education experience, energy-related facility tour experience, home discipline in energy saving, and family discussion about energy issues. Furthermore, scientific literacy, critical thinking ability, and environmental literacy are evaluated to examine their influences on the model because these aspects are vitally associated with the concept of energy literacy (DeWaters & Powers, 2013). This may potentially assist in providing informative insights from the perspective of people's knowledge, attitudes, and behaviors regarding EE issues.

### *Objectives*

Considering the aforementioned perspectives, the objectives of this paper are (1) to propose the energy literacy structural model by employing the hypothesis model approach, (2) to examine the causal relationship between basic energy knowledge and energy-saving behavior, and (3) to analyze the interactions of moderators in the model.

### *Hypothesis model*

The TPB and VBN are the most commonly used models for understanding the causal relationships among people's beliefs, norms, attitudes, and behaviors. The TPB focuses on external influences (subjective norms), while the VBN focuses on internal normative factors (personal norms) (Anable et al., 2006). Furthermore, the TPB explains the personal usefulness of a given behavior, including the intention, which is predicted by perceived control over behavior, whereas the VBN emphasizes the benefit to others (altruism) over self-interest. The TPB and VBN can be applied to the energy literacy model. From the theoretical and practical perspectives, while keeping the existing model framework, extension based on the two theories would help in interpreting the energy literacy structure to identify the potentiality and validity of the components (e.g., Klöckner & Blöbaum, 2010, 2013). In the following sections, first, the theories are separately introduced and applied to the concept of energy literacy. Then, the extended hypothesis model for the energy literacy structure is proposed based on the specified variables and their relations.

### *Theory of Planned Behavior (TPB)*

According to the TPB, a person's behavior is driven by the intention to act (INT). The INT is determined by the person's attitudes toward the behavior (ATB), subjective norms (SNs), and perceived behavioral control (PBC). The TPB is a good model for understanding pro-environmental behavior (e.g., Bamberg & Schmidt, 2003; Kaiser, Hübner & Bogner, 2005) and energy-saving behavior. The theoretical model of energy-saving behavior (ESB) from the TPB is presented in Figure 1. The ATB is determined by the behavioral beliefs and the evaluation of the behavioral outcome or attributes (Ajzen, Homepage). When students perform ESBs according to their beliefs to contribute to an energy solution or environment protection, positive and preferable ATBs have been formed in advance (Leeuw et al., 2015). The SNs are perceptions of social expectations and pressures regarding actions that an individual's valuable referents think that they should perform. Students' preferable energy-saving behaviors may result from the expectations of important or

trusted people. The PBC is a perception of a person's ability and opportunities for behavioral control, which is affected by the presence of factors that promote or hamper a given behavior (Ajzen, Homepage). Even if students are willing to perform energy-saving behaviors, it may be possible that they do not know what to do or an interference factor prevents them from carrying out the actions.

On the other hand, as Klöckner (2013) pointed out that the TPB's constructs depend on subjective recognitions, which means that the perceived control is not necessarily identified by the objective or actual control what people have, and the subjective norm does not necessarily echo what others actually expect. Furthermore, behaviors relevant energy and the environment belong to the moral dimension, in other words, it is not only determined by self-interest described in the TPB but also by altruistic beliefs about what is right or wrong for others and society (Klöckner, 2013; Thøgersen; 1996). In particular, when addressing long-term social issues such as energy and the environment where the outcomes of individual actions and efforts cannot reflect immediately, moral values may be important factors than personal interest evaluation as described in the TPB.

Anable, Lane, & Kelay (2006) pointed out that beliefs are 'the ultimate determinants' in the TPB framework, which are influenced by person's values and depend on knowledge, facts and things people believe. Although knowledge may be useful in evaluating which beliefs are more salient and valuable, the TPB will help explain that knowledge alone does not necessarily lead to behavioral changes (Anable et al., 2006). On the basis of this idea, basic energy knowledge is considered one of the most important factors in determining beliefs in ATBs. Therefore, according to the TPB, knowledge is assumed to be an antecedent of the ATBs (Levine & Strube, 2012).

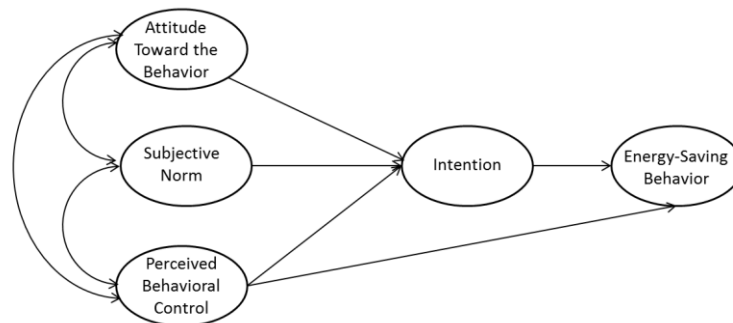


Figure 1. Energy-saving behavioral model in which the Theory of Planned Behavior is applied (Ajzen, 1991).

#### Value-Belief-Norm Theory (VBN)

The VBN is an extended model of Norm-Activation Theory (NAT: Schwartz, 1977) which focuses on the relations among personal values, moral [personal] norms, and pro-environmental behavior that is determined by social motivation. Stern et al. (1999) modified the NAT to obtain a causal model in which pro-environmental behavior is predicted by personal norms (PNs) that are activated by the ascription of responsibility (AR) and the awareness of consequences (AC). The AC is connected to the person's environmental worldview, which is assessed by the new ecological paradigm (NEP: Dunlap, Van Liere, Mertig & Jones, 2000). The NEP is related to general values: altruistic values, egoistic values, traditional values, and values regarding openness to changes. When people's behaviors are consistent with their beliefs, which reflect values that are based on the knowledge that they have, the energy-saving behavior model that is adapted from the VBN can be applied, which is presented in Figure 2. It is assumed that the ESB is predicted by the PN through the AR and AC, which are activated by the basic energy knowledge.

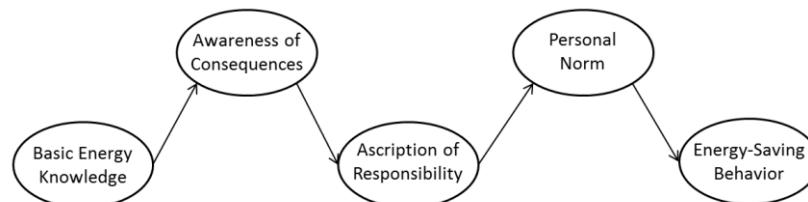


Figure 2. Structure of energy-saving behavior, as predicted by basic energy knowledge by applying the Value-Belief-Norm Theory (Stern et al, 1999, 2000).

*Hypothesis model integrated with the TPB and the VBN*

A normative aspect has been considered in the TPB. The PN is often examined in relation to pro-environmental behaviors, which have many underlying factors (Harland, Staats, & Wilke, 1999); thus, it may be more general than the ATB (e.g., Botetzagias, Dima, & Malesios, 2015; Chan & Bishop, 2013; Kaiser et al., 2005). As Klöckner (2013) concludes from his meta-analysis research, if each behavior is in line with personal values, parts of the impacts of personal norms on intentions to act are mediated by attitudes. Therefore, when assuming that knowledge contributes to modifying attitudes and values toward behavioral changes (Hines, Hungerford & Tomera, 1987; Kollmuss & Agyeman, 2002; Roy, Dowd, Muller, Pal & Prata, 2012), it can be considered that the VBN model that is predicted by the basic energy knowledge is antecedent to the attitude toward the behavior in the TPB in the configuration of the energy literacy model. Knowledge that is relevant to EE issues ignites students' interests, touches their emotions, stimulates their awareness and responsibility toward EE problems, and cultivates their norm (Anable et al., 2006). The energy literacy that we consider is not just knowledge, but through energy education, we expect that students who have learned and known the current situation regarding energy-related issues (BEK) may be stimulated and form values, beliefs, and norms (AC, AR, PN). These experiences may yield attitudes toward the proper behavior for solving energy-related issues (ATB) which derives the intention to act, and it will reflect to their behaviors of consuming in everyday life, selecting appliances and services, and voting towards energy policies. Hence, while taking advantages of characteristics of each model, the hypothesis model which is integrated both the "personal interest aspect" of the TPB and the "social motivation" of the VBN is proposed in Figure 3. The intention toward energy-saving behavior is predicted by the attitude toward the behavior, subjective norm, and perceived behavioral control, and the energy-saving behavior is predicted by independent contributions from the intention and perceived behavioral control. The energy literacy structural model can examine the links among students' relevant EE knowledge, beliefs, norms, attitudes, intentions, and energy-saving behaviors within a single model. It will facilitate the interpretation of relationships between the distal variables, such as knowledge and behavior, by applying mediation variables and the estimation of a target predictor within the same model (Klöckner, 2013).

By using the proposed model, the causal relationship between basic energy knowledge and energy-saving behavior is examined.

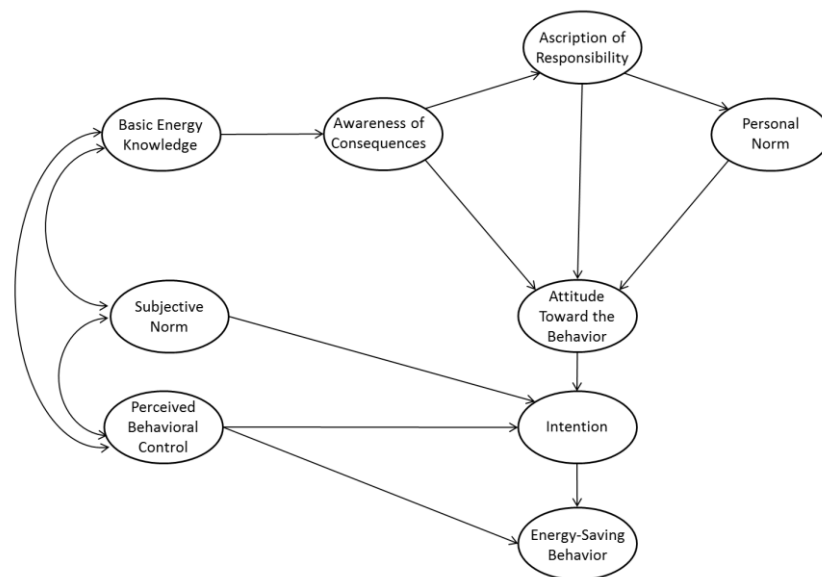


Figure 3. Hypothesis energy literacy model integrated with the Theory of Planned Behavior and The Value-Belief-Norm Theory.

## Materials and Methods

### Sampling

We targeted students who are in lower secondary school because understanding the energy literacy of adolescents, who will affect directly and indirectly future decisions through their energy use, choices, and actions, will give us important information regarding energy education. In July 2016, eight schools participated in this survey. Those were in Fukushima, Fukui, Tokyo (two schools), Kyoto, Osaka (two schools), and Nagasaki prefectures (Figure 4). Schools were selected in wide areas from northeastern to southwestern in Japan.

A written questionnaire was distributed by each teacher in the classroom. Valid responses of 1070 students (60% of the 95% response rate) from the 7th to 9th grades (ages 13-15), without missing values, were analyzed. Distribution of

gender and grade depend on each teacher because number of classes and the school years that teacher is in charge of differ by schools. Furthermore, due to the participation of one private girls' school, the gender distribution of the respondents was 33% male and 67% female.



Figure 4. Locations of participants.

#### *Survey questionnaire and measures*

An energy literacy assessment questionnaire was developed and modified on the basis of our energy literacy survey in 2014 based on the DeWaters et al. work (2013a, 2013b) (Akitsu, Ishihara, Okumura & Yamasue, 2016). In addition, we utilized the measures of TPB and VBN, which were developed in previous studies. All items were shuffled across domains, except a set of items on basic energy knowledge and civic scientific literacy. Question items in each component were combined to produce an overall component score (Ajzen et al., 2011). To avoid a residual covariance among the observed variables and predictors beyond the scales, we analyzed the residual covariance. One of items of residual covariance with largest modification index (MI) was eliminated from the variable constructed with more items than the corresponded variable. After eliminating in the subsequent analysis for reliability and consistency of a set of items, 117 question items were extracted from a set of 133 items. They are composed of nine predictors and of three moderators (civic scientific literacy, critical thinking ability, and the new ecological paradigm). The question items are presented in Appendix 1.

##### *Basic energy knowledge (BEK)*

Students chose one correct answer from five choices for sixteen statements regarding basic energy knowledge, which included five items that were relevant to the cognition of environmental issues (Akitsu et al., 2016; DeWaters, 2013b). After eliminating four items to increase internal consistency (BEK03, 05, 06, and 15), the BEK scale had a 0.76 Cronbach's alpha reliability coefficient.

##### *Awareness of consequences (AC)*

Students rated their responses to nine statements about their awareness of consequences regarding EE issues (Akitsu et al., 2016; DeWaters, 2013b; López-Mosquera, & Sánchez, 2012; Stern et al., 1999). A five-point Likert-type response with bipolar indices (e.g., from strongly disagree/definitely false to strongly agree/definitely true) was designed. After eliminating two items to avoid residual covariance across variables (AC01 (vs. residual for SN), MI 48.9; AC02 (vs. ATB01), MI 127.9), nine items of AC scale with an alpha coefficient of 0.86 were employed.

##### *Ascription of responsibility (AR)*

Students rated their responses to six statements about their responsibility toward EE issues (DeWaters, 2013b; López-Mosquera et al., 2012). A five-point Likert-type response with bipolar indices (e.g., from strongly disagree/hardly worry to strongly agree/always worry) was provided. One item was deleted to avoid residual covariance across variables (AR06 (vs. residual for BEK), MI 31.6), six items of AR scale with a coefficient alpha of 0.73 were utilized.

##### *Personal norms (PN)*

Students rated their responses to four statements about personal norms toward EE issues (López-Mosquera et al., 2012; Stern et al., 1999). A five-point Likert-type response with bipolar indices (e.g., from definitely false/disagree to definitely true/agree) was designed. After eliminating one item to increase internal consistency (PN05), the coefficient alpha for the PN scale was 0.71.

*Attitude toward the behavior (ATB)*

Students rated their responses to six statements about their attitudes towards the energy-saving behavior (Ajzen, Homepage, Homepage 2). A five-point Likert-type response with bipolar indices (e.g., from extremely unimportant/worthless/boring to extremely important/valuable/interesting) was designed. To avoid residual covariance across variables, one item was eliminated (ATB04 (vs. residual for INT), MI 123.9); the ATB scale had a 0.73 Cronbach's alpha value.

*Subjective norm (SN)*

Students rated their levels of agreement with nine statements about the perception of social pressure to engage in energy-saving behaviors (Ajzen, Homepage, Homepage 2). A five-point Likert-type response with bipolar indices (e.g., from definitely false/hardly ever/not at all to definitely true/almost always/very much) was designed. The coefficient alpha for nine items of the SN scale was 0.79.

*Perceived behavioral control (PBC)*

Students rated their levels of agreement with four statements on how easy they think energy-saving behaviors are (Ajzen, Homepage, Homepage 2). A five-point Likert-type response with bipolar indices (e.g., from definitely false/impossible to definitely true/possible) was designed. After deleting two items to increase internal consistency (PBC02 and PBC05) and one item to avoid residual covariance (PBC04 (vs. residual for ATB), MI 86.3), the coefficient alpha for this scale was 0.78.

*Intention (INT)*

Students rated their levels of agreement with four statements about their intentions toward energy-saving behaviors (Ajzen, Homepage, Homepage 2; DeWaters, 2013b). A five-point Likert-type response with bipolar indices (e.g., from extremely unlikely/I definitely will not to extremely likely/I definitely will) was designed. To increase internal consistency, one item was eliminated (INT01). The Cronbach's alpha coefficient for the INT scale was 0.72.

*Energy-saving behavior (ESB)*

Students rated their levels of agreement with eleven statements regarding energy-saving behavior, which included two items on energy-use-conscious behavior that were extracted from our previous energy literacy model (Akitsu et al., 2016; Ajzen, Homepage, Homepage 2; DeWaters, 2013b; Cabinet office, 2009). A five-point Likert-type response with bipolar indices (e.g., from hardly ever/not at all to almost always/very much) was designed. After eliminating one item to increase internal consistency (ESB07), and one for avoiding residual covariance (ESB11 (vs. INT04), MI 99.8) the coefficient alpha for eleven items for the ESB scale was 0.73.

*Moderation variables*

A definition of energy literacy that was established by DeWaters and Powers (2013) was developed based on the concepts of scientific and technological literacy, critical thinking ability, and environmental literacy. It is worthwhile to independently evaluate students' characteristics in terms of these concepts and explore their effects on the energy literacy model. Following three variables were administered as a moderator in conjunction with demographic variables.

*Civic scientific literacy (CSL)*

A sufficient level of civic scientific literacy is required for evaluating new science and technology and their associated policies, and discussing these issues in society (Miller, 1998; Shen, 1975). The concept of civic scientific literacy differs essentially from practical science literacy: acquisition of scientific information is not the same as familiarity with science and awareness of its implications (Shen, 1975). Miller (1983, 1998) suggested a minimal threshold for civic scientific literacy, which consisted of the following: (1) a basic vocabulary of scientific terms and concepts for reading daily information, (2) an understanding of the processes and methods of science, and (3) an awareness of the impacts of science and technology on individuals and society. In modern industrial societies, sound democracy depends on a scientifically literate citizenry (Durant, Evans, & Thomas, 1992). Students' civic scientific literacy was measured by eighteen items, which consisted of twelve items from Kawamoto, Nakayama & Saijo (2008); Miller (1998); NISTEP (2001), and six from Kusumi & Hirayama (2013) and Mun, Lee, Kim, Choi, Choi & Krajcik (2015). The response options were set to "True," "False," and "Do not know" The Cronbach's alpha coefficient for the CSL scale was 0.75.

*Critical thinking ability (CTA)*

For obtaining objective facts from media messages; considering, analyzing, and evaluating information; and understanding facts as well as possible (e.g., Ennis, 1986; European commission, 2011; Hobbs, 2008; ICAT), critical thinking ability is indispensable in modern society. Ennis (1986) defined critical thinking as "reasonable reflective thinking that is focused on deciding what to believe or do". It is an intellectually disciplined process of conceptualizing, analyzing, and evaluating information as a guide for belief and action (ICAT). Glaser (1941) stated that "critical thinking needs a persistent effort to examine any belief or supposed form of knowledge in the light of the evidence that supports it and the further conclusions to which it tends." To assess the critical thinking ability of Japanese students, we adopted

twenty-two items regarding “logical thinking”, “inquiring mind”, “objectivity”, and “evidence-based judgement”, which were employed in the study of Hirayama & Kusumi (2004). Students provided five-point Likert-type responses with bipolar indices (e.g., from hardly ever/not at all to almost always/very much). The coefficient alpha for the CTA scale was 0.87.

#### *New ecological paradigm (NEP)*

UNESCO defined environmental literacy as a “basic functional education for all people, which provides them with the elementary knowledge, skills, and motives to cope with environmental needs and contribute to sustainable development” (UNESCO, 1989). The existing environmental paradigm was revised by Dunlap et al. (2000) to produce the new ecological paradigm, which is a comprehensive pro-ecological worldview. In the new ecological paradigm, groups with pro-ecology worldviews, beliefs, and concerns for the environment can be identified. Since the space of the questionnaire was limited, eight question items were implemented by adopting the suggestions of previous studies (Cordano, Welcomer, & Shere, 2003; López-Mosquera & Sánchez, 2012). Students provided five-point Likert-type responses with bipolar indices (e.g., from extremely disagree to extremely agree). After eliminating one item to increase internal consistency, that is “the earth has plenty of natural resources if we just learn how to develop them,” the coefficient alpha for the NEP scale was 0.71.

#### *Demographic variables*

A subgroup of six attributes was evaluated as a moderator that are likely to affect the energy literacy model: gender, school year grade (7<sup>th</sup>, 8<sup>th</sup>, and 9<sup>th</sup>), energy education experience (Yes/No), energy-related facility tour experience (Yes/No), home discipline in energy-saving (Yes/No), and family discussions of energy-related issues (five-point bipolar adjective scale).

A summary of twelve components, their abbreviations, numbers of items and reliability is shown in Table 1. The Cronbach’s alpha value ranged from 0.71 to 0.87 which indicated better internal consistency relative to our previous energy literacy conceptual model constructed by an exploratory factor analysis approach (with values ranging from 0.52 to 0.70, Akitsu et al., 2017). Cronbach’s alpha values is usually acceptable 0.70 and above (Nunnally, 1978), and as low as 0.60 for a set of items in educational assessment scales is employed (Linn and Gronlund, 1995; Qaqish, 2005).

*Table 1. Components, their Abbreviations, Numbers of Items, and Cronbach’s alpha values for Energy Literacy Assessment*

	Predictors	Abb.	Number of item Selected / Original	Cronbach’s $\alpha$ values
1	Basic energy knowledge	BEK	16 / 20	0.756
2	Awareness of consequences	AC	9 / 11	0.860
3	Ascription of responsibility	AR	6 / 7	0.735
4	Personal norm	PN	4 / 5	0.710
5	Attitude toward the behavior	ATB	6 / 7	0.734
6	Subjective norm	SN	9 / 9	0.793
7	Perceived behavior control	PBC	4 / 7	0.784
8	Intention	INT	4 / 5	0.722
9	Energy-saving behavior	ESB	11 / 13	0.727
10	Civic scientific literacy	CSL	18 / 18	0.751
11	Critical thinking ability	CTA	22 / 22	0.870
12	New ecological paradigm	NEP	8 / 9	0.711
			117 / 133	

## **Statistical Analyses**

#### *Overall energy literacy assessment*

Item responses to the basic energy knowledge were allocated one point for each correct response and zero points for each incorrect response. In civic scientific literacy, items were allocated one point for each correct response and zero points for incorrect and “Do not know” responses. Five-point Likert-type responses to the AC, AR, PN, ATB, SN, PBC, INT, ESB, CTA, and NEP were converted into numerical scores, which ranged from one point (least preferred response) to five points (most preferred response), according to predetermined preferable answers for this study. To simplify the comparison, a common scale between components was used: the total score for each component was converted into a percentage of the maximum attained score. As a result of examining normality by the Kolmogorov-Smirnov Test, all components were not normal. Therefore, subgroups were compared by using nonparametric statistical analysis. Mean values between subgroups were compared by the Mann-Whitney *U* Test and Kruskal-Wallis Test for multiple comparisons. The inter-correlations between the predictors were evaluated with the nonparametric Spearman’s rank correlation ( $\rho$ ).

Energy literacy structural modeling

Structural equation modeling with maximum likelihood estimation was employed to test whether the hypothesis energy literacy model fits the data and estimate the magnitude and relation among the predictors. A confirmatory factor analysis was carried out to test the hypothesis model to ensure the reliability and validity of the measures that were used in this survey. To evaluate the model fitness, the goodness-of-fit index (GFI), the adjusted goodness-of-fit index (AGFI), the normed-fit index (NFI), and the comparative fit index (CFI) were examined, which were expected to be larger than 0.95 for good model interpretation. The standardized root mean squared residual (SRMR) was expected to be less than 0.05, and the root mean square error of approximation (RMSEA) of less than 0.08 was deemed acceptable (Browne & Cudeck, 1993; Hooper, Coughlan, & Mullen, 2008), on the other hand, the Akaike information criterion (AIC) was utilized to estimate the validity of each model for selection.

Conditional process analysis

To determine whether the boundary conditions affect the strength or direction of the causal effect of a predictor for an outcome, we employed a conditional process analysis (Hayes, 2013). Figure 5 presents the conceptual diagram (left) and statistical diagram (right) for the simple moderation model moderated by  $M$  (panel A), and for the mediation model which is assumed all three paths are moderated by a common moderator  $W$  (panel B). In panel A, the conditional effect of  $X$  on  $Y$  is calculated by Eq. 1, and in panel B, the conditional indirect and direct effects of  $X$  on  $Y$  are calculated by Eq. 2 and Eq. 3, respectively.



Conditional effect of  $X$  on  $Y = b_1 + b_3M$  (1)



Conditional indirect effect of  $X$  on  $Y$  through  $M = (a_1 + a_3W)(b_1 + b_2W)$  (2)

Conditional direct effect of  $X$  on  $Y = c'_1 + c'_3W$  (3)

Figure 5. A Conceptual Model (Left) and Statistical Model (Right) for A Conditional Process Analysis: Panel A as of Simple Moderation and Panel B as of All Paths are Moderated in the Mediation Model (Adopted from Hayes, 2013).

In panel B, the difference between the conditional indirect effect of  $X$  on  $Y$  through  $M$  when  $W = \omega_1$  and when  $W = \omega_2$  is presented as

$$\begin{aligned}
 & (a_1 + a_3\omega_1)(b_1 + b_2\omega_1) - (a_1 + a_3\omega_2)(b_1 + b_2\omega_2) \\
 & = a_1b_2(\omega_1 - \omega_2) + a_3b_1(\omega_1 - \omega_2) + a_3b_2(\omega_1^2 - \omega_2^2)
 \end{aligned}
 \tag{4}$$



When the moderator  $W$  is dichotomous which is coded one and zero (e.g., male is 1 and female is 0), the index of moderated mediation corresponds to the difference between the indirect effects in the two subgroups. In the first stage ( $X \rightarrow M$ ) and second stage ( $M \rightarrow Y$ ) in the mediation model, the weight for  $W$  based on Eq. 4 is simplified to  $a_1b_2 + a_3b_1 + a_3b_2$ , which is the *index of moderated mediation* (see Hayes 2013, p. 411).

In panel A, for example, “when  $XM$  is in a causal model with  $X$  and  $M$ , the coefficients for  $X$  and  $M$  are conditional effects under conditioned on the other variable being zero. When  $XM$  is not in the model, these are partial effects” (Hayes, 2013, p. 218). The current study examined the interaction effect of moderators and  $X$  and  $M$  on  $Y$  in the model.

Nine moderators were tested to determine whether they would affect the energy literacy structure by using a regression-based path analysis with PROCESS 2.13.2 for SPSS to estimate and probe the interactions and conditional direct and indirect effects (Hayes, 2014). The parameters were estimated by ordinary least squares (OLS) regression. The mean values of the variables, which are centered in advance, were employed to construct a moderation model and mediation model (Hayes, 2013, pp. 281-321). In response to our previous report, which suggested the importance of awareness of consequences in linking between the basic energy knowledge and energy-saving behavior, we examined the interaction of moderator on the following two causal relations: (1) the simple moderation model between basic energy knowledge and awareness of consequences and (2) the mediation model between awareness of consequences and attitude toward the behavior through the ascription of responsibility.

A statistical analysis was carried out at the 0.05 significance level with a two-tailed test by IBM® SPSS®, and Amos™ Version 24.

## Results

### Overall energy literacy assessment

A summary of the energy literacy results for lower secondary students in Japan is presented in Table 2. Students scored 53% on the basic energy knowledge, which is better than in the previous study (Cognitive domain, 39%,  $p < .001$ , Akitsu et al., 2016). However, they failed to meet the ideal criterion of 70% correctness for a five-response multiple-choice item (University of Washington, 2005).

The female students scored significantly higher than the males on the basic energy knowledge, awareness of consequences, ascription of responsibility, and personal norm (BEK: Male 46%, Female 56%,  $p < .001$ ; AC: Male 79%, Female 81%,  $p < .005$ ; AR: Male 75%, Female 77%,  $p < .01$ ), while the males achieved higher scores than the females on the subjective norm and critical thinking ability (SN: Male 63%, Female 61%,  $p < .05$ ; CTA: Male 65%, Female 64%,  $p < .05$ ).

The 7<sup>th</sup> grade students scored significantly higher than did those in the 9<sup>th</sup> grade on the awareness of consequences, ascription of responsibility, attitude toward the behavior, intention, energy-saving behavior, critical thinking ability and new ecological paradigm. Moreover, the actual scores on other predictors seemed to decrease with the school year progression, except the cognitive components: basic energy knowledge and civic scientific literacy.

Students who responded positively to questions on energy education experience, energy-related facility-tour experience (except basic energy knowledge), home discipline in energy-saving, and family discussions of energy-related issues achieved higher scores on all predictors than those who responded negatively.

Table 2. Energy Literacy Survey Results of Overall and Subgroup Comparisons of Lower Secondary Students in Japan.

		BEK					AC				AR			
		<i>N</i>	<i>M</i> %	<i>SD</i> %	<i>SE</i> %	<i>p</i>	<i>M</i> %	<i>SD</i> %	<i>SE</i> %	<i>p</i>	<i>M</i> %	<i>SD</i> %	<i>SE</i> %	<i>p</i>
Overall		1070	53.0	22.1	0.68		80.6	13.1	0.40		76.4	13.3	0.41	
Gender	Male	348	46.3	23.3	1.25		79.0	13.3	0.71		74.8	14.0	0.75	
	Female	722	56.2	20.8	0.78	†	81.4	13.0	0.48	***	77.2	12.8	0.48	**
Grade	7th	352	52.5	20.1	1.07		82.5	12.8	0.68	†	78.0	12.8	0.68	***
	8th	251	52.4	22.3	1.41		81.5	13.3	0.84	*	77.0	14.0	0.88	
	9th	467	53.7	23.5	1.09		78.7	13.1	0.61		75.0	13.1	0.60	
Education	Yes	866	54.4	22.0	0.75	†	81.2	13.0	0.44	***	77.1	13.2	0.45	***
	No	204	47.2	21.8	1.52		78.0	13.5	0.95		73.7	13.3	0.93	
Facility tour	Yes	317	54.8	22.2	1.25		83.1	12.7	0.71	†	78.9	13.3	0.74	†
	No	753	52.3	22.1	0.80		79.6	13.2	0.48		75.4	13.1	0.48	
Discipline	Yes	675	54.2	21.8	0.84	*	82.4	12.2	0.47	†	78.6	12.6	0.49	†
	No	395	51.0	22.6	1.14		77.6	14.2	0.71		72.7	13.5	0.68	
Discussion	Positive	283	57.5	21.0	1.25	†	84.5	12.0	0.71	†	80.2	12.8	0.76	†
	Neutral	236	56.6	22.3	1.45	†	81.5	12.7	0.82	*	77.1	12.2	0.79	**
	Negative	551	49.1	22.0	0.94		78.2	13.4	0.57	**	74.2	13.5	0.58	*

To be continued

Table 2. Continued

		PN					ATB				SN			
		<i>N</i>	<i>M %</i>	<i>SD %</i>	<i>SE %</i>	<i>p</i>	<i>M %</i>	<i>SD %</i>	<i>SE %</i>	<i>p</i>	<i>M %</i>	<i>SD %</i>	<i>SE %</i>	<i>p</i>
Overall		1070	78.5	14.2	0.43		81.6	11.6	0.36		61.5	12.3	0.38	
Gender	Male	348	77.0	15.1	0.81		80.9	12.0	0.64		62.8	12.5	0.67	*
	Female	722	79.2	13.6	0.51	*	82.0	11.5	0.43		60.9	12.1	0.45	
Grade	7th	352	80.4	13.7	0.73	†	83.0	11.6	0.62	***	62.0	12.6	0.67	
	8th	251	79.4	15.0	0.95	*	82.7	11.4	0.72	*	62.6	11.9	0.75	
	9th	467	76.6	13.8	0.64		80.0	11.6	0.54		60.5	12.2	0.56	
Education	Yes	866	78.9	14.3	0.49	*	82.4	11.5	0.39	†	61.9	12.4	0.42	*
	No	204	76.8	13.5	0.95		78.3	11.7	0.82		60.1	11.4	0.80	
Facility tour	Yes	317	80.3	14.2	0.80	***	84.3	11.2	0.63	†	63.9	12.7	0.72	†
	No	753	77.7	14.1	0.51		80.5	11.6	0.42		60.5	11.9	0.43	
Discipline	Yes	675	80.6	13.4	0.52	†	83.7	10.9	0.42	†	65.0	11.2	0.43	†
	No	395	74.9	14.7	0.74		78.0	12.0	0.60		55.6	11.7	0.59	
Discussion	Positive	283	82.8	13.1	0.78	†	85.3	10.2	0.61	†	66.9	11.5	0.69	†
	Neutral	236	79.2	13.4	0.87	**	82.1	11.1	0.73	***	62.2	10.8	0.71	†
	Negative	551	76.0	14.4	0.62	*	79.5	12.0	0.51	*	58.5	12.2	0.52	†
		PBC					INT				ESB			
		<i>N</i>	<i>M %</i>	<i>SD %</i>	<i>SE %</i>	<i>p</i>	<i>M %</i>	<i>SD %</i>	<i>SE %</i>	<i>p</i>	<i>M %</i>	<i>SD %</i>	<i>SE %</i>	<i>p</i>
Overall		1070	61.0	18.3	0.56		68.4	15.5	0.47		67.4	11.7	0.36	
Gender	Male	348	61.9	18.4	0.99		68.4	15.6	0.84		68.4	11.2	0.60	
	Female	722	60.6	18.2	0.68		68.4	15.5	0.58		66.9	11.9	0.44	
Grade	7th	352	62.1	19.5	1.04		70.0	15.4	0.82	***	68.7	12.1	0.64	***
	8th	251	62.0	17.3	1.09		69.7	15.4	0.97	*	68.4	12.1	0.77	*
	9th	467	59.7	17.8	0.82		66.4	15.6	0.72		65.9	11.0	0.51	
Education	Yes	866	61.6	18.2	0.62	*	68.9	15.7	0.53	*	67.8	11.7	0.40	*
	No	204	58.8	18.4	1.29		66.3	14.9	1.04		65.6	11.5	0.81	
Facility tour	Yes	317	63.8	18.4	1.04	***	71.6	15.5	0.87	†	70.4	11.7	0.66	†
	No	753	59.9	18.1	0.66		67.0	15.4	0.56		66.1	11.5	0.42	
Discipline	Yes	675	64.5	17.6	0.68	†	72.6	13.9	0.53	†	69.8	11.3	0.44	†
	No	395	55.1	17.8	0.90		61.3	15.7	0.79		63.2	11.1	0.56	
Discussion	Positive	283	67.5	17.5	1.04	†	76.4	13.9	0.82	†	72.9	11.2	0.67	†
	Neutral	236	61.5	16.5	1.07	***	69.6	13.5	0.88	†	67.8	9.9	0.64	†
	Negative	551	57.5	18.5	0.79	*	63.7	15.4	0.66	†	64.4	11.6	0.50	***
		CSL					CTA				NEP			
		<i>N</i>	<i>M %</i>	<i>SD %</i>	<i>SE %</i>	<i>p</i>	<i>M %</i>	<i>SD %</i>	<i>SE %</i>	<i>p</i>	<i>M %</i>	<i>SD %</i>	<i>SE %</i>	<i>p</i>
Overall		1070	52.3	17.3	0.53		64.2	10.9	0.33		76.5	11.8	0.36	
Gender	Male	348	52.7	18.8	1.01		65.4	11.0	0.59	*	76.0	11.8	0.64	
	Female	722	52.2	16.5	0.61		63.7	10.8	0.40		76.8	11.7	0.44	
Grade	7th	352	50.7	17.4	0.93		65.6	10.6	0.56	†	77.5	12.0	0.64	**
	8th	251	55.0	17.4	1.10	*	65.2	11.0	0.69	*	78.1	11.8	0.75	***
	9th	467	52.1	16.9	0.78		62.7	10.9	0.51		74.9	11.3	0.52	
Education	Yes	866	53.6	16.7	0.57	†	64.7	10.9	0.37	*	76.9	11.8	0.40	*
	No	204	47.1	18.6	1.30		62.4	10.6	0.74		74.9	11.6	0.81	
Facility tour	Yes	317	55.5	17.2	0.97	†	66.3	11.5	0.65	†	78.9	11.6	0.65	†
	No	753	51.0	17.1	0.62		63.4	10.5	0.38		75.5	11.7	0.43	
Discipline	Yes	675	54.1	16.7	0.64	†	66.6	10.4	0.40	†	77.5	11.4	0.44	†
	No	395	49.3	17.8	0.89		60.3	10.7	0.54		74.8	12.2	0.61	
Discussion	Positive	283	56.5	16.9	1.00	†	68.7	10.8	0.64	†	79.2	11.4	0.68	†
	Neutral	236	54.5	16.7	1.09	†	65.7	10.4	0.68	***	77.9	11.6	0.76	***
	Negative	551	49.3	17.1	0.73		61.3	10.2	0.44	†	74.5	11.7	0.50	

\*  $p < .05$ , \*\*  $<.01$ , \*\*\*  $<.005$ , †  $<.001$

Energy literacy structural modeling

Confirmatory factor analysis

Assuming that all factors are affected one another, we carried out a confirmatory factor analysis in a model assuming covariance between all predictors. Standardized regression coefficients of all paths were ranged from 0.18 to 0.75 and were significant. Since it is before model modification, some indices have not yet satisfied the good model-fit level: GFI

= 0.851; AGFI = 0.839; SRMR = 0.052; NFI = 0.769; CFI = 0.843; and RMSEA = 0.039. The correlations among the components reported along with the descriptive statistics in Table 3. The inter-correlations between predictors were all significant except that between the basic energy knowledge and subjective norm ( $r = 0.03, p = 0.34$ ).

Table 3. Descriptive Statistics of Variables and Spearman's rho Correlation Matrix for Path Analysis.

Predictors	M %	SD %	BEK	AC	AR	PN	ATB	SN	PBC	INT	ESB	CSL	CTA	
Basic energy knowledge	53.0	22.1	1											
Awareness of consequences	80.6	13.1	.41**	1										
Ascription of responsibility	76.4	13.3	.31**	.76**	1									
Personal norm	78.5	14.2	.32**	.76**	.73**	1								
Attitude toward the behavior	81.6	11.6	.30**	.73**	.68**	.69**	1							
Subjective norm	61.5	12.3	.03 ns	.29**	.39**	.34**	.37**	1						
Perceived behavioral control	61.0	18.3	.08*	.27**	.40**	.34**	.31**	.43**	1					
Intention	68.4	15.5	.15**	.47**	.56**	.54**	.54**	.61**	.59**	1				
Energy-saving behavior	67.4	11.7	.07*	.33**	.43**	.36**	.38**	.53**	.61**	.64**	1			
Civic scientific literacy	52.3	17.3	.51**	.47**	.36**	.39**	.35**	.15**	.09**	.21**	.13**	1		
Critical thinking ability	64.2	10.9	.24**	.45**	.48**	.41**	.45**	.43**	.31**	.52**	.43**	.42**	1	
New ecological paradigm	76.5	11.8	.47**	.72**	.58**	.61**	.55**	.15**	.15**	.28**	.18**	.51**	.39**	1

\*  $p < .05$ , \*\*  $p < .01$

#### Measurement of energy literacy model

The energy literacy structural model integrated with the TPB and VBN is presented in Figure 6, and Table 4 shows standardized and unstandardized estimates of hypothesis and proposed models and the model fitness indices. To avoid changing the model solely to pursue better model fitness indices, the paths with estimated values of less than 0.1 were not employed. Adding six paths to the hypothesis model improved model fitness. The basic energy knowledge does not predict the ascription of responsibility and personal norm directly and exerts little covariance between subjective norm and perceived behavioral control.

According to the energy literacy structural model, the intention and perceived behavioral control explained 50% of the variance in energy-saving behavior (Standardized coefficient  $\beta = 0.42, 0.37, p < .001$ ). The intention was determined relatively equally by the TPB predictors, namely the attitude toward the behavior, subjective norm, and perceived behavioral control ( $\beta = 0.31, 0.34, 0.36, p < .001$ ) before adding the prediction of personal norm, and these factors explained 58% of the variance in intention. Several studies have examined and proposed introducing the personal norm as an independent predictor of intention (e.g., Botetzagias et al., 2015; Chan & Bishop, 2013; Chen & Tung, 2010, 2014). Harland et al. (1999) found that the inclusion of moral (personal) norms increased the proportion of the explained variance of intention by one to ten percentage points. Therefore, we adopted the personal norm for the direct prediction of intention. As a result, the TPB variables (ATB, SN, PBC) and personal norm accounted for 60% of the variance in intention, which was increased from 52% of the hypothesis model.

The subjective norm, ascription of responsibility, personal norm, and awareness of consequences were able to explain 61% of the variance in attitude toward the behavior. The awareness of consequences more strongly predicted the attitude toward the behavior than other predictors ( $\beta = 0.38, p < .001$ ). The basic energy knowledge predicted the awareness of consequences significantly ( $\beta = 0.41, p < .001$ ) and accounted for 26% of the variance in awareness of consequences, along with the prediction of subjective norm. The ascription of responsibility and personal norm, which are activated by the awareness of consequences, predict the attitude toward the behavior, and the estimates of the prediction of awareness of consequences on both variables were relatively large in this model ( $\beta = 0.66$  and  $0.49, p < .001$ ). Consequently, the current study suggests that the awareness of consequences is a key determinant in the energy literacy structural model, which interprets between basic energy knowledge and energy-saving behavior through belief, norms and the attitude toward the behavior. In other words, it was able to explain the background of attitude toward the behavior by integrating advantages of both the TPB and VBN without declining the power of explanation of intention to energy-saving behavior in the TPB (both TPB and Proposed models:  $R^2 = 0.59, 0.60$ ).

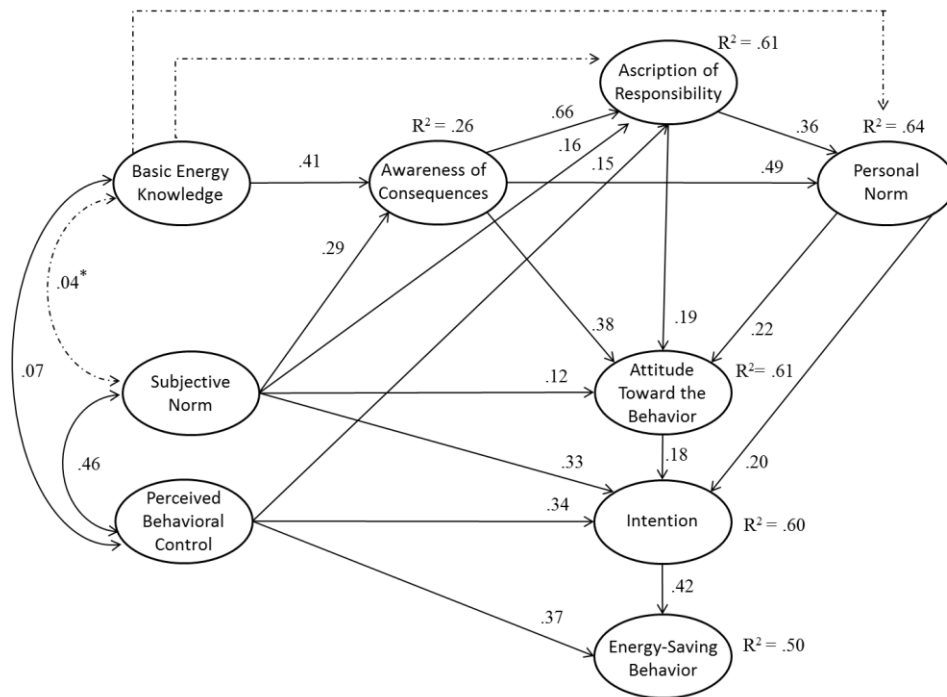


Figure 6. Energy literacy model with standardized coefficients. Non-significant estimates are indicated by the \* symbol and dashed lines.

Table 4. Summary of Estimates of Standardized and Unstandardized Regression Weights of the Theory of Planned Behavior, Value-Belief-Norm Theory, Hypothesis, and Proposed of Energy Literacy Models and their Model Fitness Indices.

Constructs	TPB			VBN			Hypothesis model			Proposed model				
	$\beta$	B	p	$\beta$	B	p	$\beta$	B	p	$\beta$	B	p		
BEK → AC	-	-		0.42	0.25	†	0.42	0.25	†	0.41	0.24	†		
SN → AC	-	-		-	-		-	-		0.29	0.31	†		
AC → AR	-	-		0.75	0.75	†	0.75	0.75	†	0.66	0.66	†		
SN → AR	-	-		-	-		-	-		0.16	0.17	†		
PBC → AR	-	-		-	-		-	-		0.15	0.11	†		
AR → PN	-	-		0.73	0.78	†	0.73	0.78	†	0.36	0.39	†		
AC → PN	-	-		-	-		-	-		0.49	0.53	†		
AC → ATB	-	-		-	-		0.38	0.33	†	0.38	0.34	†		
AR → ATB	-	-		-	-		0.25	0.21	†	0.19	0.17	†		
PN → ATB	-	-		-	-		0.24	0.19	†	0.22	0.18	†		
SN → ATB	-	-		-	-		-	-		0.12	0.11	†		
ATB → INT	0.30	0.40	†	-	-		0.32	0.40	†	0.18	0.24	†		
SN → INT	0.34	0.42	†	-	-		0.36	0.42	†	0.33	0.41	†		
PBC → INT	0.36	0.30	†	-	-		0.39	0.30	†	0.34	0.28	†		
PN → INT	-	-		-	-		-	-		0.20	0.21	†		
PN → ESB	-	-		0.38	0.31	†	-	-		-	-			
INT → ESB	0.43	0.32	†	-	-		0.41	0.32	†	0.42	0.32	†		
PBC → ESB	0.37	0.23	†	-	-		0.38	0.23	†	0.37	0.23	†		
	Corre.		Covar.				Corre.		Covar.		Corre.		Covar.	
BEK ↔ SN	-	-		-	-		0.04	11.55	0.16	0.04	11.55	0.16		
BEK ↔ PBC	-	-		-	-		0.07	27.62	*	0.07	27.62	*		
SN ↔ PBC	0.46	103.51	†	-	-		0.46	103.51	†	0.46	103.51	†		
ATB ↔ PBC	0.33	70.24	†	-	-		-	-		-	-			
ATB ↔ SN	0.40	56.86	†	-	-		-	-		-	-			
	$R^2$			$R^2$			$R^2$			$R^2$			$\Delta R^2$	
AC	-			0.18			0.18			0.26			0.08	
AR	-			0.56			0.56			0.61			0.05	
PN	-			0.53			0.53			0.64			0.11	
ATB	-			-			0.58			0.61			0.03	
INT	0.59			-			0.52			0.60			0.08	
ESB	0.51			0.14			0.48			0.50			0.02	

To be continued

Table 4. Continued

Model fitness indices	TPB	VBN	Hypo. model	Proposed model
$X^2$	40.99	377.23	751.92	116.67
$df$	2	6	22	16
GFI	0.985	0.883	0.881	0.978
AGFI	0.889	0.708	0.756	0.937
SRMR	0.028	0.086	0.196	0.053
NFI	0.982	0.846	0.866	0.979
CFI	0.983	0.848	0.869	0.982
RMSEA	0.135	0.241	0.176	0.077
AIC	66.99	395.23	797.92	174.67

$\beta$  is standardized and  $B$  is unstandardized coefficients.

\*  $p < .05$ , †  $< .001$

$\Delta R^2$  is differences between hypothesis and proposed energy literacy models.

#### Conditional process analysis

Nine moderators were evaluated those effects in the simple moderation model and mediation model we selected (See Section Moderation variables). First, it was found that the direct effect of basic energy knowledge on the awareness of consequences was moderated by civic scientific literacy, critical thinking ability, and new ecological paradigm (CSL:  $b_{3\_CSL} = -0.004$ , 95% CI =  $-0.006$  to  $-0.003$ ,  $p < .001$ ; CTA:  $b_{3\_CTA} = -0.009$ , 95% CI =  $-0.012$  to  $-0.006$ ,  $p < .001$ ; NEP:  $b_{3\_NEP} = -0.005$ , 95% CI =  $-0.007$  to  $-0.003$ ,  $p < .001$ ) (Table 5). The conditional effect of basic energy knowledge on the awareness of consequences seems to decrease with the score of moderator increasing, except for the relatively high level group of new ecological paradigm, which was no significant ( $p = 0.96$ , Table 6). In other words, relatively low level group on these moderators is more affected by the interaction of basic energy knowledge and these moderators in predicting the awareness of consequences than relatively high level group.

Table 5. Unstandardized OLS Regression Coefficients with Confidence Intervals for Estimating Awareness of Consequences (AC) under Moderation by Civic Scientific Literacy (CSL), Critical Thinking Ability (CTA), and New Ecological Paradigm (NEP). Variables are Mean-Centered.

		AC (Y)				AC (Y)				AC (Y)			
		Coeff	SE	95% CI	$p$	Coeff	SE	95% CI	$p$	Coeff	SE	95% CI	$p$
BEK ( $X$ )	$b_1 \rightarrow$	.142	.018	.107, .177	† $\rightarrow$	.198	.015	.168, .227	† $\rightarrow$	.058	.014	.031, .085	†
CSL ( $M_1$ )	$b_2 \rightarrow$	.268	.023	.223, .313	†								
CTA ( $M_2$ )	$b_2$				$\rightarrow$	.455	.031	.394, .516	†				
NEP ( $M_3$ )	$b_2$								$\rightarrow$	.753	.026	.702, .805	†
$X \times M_1$	$b_3 \rightarrow$	-.004	.001	-.006, -.003	†								
$X \times M_2$	$b_3$				$\rightarrow$	-.009	.001	-.012, -.006	†				
$X \times M_3$	$b_3$								$\rightarrow$	-.005	.001	-.007, -.003	†
Constant	$i_M \rightarrow$	81.46	.375	80.72, 82.20	† $\rightarrow$	81.12	.336	80.46, 81.78	† $\rightarrow$	81.22	.300	80.63, 81.81	†
		$R^2 = 0.302$ $F(3, 1066) = 153.367$ , $p < .000$				$R^2 = 0.338$ $F(3, 1066) = 181.438$ , $p < .000$				$R^2 = 0.739$ $F(3, 1066) = 428.239$ , $p < .000$			

†  $p < .001$

Table 6. Conditional Effects of Basic Energy Knowledge on Awareness of Consequences among Those Relatively Low, Average, and Relatively High in the Moderators: Civic scientific literacy, Critical Thinking Ability, and New Ecological Paradigm.

		Effect	SE	t (1066)	p	LLCI	ULCI
CSL	Low	0.218	0.024	9.168	0.000	0.171	0.264
	Average	0.142	0.018	7.998	0.000	0.107	0.177
	High	0.066	0.022	2.982	0.003	0.023	0.110
CTA	Low	0.295	0.021	14.006	0.000	0.254	0.337
	Average	0.198	0.015	12.959	0.000	0.168	0.227
	High	0.100	0.021	4.687	0.000	0.058	0.141
NEP	Low	0.117	0.018	6.357	0.000	0.081	0.153
	Average	0.058	0.014	4.154	0.000	0.031	0.085
	High	-0.001	0.019	-0.050	<b>0.960</b>	-0.038	0.036

Subsequently, the conditional effect of awareness of consequences on the attitude toward the behavior through the ascription of responsibility depends on at values of five moderators: gender, family discussion of energy issues, civic scientific literacy, critical thinking ability, and new ecological paradigm. In particular, the current study reports the estimated regression coefficients for family discussion of energy issues and new ecological paradigm, which indicated both mediated moderation and moderated mediation in this mediation model (Tables 7 and 8). The interaction between family discussion and awareness of consequences affects the attitude toward the behavior significantly ( $c'_3 = 0.046$ , 95% CI = 0.004 to 0.088,  $p < .05$ ) (Table 7) and holding the awareness of consequences constant, the effect of ascription of responsibility on the attitude toward the behavior depends on at value of family discussion ( $b_2 = -0.074$ , 95% CI = -0.115 to -0.034,  $p < .001$ ). Following the same procedure, this mediation model also depends on at value of new ecological paradigm (Table 8). Both effects of moderated mediation ( $b_2$ ) are negative, which means that the interaction of ascription of responsibility and the moderator (family discussion, NEP) on the attitude toward the behavior will decrease along with the score of moderator increasing. The current study can be concluded that the conditional indirect effect of awareness of consequences on the attitude toward the behavior through the ascription of responsibility depends on at values of family discussion and new ecological paradigm, which is moderated mediation.

Although significant differences were observed in the mean comparison, there was no interaction of school year grade, energy education experience, energy-related facility tour experience, and home discipline in energy-saving in the simple moderation model and mediation model.

Table 7. Unstandardized OLS Regression Coefficients with Confidence Intervals for Estimating Ascription of Responsibility (AR) and Attitude toward the Behavior (ATB) in the Moderated Mediation and Mediated Moderation by Family Discussion of Energy-Related Issues. Variables are Mean-Centered.

		AR (M)					ATB (Y)			
		Coeff.	SE	95% CI	p		Coeff.	SE	95% CI	p
AC (X)	$a_1 \rightarrow$	.743	.021	.702, .784	†	$c'_1 \rightarrow$	.426	.026	.375, .479	†
AR (M)						$b_1 \rightarrow$	.277	.026	.226, .328	†
Discussion (W)	$a_2 \rightarrow$	.554	.221	.120, .987	*	$c'_2 \rightarrow$	.506	.189	.135, .876	**
$X \times W$	$a_3 \rightarrow$	.007	.016	-.025, .039	.669	$c'_3 \rightarrow$	.046	.021	.004, .088	*
$M \times W$						$b_2 \rightarrow$	-.074	.021	-.115, -.034	†
Constant	$i_M \rightarrow$	-.025	.275	-.564, .515	.929	$i_Y \rightarrow$	81.73	.235	81.26, 82.18	†
$R^2 = 0.562$					$R^2 = 0.587$					
$F(3, 1066) = 455.103,$					$F(5, 1064) = 303.074,$					
$p < .000$					$p < .000$					

\*  $p < .05$ , \*\*  $< .01$ , †  $< .001$

Table 8. Unstandardized OLS Regression Coefficients with Confidence Intervals for Estimating Ascription of Responsibility (AR) and Attitude toward the Behavior (ATB) in the Moderated Mediation and Mediate Moderation by New Ecological Paradigm (NEP). Variables are Mean-Centered.

		AR (M)				ATB (Y)				
		Coeff.	SE	95% CI	<i>p</i>	Coeff.	SE	95% CI	<i>p</i>	
AC (X)	$a_1 \rightarrow$	.704	.031	.644, .765	†	$c'_1 \rightarrow$	.419	.032	.356, .483	†
AR (M)						$b_1 \rightarrow$	.283	.026	.232, .335	†
NEP (W)	$a_2 \rightarrow$	.079	.033	.013, .144	*	$c'_2 \rightarrow$	.024	.029	-.033, .080	.409
$X \times W$	$a_3 \rightarrow$	.000	.002	-.003, .004	.826	$c'_3 \rightarrow$	.005	.002	.000 .010	*
$M \times W$						$b_2 \rightarrow$	-.006	.002	-.011, -.002	**
Constant	$i_M \rightarrow$	-.041	.327	-.683, .601	.900	$i_Y \rightarrow$	81.61	.281	81.06, 82.16	†
		$R^2 = 0.561$ $F(3, 1066) = 454.400,$ $p < .000$				$R^2 = 0.583$ $F(5, 1064) = 297.147,$ $p < .000$				

\*  $p < .05$ , \*\*  $< .01$ , †  $< .001$

## Discussion

The current study investigated the energy literacy structural model integrated with the TPB and VBN to evaluate the causal relationship between the basic energy knowledge and energy-saving behavior for lower secondary students in Japan.

### The predictions across the TPB and VBN models

The energy literacy structural model was depicted across models of the TPB and VBN, that is the awareness of consequences and ascription of responsibility were predicted by the subjective norm and perceived behavioral control. In contrast to the TPB explains the general behavioral theory, Schwartz and Howard (1981) have introduced the NAT which focuses on altruism and helping behavior while integrating some predictors from the TPB (Klößner, 2013). The NAT assumes that people act for others if they feel obligation under morality toward a given situation. This motivation is activated by personal norms, which reflect a personal values mechanism in a given situation, and should be activated antecedent to the behavioral intention. Klößner (2013) summarized four conditions needed to activate the personal norm presented by Schwartz and Howard (1981): (1) awareness that people need the helping (subjective norm), (2) awareness of consequences, (3) ascription of responsibility, and (4) perceived behavioral control. While these conditions are affected by each other, personal norm based on morality is activated before deciding a given behavior (Figure 7). Therefore, it cannot be denied the potentiality that the effects of subjective norm and perceived behavioral control in the energy literacy model activate the awareness of consequences and ascription of responsibility, respectively. In regard to subjective norms, Japanese people tend to respect their group memberships, decisions, and expectations as the perception of that Japan is one of the representatives of a collectivistic culture in the world. If so, subjective norms can be considered one of the critical factors which affect beliefs of Japanese people. As such, we cannot overlook the potentiality that social expectations or pressure (SN) activate students' awareness of consequences and ascription of responsibility from the perspectives of not only correlation coefficients between SN and AC, AR ( $r = 0.29, 0.39, p < .01$ , respectively) but the modification indices of  $SN \rightarrow AC$  (MI 108.58) and  $SN \rightarrow AR$  (MI 97.39). This can be supported by the result of conditional process analysis. It indicated that the conditional direct and indirect effects of awareness of consequences on the attitude toward the behavior depend on the degree of family discussion of energy issues. The family influence on students' energy literacy can be also supported by our previous study (Akitsu et al., 2016). Through the relationship with parent(s), children acquire knowledge, skills, values, attitudes, and expectations in the socialization process (Peterson & Rollins, 1987). Schwartz (1977) stated that "social expectations are learned in the normal course of socialization and activated by explicit or subtle communications from others in society or by human actors' perception that his/her actions may be uncovered to those whose reactions will depend on whether or not he/she conforms to them". For Japanese students, learning the EE issues along with family participation seems to be indispensable for cultivating their energy literacy.

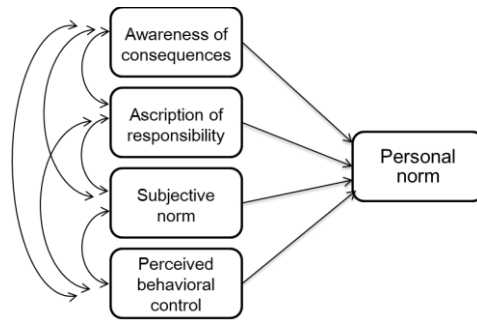


Figure 7. Norm-Activation Theory (Schwartz and Howard, 1981) adopted from Klöckner, (2013).

#### Awareness of consequences

One of findings that the awareness of consequences plays an inevitable role in linking distal predictors was consistent with our previous model (Akitsu, et al., 2017). The Schwartz's Norm-Activation Theory (NAT) holds that awareness of consequences determines the activation of personal norms, which drive pro-environmental behavior (Schwartz, 1973, 1977), and has been supported by substantial evidence for decades (e.g., Black, Stern & Elworth, 1985; Guagnano, Stern & Dietz, 1995; Schultz & Zelezny, 1999). The score of awareness of consequences was 81%, which is fairly high among the overall determinants. They are concerned that the progression of global warming due to energy overconsumption will cause environmental destruction and threats to living things (AC05: 87%, AC08: 82%). In addition, they believe that resource depletion will be a serious problem for the country (AC09: 84%). Therefore, they think people in Japan should save more energy (AC04: 82%). Most of their concern is based on the environmental issues that are derived from the mass consumption of energy and fossil resources. Therefore, it may be natural that strong inter-correlation is observed between awareness of consequences and new ecological paradigm (Table 3,  $r = 0.72$ ,  $p < .01$ ), and the interaction of these variables directly and indirectly affect the attitude toward the behavior. These results are more likely the outcome of environmental education in Japan.

Notwithstanding, the current study explained only 26% of the variance in awareness of consequences, further investigation regarding what knowledge and information effectively affect students' awareness of consequences will be required. Furthermore, we also need to identify information or knowledge that leads to the appropriate behavior.

#### Basic energy knowledge

The basic energy knowledge of Japanese students is still insufficient (53%) and civic scientific literacy is also the same (52%). In particular, on the scientific items related to energy form, efficiency, and conversion, these students scored lower than the US middle school students whom we compared in the previous study (BEK10: Japan 31%, US 44%; BEK11: Japan 39%, US 41%; BEK13: Japan 41%, US 50%,  $p < .001$ ) (Akitsu et al., 2016).

The result that female students scored significantly higher on the basic energy knowledge than the males did was supported by our previous study (Akitsu et al., 2017). The females' better achievement is likely due to the participation of a private girls' junior high school ( $N = 310$ ) in the Kansai area (Western Japan), which has excellent academic performance. However, it has been determined that this school does little to affect the gender difference in the basic energy knowledge (after excluding the results from the girls' private school, female 51%, male 46%,  $p < .005$ ) nor the energy literacy model (the model fitness indices without the results from the girls' private school are: GFI = .977, AGFI = .934, SRMR = .043, RMSEA = .076, NFI = .979, and CFI = .983). After excluding the girls' school from the entire sample, there was no longer a gender difference in the awareness of consequences, ascription of responsibility, and personal norm, and the females' scores on civic scientific literacy, critical thinking ability, and new ecological paradigm declined significantly. In addition, the exclusion of this girls' school seems to little affect to the TPB constructs (ATB, PBC, INT, and ESB) (Appendix 2).

Black et al. (1985) argued that people with greater knowledge (better-educated people) show more concern about energy. Moreover, Lyons & Breakwell (1994) found that the amount of knowledge about specific environmental issues is a powerful discriminator between the environmentally concerned group and its counterpart. These claims may support our results that the high score of females on the basic energy knowledge seems to affect the degree of awareness of consequences. In fact, the females' estimate of conditional direct effect of awareness of consequences on the attitude toward the behavior is larger than that of the males (Male:  $b_{male} = 0.35$ ,  $t(1064) = 7.69$ ,  $p < .001$ ; Female:  $b_{female} = 0.47$ ,  $t(1064) = 14.55$ ,  $p < .001$ ). Pertinent and factual knowledge about EE issues may be a powerful predictor for understanding the degree of seriousness of the problems and perceiving the adverse consequences of the current situation for future generations and society. It would be possible that the amount of basic energy knowledge affects their beliefs and normative factors, though, further investigation on the relationship between academic achievement level and gender characteristics for energy relevant knowledge, belief, normative factors is required.



*Interaction of basic energy knowledge and scientific literacy*

Despite Japanese students ranked 2nd among 72 countries and economies in PISA 2015 and they performed excellent achievement in scientific literacy, mathematics, and readings (OECD 2016), the basic energy knowledge has not dramatically improved to the ideal level of energy literacy (70% or more) since this survey began in 2014 (for the same items on the 2014 survey:  $M$  44%,  $SD$  19.2%; BEK of current study:  $M$  53%,  $SD$  22.1%,  $p < .001$ ). In fact, the conditional process analysis indicated that the interaction effect of basic energy knowledge and civic scientific literacy on the awareness of consequences decreases with the CSL increasing.

As similar to Taiwan case that Chen et al. (2015) have pointed out, interdisciplinary holistic energy learning has been little provided in the teaching guideline, as the units and subjects that are relevant to the EE topics are dispersed throughout the formal education curriculum in Japan. Despite energy education is recognized as a critical part of the environmental education in the government curriculum guidelines in Japan (MEXT, 2010, 2010a), neither comprehensive teaching materials that focus on energy-related issues nor a measurement manner for evaluating its achievement have been presented officially. The current situation of energy education in Japan tends to depend on the degree of contribution by teachers who recognize the necessity of energy education and provide their own energy relevant classes (Akitsu et al., 2017).

*Score declining with the school year progression*

Although the school year progression did not affect significantly in the energy literacy model, it may be necessary to discuss on no differences on the basic energy knowledge, and on the score declining on the awareness of consequences with school year progression. The former can be supported by the previous studies that the current school classes are not likely effective information sources to improve students' energy literacy (Misaki & Nakajima, 2005, 2005a) relative to active learning such as reading books, newspapers/magazines, and visiting museums/exhibitions (Akitsu et al., 2016). And the latter, it is, however, difficult to identify the reason, it may be that lower-graders responded to the adverse consequences of the current energy consumption more simply, intuitively, and honestly as what they feel. DeWaters & Powers (2011) reported that the middle students in the U. S. scored higher than those in high school in response to how effectively they feel they can contribute to solving energy-related problems. The question item of "I believe that I can contribute to solving the energy problems by making appropriate energy-related choices and actions" indicated a significant difference between the middle and high school students (MS: 67%, HS: 66%,  $p < .01$ ). It is conceivable that the motivation of younger students may contribute to the high performance on the affective domain. Therefore, careful consideration on the timing of implementation of effective energy education may be required.

Despite Japan is low energy self-sufficient country with high energy consumption, many Japanese teachers mention that they are unwilling to foment or stir up students' sense of crisis about the current energy situation (JAEEE, 2015). It is difficult to provide energy education including nuclear energy as same as other energy sources, due to the current controversy over nuclear energy after the severe nuclear accident occurred in 2011. The awareness of consequences is different from fueling a sense of crisis of individual by others. The awareness of consequences should be promoted by oneself with de facto information, which students obtained from energy education that improves their perception and understanding of the current energy issues. Their ability will shape a future society that is knowledgeable about energy and the environment.

According to a longitudinal study of the age-stability of political attitudes, youth is the period in life when attitudes are most flexible, and attitudes become hardened with age (Alwin & Krosnick, 1991). It is assumed that adolescents' social and political attitudes are already considerably developed by the time they finish secondary school and are maintained throughout their lives (Christensen & Knezek, 2015; Sears & Funk, 1999). The same idea may apply to energy policy: developing positive attitudes toward the EE issues in childhood is of significant importance in forming their attitudes and behaviors regarding appropriate energy choices in later life (Chawla, 1999; Meinhold & Malkus, 2005; Zografakis, Menegaki & Tsagarakis, 2008). Thus, it may be effective to begin early in energy education as possible to provide basic EE knowledge, encourage students' awareness and attitudes toward engaging in problem-solving, and cultivate preferable energy conservation habits (Akitsu et al., 2017).

The energy literacy structural model was proposed to interpret the energy literacy of Japanese lower secondary students. The students will become aware of the adverse consequences of ongoing energy-related issues by attaining basic energy knowledge, along with the scientific literacy, critical thinking ability, and ecological worldview or values. Furthermore, the current study indicated that students' attitude toward the behavior seems to be affected by the interactions between awareness of consequences/ascription of responsibility and ecological worldview or values/family discussion of energy-related issues. While incorporating collaboration with students' families into the energy learning program, the implementation of energy education at an earlier educational stage may be recommended in Japan.

In a tight school curriculum, the time allocated for energy education is limited, so energy education should be provided in the most effective way possible (Lawrenz & Dantchik, 1985). The energy literacy structural model we presented

provides a theoretical contribution to the development of an effective energy education program that considers the conceptual structure of students' energy literacy.

#### *Future research*

Energy literacy does not mean just gaining energy relevant knowledge or not just merely acting energy-saving as rational choice for self-interest. We expect energy literacy as a common culture to address prolonged global EE issues and to yield new direction of social norms for sustainable society. One of energy solutions depends on energy relevant behavior including choice by every single individual. The current study indicated that the behavioral intention explained only 50% of the variance in energy-saving behavior. This explanation power is not necessarily weak in modeling for pro-environmental behavior (e.g., 40% for Ajzen et al., 2011, 36% for Klöckner, 2013, 23% for Leeuw et al., 2015). Fields attempting to predict human behaviors such as psychology often have R-squared value of less than 50% since it is difficult to predict human beings relative to physical processes (Minitab.com, 2018). However, it also implies that much to be learned for fulfilling behavior's explanation is still remained. For example, Klöckner (2013) suggested that value-based interventions indicated only an indirect effect, while, habits was identified as a direct predictor of behavior in conjunction with other behavioral predictors. Moreover, it has been reported that intentions are influenced by past experience which is the best predictor of behaviors that are repeated frequently (Macey & Brown, 1983). Habitual behaviors should be also discussed in the energy literacy model as a key point for behavior modification and improvement along with other measures raised as effective policy programmes (Stern, Janda, Brown, Steg, Vine, & Lutzenhiser, 2016).

### **Conclusions**

This article first constructed an energy literacy structural model, which was integrated with the Theory of Planned Behavior and Value-Belief-Norm Theory. Subsequently, the causal relationship between basic energy knowledge and energy-saving behavior was examined by investigating lower secondary students in Japan. Finally, the interactions of moderators were analyzed.

The following findings were obtained: energy-saving behavior was predicted by intention to perform energy-saving behavior and the perceived behavioral control, and intention was determined by the attitude toward the behavior, subjective norms, perceived behavioral control, and personal norms. The awareness of consequences plays a critical role in the link between basic energy knowledge and attitude toward the behavior. The interactions between basic energy knowledge and civic scientific literacy, critical thinking ability, and environmental value or worldview are important in predicting the awareness of consequences. Furthermore, in the mediation model, the conditional direct and indirect effects of awareness of consequences on the attitude toward the behavior through the ascription of responsibility depend on environmental values or worldview and family discussion of energy and environmental issues.

The energy literacy structural model proposed provides a theoretical contribution to the development of an effective energy education program by adapting the concept of energy literacy to link basic energy knowledge and energy-saving behavior.

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**Appendix 1.****Question Items for Energy Literacy Model Extended from the Theory of Planned Behavior and Value-Belief-Norm Theory.**

Predictors	Question items
Basic energy knowledge	
BEK01	Each and every action on Earth involves...(2. <b>Energy</b> ) <sup>a</sup>
BEK02	One advantage to using nuclear power instead of coal or petroleum for energy is that...(2. <b>there is less greenhouse gas emission</b> )
*BEK03	How much does our energy consumption depend on imported energy resources? (1. <b>Almost 100%</b> )
BEK04	It is impossible to...(3. <b>build a machine that produces more energy than it uses</b> )
*BEK05	Which of the following is produced by photosynthesis? (5. <b>All of the above: Coal, Petroleum, Natural gas, Shale gas</b> )
*BEK06	Which of the following statements best DEFINES energy? (4. <b>The ability to do work</b> )
BEK07	Which two things determine the amount of ELECTRICAL ENERGY (ELECTRICITY) an electrical appliance will consume? (4. <b>The power rating of the appliance (watts or kilowatts), and the length of time it is turned on</b> )
BEK08	Which of the following description is correct about energy? Energy ...(5. <b>is indispensable whenever we act</b> )
BEK09	How do you know that a piece of wood has stored chemical potential energy? (3. <b>It releases heat when burned</b> )
BEK10	All of the following are forms of energy EXCEPT...(5. <b>Coal</b> )
BEK11	What does it mean if an electric power plant is 35% efficient? (5. <b>For every 100 units of energy that go into the plant, 35 units are converted into electrical energy</b> )
BEK12	Which of the following choices ALWAYS SAVES energy? (3. <b>Less frequent washing until a certain volume of laundry is obtained</b> )
BEK13	Some people think that if we run out of fossil fuels, we can just switch over to electric cars. What is wrong with this idea? (1. <b>Most electricity is currently produced from fossil fuels such as coal, oil, and natural gas.</b> )
BEK14	Which of the following descriptions is correct about petroleum, which is the energy source that our country consumes most? (4. <b>There is a risk because petroleum is imported from the middle east</b> )
*BEK15	The original source of energy for almost all living things on the earth is...(1. <b>The Sun</b> )
<sup>b</sup> CEI01	The best reason to buy an appliance that is labeled "energy efficient" ...(3. <b>use less energy</b> )
CEI02	Which of the following descriptions is correct about increasing CO <sub>2</sub> emission as the cause of global warming? (5. <b>Burning of large amounts of fossil fuels</b> )
CEI03	Many scientists say the Earth's average temperature is increasing. They say that one important cause of this change is...(4. <b>increasing carbon dioxide concentrations from burning fossil fuels</b> )
CEI04	Which of the following energy-related activities is LEAST harmful to human health and the environment? (5. <b>Generating electricity with photovoltaic (solar) cells</b> )
CEI05	Which of the following is the MOST appropriate description about the environmental impact by energy resource development and use? (4. <b>Impact on environment cannot be avoided when humans develop and use energy resources</b> )
Awareness of consequences	
*AC01	All electrical appliances should have a label that shows the resources used in making them, their energy requirements, and operating costs.
*AC02	Saving energy is important.
AC03	The government should place stronger restrictions on the gas mileage of new cars.
AC04	People in our country should save more energy.
AC05	If global warming progresses due to mass energy consumption, thousands of plant and animal species will become extinct.
AC06	If global warming progresses due to mass energy consumption, environmental threats to public health will become serious.
AC07	Energy-saving is beneficial for environmental protection and for my health.
AC08	Massive consumption of fossil fuel causes global warming, environmental damage, and affects people all over the world.
AC09	Resource depletion by massive energy consumption will be a very serious problem for the country.
AC10	Climate change will be a very serious problem for me and my family.
AC11	The destruction of tropical forests to meet humans' demand will be a very serious problem for me and my family.



Predictors	Question items
Ascription of responsibility	
AR01	Even if the school pays for the electricity, I should worry about turning off the lights or computers in the classroom.
AR02	Even if new technologies will be developed to solve the energy problems for future generations, we should continue energy-saving.
AR03	Even if it would reduce energy production in the future, the laws that protect the natural environment should be made stricter.
AR04	The way I personally use energy makes a difference in the energy problems that face our nation.
AR05	Every member of the public should accept responsibility for energy-saving to protect the global environment.
*AR06	If global warming progresses due to mass energy consumption, environmental threats to public health will become serious.
AR07	I am not worried about energy-saving and the global environment (R) <sup>c</sup> .
Personal norm	
PN01	I feel guilty when I squander energy
PN02	I feel I ought to save energy to prevent climate change and protect the global environment.
PN03	Business and industry should conserve energy consumption to reduce greenhouse gas emissions to help prevent climate change.
PN04	The government should take a strong leadership role in developing energy policy to reduce greenhouse gases emissions and prevent global climate change.
*PN05	I feel a personal obligation to do whatever I can contribute including energy-saving to prevent climate change.
Attitude toward the behavior	
ATB01	For me, energy-saving is important.
ATB02	For me, saving energy is valuable.
ATB03	For me, saving energy is effective.
*ATB04	For me saving energy is interesting.
ATB05	Energy-saving will help us reduce greenhouse gas emissions.
ATB06	Energy-saving will help us save money.
ATB07	Energy-saving will give us an opportunity to consider new lifestyle values.
Subjective norm	
SN01	My family thinks that I should save energy.
SN02	Most people who are important to me think that I should save energy.
SN03	Most of the students in this class think that I should save energy.
SN04	My family has saved energy.
SN05	Most people who are important to me have saved energy.
SN06	Most of the students in this class have saved energy.
SN07	Most people who I respect appreciate my energy-saving behavior.
SN08	When it comes to energy-saving, I want to do what the important people expect me to do.
SN09	Generally, how much do you care about that the people around you think you should save energy?
Perceived behavior control	
PBC01	For me, saving energy is difficult. (R)
*PBC02	Energy-saving is up to me.
PBC03	I am confident that I can save energy.
*PBC04	For me saving energy is possible.
*PBC05	How often do you encounter unanticipated events that you cannot do saving-energy? (R)
PBC06	How often do you forget to save energy? (R)
PBC07	How often do you feel that it is troublesome to save energy? (R)
Intention	
*INT01	If there were ten people around you, what do you think how many people save energy? (Choose the number of 1-10 persons).
INT02	I am always thinking about ways to save energy.
INT03	I will make an effort to save energy.
INT04	I would do more to save energy if I knew how.
INT05	I believe that I can contribute to solving the energy problems through appropriate energy-related choices and actions.

Predictors	Question items
Energy-saving behavior	
ESB01	When I leave a room, I turn off the light.
ESB02	I always sort household waste according to the regulations.
ESB03	I usually set the temperature on the air-conditioners higher in summer and lower in winter.
ESB04	I turn off the computer when it is not being used.
ESB05	I always keep the water running when brushing my teeth, washing my face or shampooing. (R)
ESB06	I try to choose appliances/products that are labeled “energy efficient”.
*ESB07	When I (my family) travel to remote area, I use public transportation such as a bus or a train instead of own car as possible.
ESB08	I cut down on my consumption of disposal items whenever possible, e.g., plastic bags from the supermarket and excessive packaging at the department store
ESB09	I try to reduce the amount of garbage that I produce.
ESB10	In the past six months, I have made an effort to save energy.
*ESB11	For me to gain a better understanding of energy-saving is important.
<sup>d</sup> ECB01	Many of my everyday decisions are affected by my thoughts on energy use.
ECB02	I am willing to buy fewer things to save energy.

Some wordings are adapted from the DeWaters’ questionnaire for the middle students energy literacy survey (DeWaters, 2013b).

\* Items with this symbol were eliminated in the subsequent analysis for reliability and consistency of a set of items and for residual covariance across variables.

a Correct answer is in parentheses in bold.

b Items of cognition of environmental issues (CEI) are embedded into the basic energy knowledge.

c (R) is a reverse question, which is allocated a reverse point.

d Items of energy-use conscious behavior (ECB) are embedded into the energy-saving behavior.

**Appendix 2.**

**Gender Comparison with Female Groups Before/After Excluding A Private Girls’ School.**

	N	M %	SD %	SE %	p	M %	SD %	SE %	p	
		BEK					AC			
Male	348	46.3	23.3	1.25		79.0	13.3	0.71		
Female	722	56.2	20.8	0.78	†	81.4	13.0	0.48	***	
Female after deleting	412	51.2	20.8	1.03	***	79.4	13.2	0.65		
		AR					PN			
Male	348	74.8	14.0	0.75		77.0	15.1	0.81		
Female	722	77.2	12.8	0.48	**	79.2	13.6	0.51	*	
Female after deleting	412	76.6	12.8	0.63	0.08	77.5	13.8	0.68		
		ATB					SN			
Male	348	80.9	12.0	0.64		62.8	12.5	0.67		
Female	722	82.0	11.5	0.43		60.9	12.1	0.45	*	
Female after deleting	412	80.7	11.8	0.58		61.9	12.2	0.60		
		PBC					INT			
Male	348	61.9	18.4	0.99		68.4	15.6	0.84		
Female	722	60.6	18.2	0.68		68.4	15.5	0.58		
Female after deleting	412	61.9	18.6	0.92		69.2	15.2	0.75		
		ESB					CSL			
Male	348	68.4	11.2	0.6		52.7	18.8	1.01		
Female	722	66.9	11.9	0.44		52.2	16.5	0.61		
Female after deleting	412	67.1	11.7	0.58		47.7	16.0	0.79	†	
		CTA					NEP			
Male	348	65.4	11.0	0.59		76.0	11.8	0.64		
Female	722	63.7	10.8	0.40	*	76.8	11.7	0.44		
Female after deleting	412	63.1	10.5	0.52	***	74.0	11.4	0.56	**	

\* p < .05, \*\* < .01, \*\*\* < .005, † < .001