

# EFFECTS OF PROJECT-BASED ACTIVITIES IN DEVELOPING HIGH SCHOOL STUDENTS' ENERGY LITERACY

**Kuen-Yi Lin,  
Shao-Chuan Lu**

## Introduction

Sustainable development is one of the most important issues in science education, more and more positioned and research papers focused on ensuring the protection of the environment and satisfaction of human need has become an important research subject (Ušeckienė & Targamadžė, 2005). In recent years, more and more studies have focused on the cultivation of energy literacy in Taiwan, with hopes of protecting the natural environment by improving the energy literacy of society (Lee, Lee, Altschuld, & Pan, 2015; Yeh, Huang, & Yu, 2017). According to the findings of research on energy literacy, people's energy-related knowledge and attitudes are satisfactory; however, their engagement in energy conservation behavior is not as satisfactory. Therefore, Lee et al. (2015) and Lee, Chang, Lai, Guu and Lin (2017) suggest developing methods to effectively improve energy conservation behavior as a valuable research topic in the field of sustainable development.

Past research suggested that an energy-related attitude is a key factor influencing energy conservation behavior (Lee et al., 2015; Lee et al., 2017). However, a research by Ntona, Arabatzis, and Kyriakopoulos (2015) on students' lack of willingness to engage in energy conservation behavior showed that personal traits as well as social and environmental constraints likely play a role. For example, in areas with frequent rain, it is considered inconvenient to save energy by riding a bicycle to school. Therefore, students usually go to school by car. In addition, although it was found that students have a reasonable level of understanding of energy-related knowledge and various scientific concepts related to the impact of energy use on the environment, they seem less concerned about major energy-related issues. Some students implement simple energy conservation practices in daily life; however, for energy-saving measures that require more effort such as collecting recyclable items and persuading others to take steps to conserve energy and reduce their carbon footprint, the willingness to participate is greatly reduced (Chen, Chou, Yen, & Chao, 2015)

To effectively improve energy literacy and energy conservation behavior this research initiated a project-based activity. Other scholars have also attempted to use project-based activities to cultivate students' energy literacy. Verbič, Keerthisinghe, and Chapman (2017) utilized project-based activities to guide students to explore the sustainable energy system. The results showed that the project-based approach could help students develop a positive



JOURNAL  
OF BALTIC  
SCIENCE  
EDUCATION

ISSN 1648-3898 /Print/  
ISSN 2538-7138 /Online/

**Abstract.** *Energy literacy is a key factor in ensuring the protection of the natural environment. Numerous studies on energy literacy have demonstrated the development of instructional methods to promote the willingness to save energy as a critical research subject. Through a project-based activity, this research explored how hands-on activities improve the energy literacy of students. A quasi-experimental design was adopted, namely a pre-test and post-test nonequivalent control group design. In total, 77 senior high school students participated in a 6-week teaching experiment. A single-factor analysis of covariance (ANCOVA) and multiple regression analyses were employed to analyze the collected data. The main findings were as follows: (1) Project-based hands-on activities helped improve the energy literacy of senior high school students; however, the effect was not statistically significant in both experimental and control groups. (2) The key factor influencing the energy conservation behavior of senior high school students was energy-related attitudes following the project-based learning process.*

**Keywords:** *Energy literacy, project-based activity, senior high school students, solar-powered insect trap.*

**Kuen-Yi Lin**  
National Taiwan Normal University, Taiwan  
**Shao-Chuan Lu**  
New Taipei Municipal Yong Ho Junior High  
School, Taiwan



attitude towards energy conservation and indirectly influence their energy conservation practice. Karpudewan, Ponniah, and Zain (2016) introduced a project-based activity to cultivate students' energy conservation practices. An analysis of the collected qualitative data indicates that students' energy conservation behavior improved following the activity. Although previous research explored the correlation between project-based activities and energy literacy, a direct quantitative evidence has been obtained to empirically confirm that project-based activities improve energy conservation knowledge and attitude but energy conservation behavior is not included.

To address this research gap in this research, the project-based activities were developed, which involved designing and constructing a solar-powered insect trap. The justification for utilizing solar-powered insect traps as the focus of the project-based activity is that by doing so, students engage in an in-depth exploration. Thus, when they are involved in agricultural jobs in the future, they may have the awareness to reduce the application of pesticides and adopt more environmentally friendly techniques to curb pests. In order to discuss the effect of project-based activities on high school students' energy literacy, this research has two primary purposes: (1) To explore the effect of the project-based design and construction of solar-powered insect traps on senior high school students' energy literacy (energy-related knowledge, energy-related attitude, and energy conservation behavior); and (2) to examine the key factors affecting senior high school students' energy conservation behavior.

### *Energy Literacy and Key Factors Influencing Energy Conservation Behavior*

Energy literacy and the contents thereof have been researched at length. DeWaters and Powers (2013) reviewed and summarized numerous related studies, concluding that energy literacy is composed of cognitive, affective, and behavioral dimensions. Based on this conclusion, individuals that are energy literate should have the following characteristics. They should (1) have a basic understanding of energy consumption in their daily lives; (2) understand the environment and social impact of energy production and consumption; (3) recognize the impact of energy-related decisions and actions of individuals, groups, and corporations on global society; (4) understand the necessary requirements for energy conservation, carbon footprint reduction, and the development of alternative energy sources; and (5) be dedicated to adopting choices, decisions, and actions that reflect such an understanding and attitude towards energy development and consumption, as well as corresponding skills (DeWaters & Powers, 2013).

In addition to the dimensions and definition proposed by DeWaters and Powers (2013; 2011), energy literacy includes the educational dimensions of civic responsibility and participation. In addition to the subtle influence on students' behaviors, energy literacy requires that students acquire scientific knowledge and the ability to make informed judgments (Chen, Liu, & Chen, 2015). Therefore, DeWaters and Powers (2013) emphasized that energy literacy includes an in-depth understanding of the relevant science and technology to ensure that accurate value-based judgments can be made during energy conservation practices. Studies on energy literacy education determined that students' misconceptions negatively impact the learning of scientific knowledge and the tendency to mislead energy literacy education, damaging energy-related behaviors. One such example is that students in Taiwan generally believe that wind power should replace thermal power generation; however, they are not aware of the topographical and social factors that hinder wind power. Therefore, the successful application of scientific knowledge is an important subject in energy-related education (Yeh, Huang, & Yu, 2017).

Further exploration on the behavioral dimensions of energy literacy revealed that the cultivation of energy literacy should focus on developing civic responsibilities and changes in living habits, and the ability to aptly apply scientific and technological knowledge to adopt appropriate energy conservation behaviors when faced with energy issues (Chen, Huang, & Liu, 2013; DeWaters, & Powers, 2013; Lee, Lee, Altschuld, & Pan, 2015). Chen, Huang, and Liu (2013) proposed a framework for energy education, emphasizing that civic responsibility for creating a sustainable society is the major behavioral dimension impacting energy literacy. As for college students' energy behaviors in college accommodation, these energy behaviors may differ in their daily life that imply some other factors, like motivation, civic responsibility or even country policy, which may affect their attitudes (Cotton, Shiel, & Paço, 2016; Chiang, Mevlevioglu, Natarajan, Padget, & Walker, 2014). In order to explore the approaches in developing college students' energy literacy, Demeo, Feldman, and Peterson (2013) utilized the human ecology approach and hands-on projects in enhancing college students energy literacy, and the results of students' feedback are positive.

In addition to cultivating energy literacy, energy education should further consider and explore solutions to the lack of energy conservation behaviors (Lee et al., 2015; Lee et al., 2017). DeWaters and Powers (2011) contend that energy conservation behavior is influenced by energy-related attitudes rather than energy-related knowledge.



Specifically, even if students are well versed in energy-related knowledge, they may not necessarily engage in energy conservation behaviors. However, if students have a constructive attitude towards energy conservation, they are more likely to demonstrate such attitudes through their actions. The viewpoints of DeWaters and Powers (2011) are well accepted by scholars (Lee et al., 2015; Lee et al., 2017). Hence, further studies have been conducted to analyze the likely contexts and explanations for the situation. Ntona, Arabatzis, and Kyriakopoulos (2015) suggested that students' lack of willingness to implement energy conservation measures is related to their personal traits and societal and environmental constraints. According to their research, 66.67% of explored students had the habit of turning off the lights when they were the last to leave the rooms of their house; however, only 21.69% of students turned off the lights when they were the last to leave the classroom. Chen et al. (2015) believed that students apply only basic energy conservation measures and are less willing to actively participate in energy-saving and environmental protection activities, even if they are aware of the destruction of not doing so on the global environment. According to the results of these studies, it is important to encourage students to actively adopt a wider range of energy conservation measures to protect the environment in addition to daily energy-saving practices. In the present research, the researchers aimed to resolve this problem through the project-based activities.

### *Effects of Project-Based Activities on Energy Literacy*

Project-based activities have three design characteristics: the learning processes should be well designed, learners should be actively involved in the learning, and the teaching process should be achieved through knowledge sharing and team-based cooperation (Kokotsaki, Menzies, & Wiggin, 2015). Therefore, the content of project-based learning activities requires careful design and adjustment to match the context to enable students to actively participate in activities and engage in discussions (Can, Yıldız-Demirtaş, & Altun, 2017). Through peer interaction, students can receive feedback and make cognitive, affective, and behavioral changes when necessary (Han, Capraro, & Capraro, 2015). The purposes of project-based activities are to develop students' sense of responsibility for the learning content and provide them with the ability to learn through cooperation with others (Bilgin, Karakuyu, & Ay, 2015). In the activities, students receive feedback through group discussion and recognition by playing their assigned roles, establishing a positive attitude towards the learning content. Well-designed project-based activities have been shown to enhance students' achievements and improve attitudes (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 2011). Project-based activities with other pedagogical methods, like STEM, would change students' attitudes toward the learning topics (Al-Balushi, & Al-Aamri, 2014). Therefore, compared to teacher-centered teaching methods, project-based learning stimulates students' learning motivation, affects their attitudes and cultivates their comprehension of the content (Kokotsaki, Menzies, & Wiggins, 2016; Lee, Lin, Guu, Chang, & Lai, 2013).

Many scholars have utilized project-based activities (e.g. design and making an energy-saving house) to cultivate students' energy literacy. DeWaters and Powers (2011) designed project-based activities based on energy use, finding that students acquired extensive knowledge related to energy use in daily life and could reflect on energy-related issues such as energy consumption and conservation. Verbič, Keerthisinghe, and Chapman (2017) designed project-based activities to help students better understand sustainable energy sources. Their results showed that students were very satisfied with the implementation of the project-based activity and presented a positive energy-related attitude. Karpudewan, Ponniah, and Zain (2016) utilized project-based activities to demonstrate solar furnaces and generative fuel. Their analysis of qualitative data revealed a positive change in students' energy-related knowledge and attitudes, and in their energy conservation behavior. Lee et al. (2012) developed project-based activities based on energy saving in homes. The findings suggested that such activities benefitted students' acquisition of energy-related knowledge, established a positive attitude towards energy conservation, and developed energy conservation behaviors.

Although previous research explored the effects of project-based activities on improving energy literacy and discovered a positive impact on energy-related knowledge and attitudes, concrete results on the impact on energy conservation behavior remain insufficient. Karpudewan, Ponniah, and Zain (2016) adopted an observation method and analyzed qualitative data, but did not use quantitative, empirical data to support their findings. Although Lee et al. (2013) suggested that project-based activities are beneficial to improving energy conservation behavior, their experiment only revealed that the performance of the experimental group in the posttest was better than that in the pretest. Results of the one-way ANOVA indicated that the differences in performance between the experimental and control groups were not statistically significant.



To address this research gap, this research aimed to design project-based activities to effectively alter students' energy conservation behaviors, cultivate their sense of civic responsibility, and change their living habits so that they can apply corresponding scientific and technological knowledge, possess positive attitude toward energy conservation and adopt beneficial behaviors related to energy issues.

## Methodology of Research

### Research Design

This research explored the effects of project-based activities on cultivating the energy literacy of senior high school students using project-based activities in the design and construction of a solar-powered insect trap. The pre-test and post-test nonequivalent control group from a quasi-experimental design was adopted (Table 1). The theme of the project was to design and construct a solar-powered insect trap. Students received knowledge related to the development of the solar-powered insect trap and conducted in-depth discussions and related research on the design and construction thereof. In terms of the experiment method, the experimental group received a set of project-based hands-on activities on the design and construction of a solar-powered insect trap, while the control group was taught the same subject matter through traditional teaching methods, where written reports served as the channel for discussion. The written reports were developed in group and the group leaders were in charge of distributing tasks for each team members. They have to discuss the results of data collection and interviews, and recoding what they have found during the process of discussion. The Energy Literacy Scale (ELS) developed by Lee et al. (2017) was employed in the pretest to control differences in students' prior knowledge, attitudes, and behaviors. The same scale was employed in the posttest. However, to avoid the impact of the memory effect on the results, the researchers purposely adjusted the order of the questions without changing the wording of the items in the Energy Literacy Scale questionnaires.

**Table 1. Research design of this research.**

Group	Pre-test	Experimental treatment	Post-test
Experimental group	Energy Literacy Scale (Lee et al.2015)	A project-based hands-on activities focusing on the design and construction of solar-powered insect traps.	Energy Literacy Scale (Lee et al.2015)
Control group	Energy Literacy Scale (Lee et al.2015)	A teacher-centered teaching activities focusing on introducing knowledge related to solar-powered insect traps, with a focus on submitting research reports without constructing actual solar-powered insect traps.	Energy Literacy Scale (Lee et al.2015)

*Note: The Energy Literacy Scale questionnaires used in the posttest were altered to limit the effect of memory. The order of the questions was different, but the questions themselves were unchanged.*

### Sample

Two groups of third-year students from a senior high school in Taiwan were selected as the participants. The researchers randomly selected one group (40 students) as the control group to receive the teacher-centered teaching activities and the other group (37 students) as the experimental group to participate in the project-based activities. The control group consisted of 21 male and 19 female students, while the experimental group consisted of 20 male and 17 female students. The selected school specialized in farm management. Therefore, the designed project-based activities should stimulate past knowledge and install a methodology to combine the research findings of the course with future farming practices. In addition, this design allowed the researchers to control variables that may have affected the outcome of the experiment, such as the "subject characteristics" threat, "data collector" bias, "testing" threat, and "implementation" threat ) to ensure the validity and reliability of the results (Fraenkel, Wallen, & Hyun, 2012). As for the ethical procedure, all the participants are informed about the purposes of this study, all data will be safeguarded, and they can refuse to participate in the research or cut short their participation without



any reason. Besides, all participants in the control group with receiving the teacher-center teaching activities will be invited to join an extra project-based activities after the teaching experiment for the purpose of allowing them to experience hands-on activities.

### Procedure

This research design was made of project-based activities. The project-based activities included 12 sessions (600 minutes in total) over 6 weeks. The theme of the course was solar-powered insect traps (Figure 1). In Taiwan, it is hard to see solar-powered insect traps, most farmers are using chemical pesticides for their conveniences and lead to server environmental pollution. The solar-powered insect traps with water pan are much more efficient and environmentally friendly than other devices. Since the target samples may engage in related work in the future, the project provides them a practical way in improving their energy literacy. The solar-powered insect traps are controlled by CdS photoresistor and the bulb light powered by solar panels was designed to attract insects in the night. The water pan below was used to kill insects (Figure 2). Students were expected to acquire related knowledge and participate in in-depth discussions and research. The experimental group was given project-based activities, wherein they were expected to design and construct solar-powered insect traps. The control group was taught through teacher-centered teaching activities, and was expected to submit written reports. The teaching activities conducted in both groups are described in Table 2. Furthermore, in order to explore the effects of project-based activities in developing students' energy literacy, this research conducted a pre-test and post-test in the first week and twelfth week respectively. In addition, to avoid the memory effect on the outcome of the experiment, the order of the items in the ELS was different in the two tests.

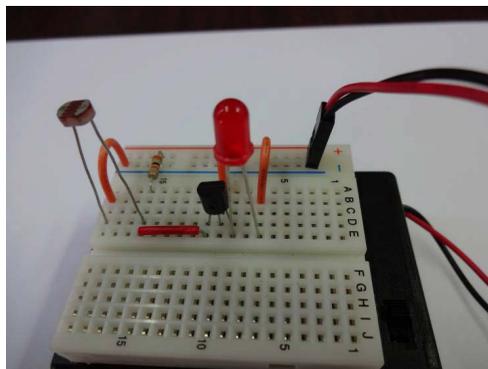
**Table 2. Teaching activities.**

Sessions	Experimental Group	Control Group
1	<ul style="list-style-type: none"> <li>Course introduction</li> <li>Pre-test of energy literacy</li> </ul>	
2	<ul style="list-style-type: none"> <li>Introduction of solar energy</li> <li>Understanding solar cells and storage devices</li> </ul>	
3	<ul style="list-style-type: none"> <li>Introduction of pest control technology</li> <li>Understanding how light-based insect traps work</li> </ul>	
4	<ul style="list-style-type: none"> <li>Understanding the physical structure and theoretical principle of solar insect traps</li> <li>Learning about the materials used in "drowning type" solar insect traps</li> </ul>	
5	<ul style="list-style-type: none"> <li>Design of the solar insect trap (Session 5-6)</li> </ul>	<ul style="list-style-type: none"> <li>Collection of past studies on solar insect traps</li> </ul>
6		<ul style="list-style-type: none"> <li>Analysis of past studies on solar insect traps</li> </ul>
7	<ul style="list-style-type: none"> <li>Construction of the solar insect trap (Session 7-10)</li> </ul>	<ul style="list-style-type: none"> <li>Exploration of the current situation and problems in the practical application of solar insect traps</li> </ul>
8		<ul style="list-style-type: none"> <li>Proposition of measures to improve the practical application of solar insect traps</li> </ul>
9		<ul style="list-style-type: none"> <li>Conducting of interviews to examine the feasibility of the proposed measures</li> </ul>
10		<ul style="list-style-type: none"> <li>Compilation of the results of the interviews</li> </ul>
11	<ul style="list-style-type: none"> <li>Presentation of the constructed solar insect trap</li> <li>Testing the constructed solar insect trap</li> </ul>	<ul style="list-style-type: none"> <li>Creation of reports of what was learned</li> </ul>
12	<ul style="list-style-type: none"> <li>Reflection on the course</li> <li>Post-test of energy literacy</li> </ul>	





**Figure 1.** Applying the constructed solar insect trap in the field.



**Figure 2.** Light activated switch for light-emitting diode designed by the students.

#### *Instruments*

The ELS developed by Lee et al.(2017) was introduced to measure the energy literacy of the participants. The ELS consists of three sub-scales, measuring energy-related knowledge (knowledge), energy-related attitude (attitude), and energy conservation behavior (behavior). The knowledge sub-scale consists of 38 items covering the dimensions of basic scientific energy concepts, energy sources and resources, energy generation and usage, and energy impact on the environment/society. The attitude sub-scale is composed of 19 items, covering dimensions regarding concerns about the issues of global energy and positive attitudes and values. The behavior sub-scale includes 27 items, covering dimensions related to actions for energy conservation and change advocacy. The results of the pre-test, item analysis, and factor analysis indicated that the item discrimination is good in knowledge subscale, and the reliability analysis is 0.88 in behavior subscale and 0.90 in affect subscale (Lee et al., 2017). Therefore, the scale had good reliability and validity and could be used to effectively measure the energy literacy of high school students.

#### *Data Analysis*

An ANCOVA was employed to compare the effects of teacher-centered and project-based activities on improving the energy literacy of senior high school students. The students' ELS results, which are developed by Lee et al. (2017) were adopted as the covariate to exclude any prior differences in knowledge, attitude, and behavior. In addition, a multiple regression analysis was conducted to further explore the factors influencing participants' energy conservation behavior.



## Results of Research

### *Effects of the Project-Based Activities on Energy Literacy*

According to the results of the pre-test and post-test (Table 3), knowledge, attitude, and behavior in the experimental group in the post-test were all slightly greater than those obtained in the pre-test. The attitude and behavior dimensions of the control group in the posttest were also slightly greater than that in the pretest; however, the results for knowledge in the posttest declined slightly from those obtained in the pretest. Since these results did not exclude prior differences in energy literacy among participants, an ANCOVA was employed to explore the effects of the project-based and teacher-centered activities on improving participants' energy literacy.

**Table 3. Summary of ELS results.**

Dimension	Experimental Group (N = 37)			Control Group (N = 40)		
	<i>M</i>	<i>SD</i>	95% CI	<i>M</i>	<i>SD</i>	95% CI
Pre-test						
1. Knowledge	65.08	9.15	[62.03, 68.13]	63.88	12.34	[59.93, 67.83]
2. Attitude	4.44	.46	[4.28, 4.59]	4.28	.55	[4.10, 4.46]
3. Behavior	3.88	.47	[3.72, 4.04]	3.74	.70	[3.51, 3.96]
Post-test						
1. Knowledge	67.35	8.96	[64.37, 70.34]	62.89	13.96	[58.43, 67.36]
2. Attitude	4.48	.40	[4.35, 4.62]	4.40	.56	[4.23, 4.59]
3. Behavior	4.02	.58	[3.83, 4.22]	3.95	.77	[3.71, 4.20]

Before conducting the ANCOVA, the homogeneity hypothesis of the within-group regression coefficients was tested. The results showed that the hypothesis was supported for knowledge ( $F [1, 73] = 1.13, p = .29$ ), attitude ( $F [1, 73] = .17, p = .68$ ), and behavior ( $F [1, 73] = .63, p = .43$ ), suggesting that an ANCOVA could be performed.

The results of the ANCOVA are exhibited in Table 4. The table shows that the between-group effects of knowledge, attitude, and behavior were not statistically significant. These findings indicate that no substantial differences exist in the improvement of knowledge, attitude, and behavior between participants that received teacher-centered and project-based activities.

**Table 4. Results of the ANCOVA of energy literacy.**

Source of Variation	<i>SS</i>	<i>Df</i>	<i>MS</i>	<i>F</i>	$\eta^2$
1. Knowledge					
Between-Group	288.83	1	288.83	2.54	.03
Within-Group (Error)	8403.22	74	113.56		
Corrected Total	10870.82	76			
2. Attitude					
Between-Group	.01	1	.01	.08	<.01
Within-Group (Error)	10.40	74	0.14		
Corrected Total	18.13	76			
3. Behavior					
Between-Group	.02	1	.02	.07	<.01
Within-Group (Error)	20.67	74	.28		
Corrected Total	35.26	76			

Remark: \* $p < .05$



*Factors Influencing Energy Conservation Behavior*

Since the results of the ANCOVA suggested that the project-based activities did not achieve their expected outcome, further analysis was conducted to explore the factors influencing participants' energy conservation behavior. The results of the behavior-sub-scale in the posttest were used as the dependent variable, and all-possible-regression procedure was applied to enter all other variables as independent variables in the multiple regression analysis. A standardized regression coefficient was used as the path coefficient.

**Table 5. Summary of simultaneous regression analysis.**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.76	.58	.55	.46	2.09

**Table 6. Summary of regression ANOVA.**

Model	Sum of Squares	Degree of Freedom	Mean Square	F
1 Regression	20.34	5	4.07	19.36*
Residual Error	14.92	71	.21	
Total	35.26	76		

Remark: \*  $p < .001$

**Table 7. Summary of regression coefficients.**

Model	Unstandardized Coefficients		Standardized Coefficients	t	Confidence Interval	
	B	SE	$\beta$		Lower limit	Upper limit
1 (Constant)	-.05	.57		-.09		
Knowledge (Pre-test)	-.01	.01	-.12	-1.31	.73	1.38
Attitude (Pre-test)	-.24	.15	-.17	-1.58	.47	2.13
Behavior (Pre-test)	.51	.12	.45	4.15*	.51	1.96
Knowledge (Post-test)	<.01	.01	.06	.73	.77	1.30
Attitude (Post-test)	.76	.15	.55	5.02*	.50	1.99

Note: 1. \*  $p < .001$ ; 2. The dependent variable is the participants' performances in the behavior sub-scale in the post-test.

As shown in Tables 5 to 7, attitude in the posttest and behavior in the pretest effectively explained 58.0% of the total variance in energy conservation behavior ( $F [5, 71] = 19.36, p < .001$ ). However, further examination of Table 7 reveals that participants' attitude following the project-based activities was the main factor improving their behavior.

**Discussion**

The results of the experiment revealed that compared to a teacher-centered activities, the application of the project-based activities had no statistically significant effect on improving the energy literacy of senior high school students after receiving education on solar-powered insect traps. One explanation of these findings could be that both the control and experimental groups were given a theme-based course which is focused on the solar insect traps. The main difference is that the experimental group was required to actually design and construct solar insect traps, while the control group was not required to do so. Therefore, the impact of the hands-on activity on improving energy literacy was limited. These findings echoed the results of Lee et al. (2013), which found that to effectively change students' energy conservation behavior, the focus should be on guiding students to reflect on



their civic responsibilities. However, it is still hard to present the effects of project-based activities if we just focused on the civic responsibilities. Therefore, we believe that there are other reasons to explain the results of this research.

Another explanation could be insufficient time. Since the experiment consisted of 12 sessions over a 6-week period, participants in the experimental group were required to learn the relevant knowledge and related skills required to construct a solar insect trap (such as welding circuits). Thus, it was unlikely that there was sufficient time to improve energy conservation behavior. Verbič, Keerthisinghe, and Chapman (2017) also found that during the first year of their research project, students complained about insufficient learning time, reported low satisfaction with the project, and demonstrated limited achievements in their research. However, after increasing the learning hours in the second year, students' satisfaction and learning effects considerably improved. The students who were more familiar with the topic may improve more. Therefore, if sufficient learning hours could be included in the design of future experiments, students' energy conservation behavior may improve.

In addition to the ANCOVA, this research also employed a multiple regression analysis to explore the major factors influencing students' energy conservation behavior following the experiment. The results showed that students' attitude towards energy conservation following the experiment had the greatest explanatory power ( $\beta = .55, p < .001$ ), followed by their behavior prior to the experiment ( $\beta = .45, p < .001$ ). The effects of pre-experiment behavior on behavior following the experiment was as expected. Students who participated effectively in energy conservation also did so following the course. However, noteworthy is that students' attitude following the course had the greatest explanatory power on their subsequent behavior. This correlation between energy-related attitude and energy conservation behavior is consistent with the findings of previous studies (Lee et al., 2015; Lee et al., 2017). More important, the results confirmed that the attitude following the corresponding courses had the greatest impact on improving students' energy conservation behavior. Therefore, if teachers design project-based activities that promote students' positive attitudes towards energy consumption and conservation, their energy conservation behavior is likely to improve.

According to previous discussion, we know that the energy-related attitude plays an important role in influencing students' energy conservation behavior according to the previous studies (Lee et al., 2015; Lee et al., 2017). However, this research proposes the idea that if teachers hope to design the project-based activities in developing students' energy conservation behavior, they have to notice the following two principles: (1) to provide sufficient time to students in project-based activities; (2) to focus on developing students energy-related attitude in project-based activities.

## Conclusions

How to effectively improve energy conservation behavior is a valuable research topic in the field of sustainable development. This research focused on exploring the effects of project-based hands-on activities in developing students' energy literacy and two major conclusions are made in this research. First of all, the project-based hands-on activities helped improve the energy literacy of senior high school students; however, the effect was not statistically significant in both experimental and control groups. Secondly, the key factor influencing the energy conservation behavior of senior high school students was energy-related attitudes following the project-based learning process. According to these conclusions, the most important contribution of this study is that we provide two important principles in designing project-based activities; that is, to provide sufficient time to students, on the one hand, and to focus on developing students' energy-related attitude, on the other hand.

## Limitations

The major limitation of this research is the duration of the experiment. Since the duration of the experiment must satisfy the requirements of the school curriculum, teachers' agendas, and students, the solar insect trap project had to be completed within a limited period. Besides, the students' hands-on experiences in experimental group and control group are not taken into consideration, which may lead to the limitation of controlling students' practical skills. Furthermore, existing energy literacy scales tend to target general energy literacy. As such, they cannot effectively reflect specific energy conservation behaviors. Specifically, the results of this research did not effectively indicate whether participation in the project-based activities encouraged participants to utilize solar insect traps rather than pesticides to avoid environmental pollution in their future farm management practices.



### Implications

Based on the findings and discussions of the research, the current researchers believe that project-based activities remain a valuable practice to improve students' energy literacy. It is recommended that future studies consider the following suggestions. (1) It is recommended to provide sufficient learning time when designing project-based activities to ensure that students have sufficient practice and reflection time, thereby removing the negative impact of insufficient time on the outcome of the experiment. (2) It is recommended that the items in the ELS be modified to fit the theme of the project, thereby enabling more effective measurement of the changes in students' behavior following the project. (3) Since energy-related attitudes were found to alter energy conservation behavior, it is recommended that further research be conducted to discover concrete methods to improve students' energy-related attitudes, thereby improving their energy conservation behaviors.

### Acknowledgements

This research was supported by the Ministry of Science and Technology of Taiwan, under project number NSC 102-3113-S-239-001 and MOST 105-2628-S-003-001-MY3.

### References

- Al-Balushi, S. M., & Al-Aamri, S. S. (2014). The effect of environmental science projects on students' environmental knowledge and science attitudes. *International Research in Geographical and Environmental Education*, 23 (3), 213-227.
- Bilgin, I., Karakuyu, Y., & Ay, Y. (2015). The effects of project based learning on undergraduate students' achievement and self-efficacy beliefs towards science teaching. *Eurasia Journal of Mathematics, Science Technology Education*, 11 (3), 469-477.
- Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (2011). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational psychologist*, 26 (3-4), 369-398.
- Can, B., Yildiz-Demirtaş, V., & Altun, E. (2017). The effect of project-based science education programme on scientific process skills and conceptions of kindergarten students. *Journal of Baltic Science Education*, 16 (3), 395-413.
- Chen, K. L., Huang, S. H., & Liu, S. Y. (2013). Devising a framework for energy education in Taiwan using the analytic hierarchy process. *Energy Policy*, 55, 396-403.
- Chen, K. L., Liu, S. Y., & Chen, P. H. (2015). Assessing multidimensional energy literacy of secondary students using contextualized assessment. *International Journal of Environmental and Science Education*, 10 (2), 201-218.
- Chen, S. J., Chou, Y. C., Yen, H. Y., & Chao, Y. L. (2015). Investigating and structural modeling energy literacy of high school students in Taiwan. *Energy Efficiency*, 8 (4), 791-808.
- Chiang, T., Mevleviöglu, G., Natarajan, S., Padget, J., & Walker, I. (2014). Inducing [sub]conscious energy behaviour through visually displayed energy information: A case study in university accommodation. *Energy and Buildings*, 70, 507-515.
- Cotton, D., Shiel, C., & Paço, A. (2016). Energy saving on campus: a comparison of students' attitudes and reported behaviours in the UK and Portugal. *Journal of Cleaner Production*, 129, 586-595.
- Demeo, A. E., Feldman, D. P., & Peterson, M. L. (2013). A human ecological approach to energy literacy through hands-on projects: An essential component of effectively addressing climate change. *Journal of Sustainability Education*, 4, 1-16.
- DeWaters, J. E., & Powers, S. E. (2011). Energy literacy of secondary students in New York State (USA): A measure of knowledge, affect, and behavior. *Energy Policy*, 39 (3), 1699-1710.
- DeWaters, J., & Powers, S. (2013). Establishing measurement criteria for an energy literacy questionnaire. *The Journal of Environmental Education*, 44 (1), 38-55.
- Han, S., Capraro, R., & Capraro, M. M. (2015). How science, technology, engineering, and mathematics (STEM) project-based learning (PBL) affects high, middle, and low achievers differently: The impact of student factors on achievement. *International Journal of Science and Mathematics Education*, 13 (5), 1089-1113.
- Karpudewan, M., Ponniah, J., & Zain, A. N. Md. (2016). Project-based learning: An approach to promote energy literacy among secondary school students. *The Asia-Pacific Education Researcher*, 25 (2), 229-237.
- Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving schools*, 19 (3), 267-77.
- Lee, L. S., Chang, L. T., Lai, C. C., Guu, Y. H., & Lin, K. Y. (2017). Energy literacy of vocational students in Taiwan. *Environmental Education Research*, 23(6), 855-873. <https://doi.org/10.1080/13504622.2015.1068276>.
- Lee, L. S., Lee, Y. F., Altschuld, J. W., & Pan, Y. J. (2015). Energy literacy: Evaluating knowledge, affect, and behavior of students in Taiwan. *Energy Policy*, 76, 98-106.
- Ntona, E., Arabatzis, G., & Kyriakopoulos, G. L. (2015). Energy saving: Views and attitudes of students in secondary education. *Renewable and Sustainable Energy Reviews*, 46, 1-15.



- Ušeckienė, L., & Targamadžė, V. (2005). Challenges of sustainable development education to higher education in Lithuania. *Journal of Baltic Science Education*, 4 (2), 68-79.
- Verbič, G., Keerthisinghe, C., & Chapman, A. C. (2017). A Project-based cooperative approach to teaching sustainable energy systems. *IEEE Transactions on Education*, 60 (3), 221-228.
- Yeh, S. C., Huang, J. Y., & Yu, H. C. (2017). Analysis of energy literacy and misconceptions of junior high students in Taiwan. *Sustainability*, 9 (3), [423]. <https://doi:10.3390/su9030423>.

Received: June 06, 2018

Accepted: September 30, 2018

**Kuen-Yi Lin**

PhD, Professor, Department of Technology Application and Human Resource Development, National Taiwan Normal University, Taipei City 106, Taiwan.  
E-mail: linkuenyi@ntnu.edu.tw

**Shao-Chuan Lu**

Technology Teacher, New Taipei Municipal Yong Ho Junior High School, New Taipei City 234, Taiwan.  
E-mail: mrfpkimo@gmail.com

