Energy Literacy of Secondary Students in Taiwan: A Computer-based Assessment

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ABSTRACT

Energy literacy is multidimensional, comprising broad content knowledge as well as affect and behavior. Our previous study has developed a framework for energy education through literature analysis and collation of expert opinions [1]. The framework comprises four dimensions: energy concepts, reasoning on energy issues, low-carbon lifestyle, and civic responsibility for a sustainable society. The design of the test items is referred to the PISA's format, and then converted into a computer-based assessment. Various types of question items (e.g. cluster true-false, multiple choice, and short answer questions) are organized in groups under a multimedia material (eg., image, short video, and animation) that require students to construct responses and make judgments in a contextualized task. This assessment has been used for field study with a sample of 686 middle and high school students. Results indicate examinees have higher confident and acceptance of the test and complete the assessment in the time of testing. Results show that there are significant differences between groups of 7th and 11th graders on the performance of energy literacy. The 11th graders gain higher scores on three dimensions of energy literacy (energy concepts, reasoning on energy issues, and low-carbon lifestyle) than the 7th graders. Data generated from this computer-based test has a good fit of model and provides empirical evidence to evaluate the validity of the assessment framework of energy literacy for secondary school students. Implications of these findings for promotion of energy education with energy literacy are discussed.

KEYWORDS Energy education, Energy literacy, Assessment, Contextualized test unit.

1 INTRODUCTION

Over the past two decades, research in energy education has gained importance on account of wars and economic turmoil [2]. Educational programs enhance individual attitudes and promote values to improve the rational use of energy [3]. The Directorate-General for Energy and Transport [4] has noted that a carbon-reduction curriculum could improve energy saving awareness and behavior. Previous studies have shown positive changes in energy-related behavior after participation in

an educational program [5][6].

The success of an energy education program should be based on an adequate assessment that includes not only cognitive aspects but affective and behavioral characteristics as well. Substantial studies have been performed on energy literacy surveys, but there is still a critical lack of comprehensive tests for energy literacy. The availability of a suitable instrument that measures broad energy literacy has been limited or non-existent [7] because literacy in these various aspects indicates having the knowledge and skills that are needed by everyone and the ability to use a general understanding of the main ideas when making informed decisions and participating in society [8]. We argue that the results generated from this kind of assessment do not represent the energy literacy levels because the assessment lacks a context for the respondents to think and solve energy-related problems in a holistic manner. In addition, based on a non-curricular approach, the test format is coherent with the general theoretical framework of the study [9][10]. Therefore, the format of the literacy-related assessment may be conducted as a series of contextualized questions to evaluate, from various perspectives, the complex process of the respondents' understanding of the material [11].

As moving into a future with limited fossil fuels resources and worsening environmental conditions, societies in the developed world are faced with defining new options with respect to energy consumption, energy resources, and a shift toward energy independence[12]. Energy literacy supports an understanding of the impact of energy use on sustainability [13]. Increasing energy literacy amongst pupils can transform them into sustainable energy-friendly consumers and citizens when they grow up [6]. In the Taiwanese context, the concepts and components of energy literacy are not taught as a single subject but integrated across curricula at all levels of schools. There is a need to know the level of energy literacy among students as an indicator of the effectiveness of the energy literacy efforts for shifting toward an energy conservation society [14]. To measure energy literacy among secondary students in Taiwan, we recently developed a computer-based assessment based on a comprehensive framework proposed by Chen et al.[1] and referred to PISA's format that used a computer-based test in which a multimedia material (eg., image, short video, and animation) that require students to construct responses and make judgments in a contextualized task. This instrument had multiple types of questions in groups within contexts that pertained to real-life situations and required the students to construct responses and make judgments. Our goal was to determine the following:

- How do Taiwanese students perform on the four dimensions of energy literacy: Energy concepts, reasoning on energy issues, low-carbon lifestyle, and civic responsibility for a sustainable society?
- Is there any relationship between four dimensions and overall energy literacy?
- How does performance vary between groups of 7^{th} and 11^{th} graders on the performance of energy literacy?

2 LITERATURE REVIEW

2.1 Environmental literacy

Energy conservation is an environmental issue [1]. Environmental literacy is a basic educational goal that empowers individuals

with the motivation, fundamental knowledge, and skills to cope with environmental needs and encourages them to contribute to sustainable development [15]. Environmental education has risen at this point with a target of growing environmental literate citizens [16]. In the 1990s, numerous research was conducted in the field of environmental education to develop frameworks for defining the components of environmental literacy [17], and these frameworks guided several national assessments of environmental literacy [18][19][20]. According to the research on assessment frameworks, the components of environmental literacy include knowledge, skill, affective, and behavior [21].

The North American Association for Environmental Education defined environmental literacy as, "the knowledge, dispositions, competencies, and environmentally responsible behavior of students that enables students to make decisions and act to address environmental issues." McBeth et al. [18] proposed the "Middle School Environmental Literacy Assessment" (MSELS) and provided empirical findings from a North Carolina survey to identify the different parts of environmental literacy: (a) ecological knowledge, (b) verbal commitment, (c) actual commitment or environmental behavior, (d) environmental sensitivity, (e) issue identification and issue analysis skills, and (f) action planning. MSELS includes measures in four of the five domains commonly regarded as critical to environmental literacy: Knowledge, affect, cognitive skills, and behavior [22].

2.2 Energy literacy

Energy is a key topic of education for climate change. Energy literacy is the greatest potential resource for solving our national energy crisis (DeWaters and Powers, 2011). The notion of energy literacy comprises broad content knowledge as well as affective and behavioral dimensions and the competency that people should have to make wise choices and commit to energy conservation [7][12][23][24].

DeWaters and Powers[7][23] provided empirical findings from their survey in New York State. They developed the "Energy Literacy Questionnaire" to assess secondary students' energy literacy in the three core dimensions: Cognitive (knowledge), affective (attitudes, values), and behavior. The study emphasized that energy literacy embodies more than just content knowledge, it also includes citizen engagement. Furthermore, other studies [12][25] utilized the Energy Literacy Questionnaire to investigate the levels of energy literacy among 8th grade students in Malaysia. Those findings showed a need to emphasize the importance of practical energy-related knowledge, decision-making skills, value judgments, and ethical and moral dimensions related to energy conservation. Chen et al.[1] adopted the ideas of energy literacy and carbon capability and extended DeWaters and Powers' [7] original framework and conducted an analytical hierarchy process (AHP) method with a panel of experts to determine the four core dimensions of the framework: Energy concepts, reasoning on energy issues, low-carbon lifestyle, and civic responsibility for a sustainable society. As mentioned above, environmental literacy and energy literacy have certain dimensions in common, including knowledge, attitude, behavior, and civic engagement. The four core dimensions of energy literacy are described briefly as follows.

- Energy concepts: The measures of energy conservation and carbon are based on energy-related knowledge. An energy-literate individual should possess a basic understanding of energy concepts in order to actively participate in decision making for a low-carbon society.
- Reasoning on energy issues: An energy-literate person has the ability to evaluate the reliability of information sources that help ascertain how to use energy effectively. The dimension of reasoning of energy issues emphasizes an ability to examine and make judgments on energy-related issues.
- Low-carbon lifestyle: Individual behavior is important for government policy on carbon reduction and energy-related issues. For a sustainable society, individuals must choose to adapt their daily lifestyles to contribute to carbon reduction and energy conservation.
- Civic responsibility for a sustainable society: Individuals' awareness about climate change leads to their engagement in energy conservation activities and a shift towards a sustainable society. In the energy literacy assessment, the essential qualities of energy literacy include the ability to make informed judgments about the use of energy and the ability to take effective actions with regard to energy management.

2.3 Computer-based test (CBT)

Information and Communication Technology (ICT) has become a crucial component in education process [26]. A special form of ICT for assessment is the CBT, also known as Computer-Based Test [26]. CBT has been applied to test knowledge and problem solving skills since 1960s[27]. The ancient type of assessment using computer technology was designed to ask examinees to fill in their responses on a paper form and then to feed the paper into a computer optical mark reader. With computer technology advanced, the CBT represents a form that computers provide the assessment interface for student to input their answers via a computer. The advantages of CBT have been demonstrated in previous study [28] and as mentioned, CBT provide a standardized testing to be as nearly equal as possible for all examinees [29]. For example, using multimedia in CBT items, such as audio and large-print accommodations for vision-impaired students, becomes more accessible and convenient than the paper-and -pencil test (PPT) format for test developers and test takers [30]. Therefore, CBT have become a crucial part throughout the educational process at school, state, and national levels [31].

CBT becomes increasingly important in various field of competence assessment[29]. Complex problem solving is considered as the required competence for students to learn how to control a complex and dynamic system [32], and the competence performances can be measured by CBT even in large-scale assessments [33]. CBT are also used in the assessment of tacit knowledge about procedures and strategies that cannot easily be verbalized and therefore is very difficult to assess using conventional PPT [34]. The framework of energy literacy, as described above, includes the components that students are expected to have the ability to acquire energy-related knowledge, make informed judgments about energy saving and take actions as regards energy management in complex situation. In order to assess students' energy literacy in a more comprehensive manner, this study designed an assessment tool

that students are required to answer a series of question items after comprehending the scenarios presented as short texts, table and graphs, or even multimedia (e.g., image, short video, and animation). As such, the CBT provides accessibility and flexibility to this assessment design.

3 MATERIALS AND METHODS

3.1 Design of the computer-based assessment for measuring energy literacy

In consideration of the non-curricular approach and the various aspects of energy literacy, this study conducted a PISA-type assessment to gauge the energy literacy of secondary students. We design an energy literacy computer-based assessment to understand the energy literacy levels of a broad sample of Taiwanese secondary students.

The assessment included two parts: students' information survey and the energy literacy assessment. The first part of the instrument is consisted of items related to the students' backgrounds. The other part of the instrument is to assess the students' energy literacy. The contextualized test units presented the students with a real-life situation taken from authentic sources such as newspapers, blogs, and books about energy issues; the students were then asked to respond to a series of items about each problem or issue. Each item required the use of one of the skills and comprehensive energy knowledge. The items were arranged in units-groups of independently scored items based on a common stimulus. Many different types of stimuli (problems or issues) were used, including passages of image (Figure 1), short video (Figure 2), animation (Figure 3), as well as text (Figure 4), often in combination. This unit structure enabled us to use contexts that were as realistic as possible and that reflected the complexity of life situations, while making an efficient use of the testing time.

Figure 1. Contextualized test unit with image and true-false items

Figure 2. Screenshots of the short video

Figure 3. Screenshots of the animation

Figure 4. Contextualized test unit with text and multiple choices items

In addition to the items assessing the students' knowledge, and cognitive skills relevant to energy issues, each unit included two or three items designed to assess aspects of the students' attitudes toward energy conservation. In this article, we use the terms "cognitive items" and "attitudinal items" to distinguish between these two separate types of items, where necessary. Previous research indicated that a variety of test item formats could help accommodate the full range of student abilities [35]. Each unit contained up to four cognitive items. Each item aligned with one of the indicators in the energy literacy framework. In most cases, more than one component was assessed within a unit. Four types of item formats were used in the assessment. About a third of the items were selected-response (multiple-choice) items requiring the selection of a single response from four options. Another third were cluster true-false items and brief answer questions. The cluster true-false items required respondents to judge the correctness of each

statement. The brief answer questions required a relatively extended written response and some explanations or justification. The other third were 4-point Likert-type response scale questions for the attitudinal items.

3.2 Sample

The 687 participants in this study were secondary school students drawn from stratified randomly selected schools (18 junior high schools and 13 senior high schools). The students were gathered in the computer classroom at their school. Respondents were instructed on the nature of the instrument and how the instrument should be answered on the internet. Finally, the data was gathered from 376 junior (7^{th} graders) and 311 senior high school students (11^{th} graders), with roughly equal male/female composition across both groups (F: 48.2%/M: 58.2%).

3.3 Data collection and analysis

The students' questionnaire responses were converted to numerical scores and were written according to the particular subscale. The cognitive items were assigned one point for each correct answer and zero points for each incorrect or blank response. The affective items were converted to numerical values according to a predetermined preferred direction of response in order to calculate the summated rating totals for each subscale. The values for each Likert item ranged from one (strongly disagree) to four (strongly agree). The blank responses in these subscales were omitted case wise from the analysis. The total scores for each subscale were converted to a percentage. To ensure the reliability and validity of the scale item, we conducted Cronbach's alpha to evaluate the internal consistency, which exceeded the recommended minimum of 0.7 [36]. A confirmatory factor analysis, using structural equation modeling software (LISREL 8.51), was performed to test the validity and reliability of the assessment. The factor loadings were statistically significant and had values of 0.82 to 0.22, the composite reliability was 0.69, and the average extracted variance was 0.40. These values combined with good Cronbach's alpha coefficients of 0.85 provided evidence of the scale's reliability [37]. Finally, the discriminant validity among the dimensions of energy literacy was tested using Fornell and Larcker's [38] criteria, where the square root of AVE should be greater than the correlations between the construct for satisfactory discriminant validity. Consequently, it was determined that all dimensions exhibited satisfactory discriminate validity.

4 RESULT

4.1 Overall survey results

The performance summaries for the four dimensions of energy literacy are presented in Table 1. The assessment results in Table 1 indicate that the energy literacy level of this large sample of Taiwanese secondary students is discouragingly low, particularly with respect to their performance on the dimension of "Reasoning on energy issues."

4.2 Relationship between four dimensions and overall energy literacy

The result of the correlation analysis shows that the four dimensions are related to energy literacy, and the dimensions of energy literacy are positively correlated with one another

(Table 2). Of the 10 correlation coefficients, it can be seen that all of them are positive and seven are above r = .399. The obtained r is as large as .468 to .763, which indicates high relationships existing among "energy concepts," "reasoning on energy issues," and "overall energy literacy." The data summarized indicate that there are weak relationships between "civic responsibilities for a sustainable society" and the other dimensions of energy literacy. On the other hand, "Energy concepts" is the one factor that is most likely to be associated with the other components of energy literacy. Knowledge and behavior are more closely correlated than affect and behavior. This aligns with early models of environmental behavior that assumed the widely held position that education and knowledge lead to changes in attitudes and values, which in turn to foster action or behavior [14].

Table 1 Overall survey result

	Mean	SD
1.Energy concepts	15.47	3.91
2.Reasoning on energy issues	5.95	1.40
3.Low-carbon lifestyle	8.09	2.56
4.Civic responsibility for a sustainable society	3.29	.39
5.Overall EnergyLiteracy	75.70	9.49

Table 2. Intercorrelation between four dimensions of and overall energy literacy

Energy literacy	1.	2.	3.	4.	5.
1.Energy concepts	1				
2.Reasoning on energy issues	.530**	1			
3.Low-carbon lifestyle	.637**	.468**	1		
4.Civic responsibility for a sustainable society	.174**	.108**	.168**	1	
5.Overall Energy Literacy	.763**	.555**	.699**	.714**	1

**p<.01

4.3 Difference between groups of 7th and 11th graders

We applied the t-test to detect the differences of dimensions of energy literacy between the groups of 7th and 11th graders. The result showed that 11th graders gain higher scores on three dimensions of energy literacy and perception than the 7th graders. In general, 11th graders had significantly better energy literacy compared to 7th graders. This result may be used to interpret the effectiveness of energy education policy. It is suggested that energy education programs should aim to provide the opportunity to familiarize students with energy conservation, renewable energy, and energy saving, and that creating energy awareness and promoting energy efficiency must be done repeatedly when the project is implemented[6]. On the other hand, the scores on the behavioral items are slightly higher for 7th graders than they are for 11th graders. Similar to the findings from earlier studies [7][39], there appears to be a value-action gap among students' cognitive, affect and their actions. Although senior students concerned about the energy problems that our society is encountering, they apparently lacked the actions to engage in energy-conservation behaviors in their daily lives. DeWaters and Powers [7] clarified that as adolescents become young adults, they are less willing to change their habits that consume more energy. The students in higher grades have lower levels of environment-friendly behavior because the current provision systems are not conducive to environment-friendly practices [39].

Table 3. Comparison of student responses to energy literacy assessment, 7th vs. 11th graders

	7th graders		11th graders		
	Mean	SD	Mean	SD	
Energy concepts	14.37	3.60	16.81	3.86	7<11**
Reasoning on energy issues	5.65	1.32	6.32	1.41	7<11**
Low-carbon lifestyle	7.63	2.44	8.66	2.60	7<11**
Civic responsibility for a sustainable society	3.31	.41	3.28	.38	7>11
Overall EnergyLiteracy	74.01	9.35	77.75	9.27	7<11**

**p<.01

5 CONCLUSION

The purpose of this study was to examine the effects of individual variables on the dimensions of energy literacy and the overall energy literacy to support future development of energy-related education curricula and materials for secondary school students. The assessment in this study consisted of contextualized test units with a variety of test items to accommodate the students' comprehensive energy literacy including cognitive, affective, and behavioral aspects. Based on the assessment results, students had limited abilities to evaluate information about global energy issues and lacked knowledge regarding new energy resources. The correlational analyses show that energy knowledge and behavior are more closely correlated than affect and behavior. Senior students had significantly better energy literacy compared to junior students. This result may be used to interpret the effectiveness of energy education policy. It is suggested that energy education programs should aim to provide the opportunity to familiarize students with energy conservation, renewable energy, and energy saving, and that creating energy awareness and promoting energy efficiency must be done repeatedly when the project is implemented.

Consistent with our observations in the field study, examinees have higher confident and acceptance of the test and complete the assessment in the time of testing. This result may be used to interpret the advancement of ICT and students' familiarity of computer. It is suggested that the CBT for energy literacy assessment could be conducted for a wider population (e.g., including students, teachers, and parents). The items from internet-based banks could be shared by researchers and teachers to create and manage literacy-related assessments.

This research represents an initial investigation of energy literacy for secondary school students in Taiwan, and as such, it includes only student in grades 7 and 11. Further work should build on this study to explore the energy literacy of K-12 students to improve our understanding of energy education and the factors that influence energy-related behaviors, and to evaluate the effectiveness of energy education in Taiwan.

6 Reference

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