Assessment of Prospective Physics Teachers' Energy Literacy: A Recent Approach

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Assessment of Prospective Physics Teachers' Energy Literacy: A Recent Approach

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ABSTRACT

Energy literacy is one of the keys to addressing the energy problems in the world today, along with efforts to develop green energy technologies. We need to know how energy-literate the citizens are. Measuring literacy energy among prospective physics teachers is essential because they are the next generation of educators responsible for this problem. Nevertheless, there is no assessment instrument to measure how literate they are. This study aims to develop a framework for the assessment of the prospective physics' teacher. Sample of items developed based on the framework also included in this article.

Keywords: Energy; energy literacy; prospective teachers; assessment framework; physics education.

1. INTRODUCTION

Energy literacy is a growing topic in science education research over the last few decades. The majority of research has concentrated on either determining attitudes toward energy conservation and education or attempting to change attitudes toward energy conservation and education through courses and workshops [1]. Researchers then broadened the domain of energy literacy. DeWaters, Powers, and Graham [2] developed an energy literacy scale for a written Energy Literacy Questionnaire survey. The scale measures energy literacy for secondary students in three domains: cognitive, affective, and behavioral outcomes. Many researchers used this scale in different countries [3–7].

Other researchers [8] developed a framework for energy literacy in four domains by adopting and extending the framework developed by DeWaters and Powers [3]: energy concepts, energy reasoning, low carbon lifestyle, and civic responsibility for a sustainable society. These frameworks, like the former, were designed to be used adequately for assessing energy literacy among middle and high school students.

A pre-service teacher is an essential intervention for the next generation of citizens confronted with sustainability challenges [9]. As a result, addressing energy literacy as part of future teacher preparation is critical. Teacher preparation education has the potential to change human behavior and increase energy literacy [10]. Pre-service teacher education is a good program for effecting this change [9].

The National Science Teachers Association established Science Teacher Preparation Standards [11]. One of the standards stated that science teachers should understand that educated people must be prepared to make decisions and take action on current science-and-technology-related topics of societal concern of general societal interest. For this reason, we believe that an assessment framework to assess physics pre-service teachers' energy literacy is required. The existing frameworks are not adequate because of their intended purpose for middle and high school students.

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2. METHOD

We developed the assessment framework in the following steps. Firstly, we established the concept of energy literacy and the characteristics of those who possess it. We used concepts of literacy, several national frameworks for energy education, and relevant studies to create a working concept of energy literacy that can be used to construct an assessment. Secondly, we developed a framework model by matching the criteria with a model of the taxonomy of educational objectives we selected. In selecting the taxonomy of educational objectives, we applied the following procedures: (1) We considered cognitive processes and knowledge domains that former researchers [8,12,13] identified as relevant for energy literacy. (2) We searched among taxonomies of educational objectives [14–20] and chose one that appropriates to be applied for energy literacy assessment.

2.1 Energy Education and Energy Literacy

The role of energy education in instilling knowledge, making connections with the environment and society, cultivating responsibility, and shaping behavior regarding energy issues has gotten a lot of attention [5]. There is no agreement among researchers or curriculum developers about energy education definition. One definition of energy education is a vehicle to help students respond to present and future energy-related concerns, including the political, social, economic, and environmental dimensions [1]. The broad objectives of energy education for students are as follows [21,22].

a) They are becoming acquainted with various forms of energy and their interconversion.
b) They are learning about the role of energy in their daily lives.
c) They are becoming aware that energy is not infinitely available—through this, the methods of conserving energy, augmenting it.
d) They are developing awareness about the nature, cause of energy crises, and methods of overcoming them.
e) They are aware of various types of non-renewable and renewable sources of energy, their resource potential, existing technologies to harness them, the economics and energetics of these technologies, and their socio-cultural and environmental aspects.
f) Making the students appreciate the consequences of various energy-related policy measures.
g) Making the students appreciative of the energy-environment nexus and enable them to evolve holistic solutions to ensure sustainability

The goal of energy education is to develop energy-literate citizens. Energy literacy is an understanding of the nature and role of energy in the universe and our lives. Energy literacy can also apply this understanding to answer questions and solve problems [23]. By reviewing literature [12], [23], we defined an energy-literate person as one who:

a) can trace energy flows and think in terms of energy systems;
b) knows how energy is used in everyday life;
c) can assess the credibility of information about energy;
d) can communicate about energy and energy use in meaningful ways;
e) can make informed energy and energy use decisions and take action based on an understanding of impacts and consequences;
f) understands the impacts that energy production and consumption have on all spheres of environment and society;
g) is aware of the need for energy conservation and the need to develop renewable energy resources; and
h) continues to learn about energy throughout his or her life.

2.2 Choosing an Appropriate Taxonomy for Assessment Framework

We did not use those aforementioned energy-literacy-related assessment frameworks [8, 12] because for three reasons. Firstly, they did not represent a model or a theory of human thought instead of a

taxonomy [24]. Secondly, they did not give clear information about at what level of thinking the item of assessment would be addressed. Thirdly, they did not clear about how knowledge type and context are integrated into assessment items.

We examined among the taxonomies [14–20] that could be categorized as a framework, because of their broad use in the world. The criteria we used to select the taxonomy that appropriate for our purpose were:

(1) addresses cognitive, as well as affective, behavioral, and knowledge domain in one integrated model;
(2) makes a clear distinction between the thinking processes and the knowledge; and
(3) be able to predict phenomena of energy behavior.

Employing the above criteria, we found that only Marzano's taxonomy [20], named The New Taxonomy that fulfilled both criteria (1) and (2). The New Taxonomy also gave us a model of behavior that satisfied our criteria (3) and was in line with our definition of energy literacy.

Briefly, The New Taxonomy is a two-dimensional framework having three systems of thinking as one dimension and three types of knowledge as the other dimension. The three systems of thinking are ordered in the following six levels:

Level 6: Self-system
Level 5: Metacognitive system
Level 4: Knowledge utilization (cognitive system)
Level 3: Analysis (cognitive system)
Level 2: Comprehension (cognitive system)
Level 1: Retrieval (cognitive system)

For the purpose of our work, we did not include all three types of knowledge in The New Taxonomy, which are information, mental procedures, and psychomotor procedures. We substituted them with system knowledge, action-related knowledge, effectiveness knowledge [25], and pedagogical content knowledge (PCK) [26]. The first three are forms of declarative knowledge, which is akin to information knowledge in The New Taxonomy. We included PCK in this framework because PCK is a unique type of knowledge to teachers, as this framework is intended. The elaboration of these systems of thinking and types of knowledge are presented in the following section.

3. ORGANIZING THE DOMAINS

The way the domain of energy literacy is organized determines the assessment design, including the test items. As we presented in the previous section, we decided to use The New Taxonomy as a basis of the framework we will develop. The framework comprises five interrelated components: self-system, metacognitive system, cognitive system, knowledge, and contexts. Fig. 1 presents these components.

3.1 Knowledge Domain

Knowledge is needed to solve a particular task. A review of the knowledge domain from existing frameworks for environmental literacy provided the basis for this framework. We adopted the forms of environmental knowledge proposed by Frick et al. [25]. The first form of knowledge is system knowledge. System knowledge is defined as "knowing what." This knowledge usually relates to the question of how energy systems operate or knowledge about energy issues. A typical example is knowledge of the relationship between carbon dioxide (CO_2) and global climate change.

The second form of knowledge is action-related knowledge defined as "knowing how" or knowledge of behavioral options and possible courses of action. Unlike factual knowledge, action-related knowledge is more likely to affect behavior. For example, even if people are aware that CO_2 leads to global warming, they may not be aware of their actions to reduce their CO_2 emissions. The third form

of knowledge is effectiveness knowledge, which addresses the relative gain or benefit (i.e., the relative conservational effectiveness) associated with a particular behavior. With this form of knowledge, the focus on action-related knowledge has been extended from mere knowing-how-to conserve to knowing-how-to get the most significant environmental benefit. For example, buying an energy-efficient light bulb is a better way to reduce energy consumption than an incandescent light bulb.

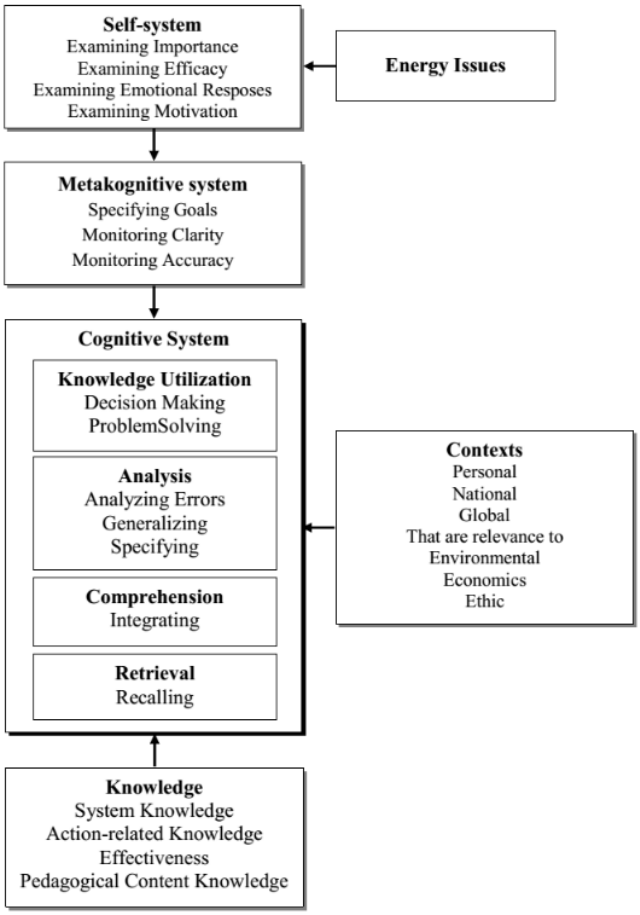

Fig. 1. A framework for assessing energy literacy of pre-service physics teachers (adapted from [20]). Some components from the original framework are excluded due to the purpose of our framework

3.2 Contexts for the Assessment Item

Individuals confront their everyday life situations in which they must use knowledge. Context refers to these situations in which knowledge about energy issues must be applied, ranging from personal to global, combined with environmental, economic, and ethical aspects. The combinations are shown in Table 1. Energy literacy assessment does not assess contexts; instead, it assesses competencies and knowledge in *a* particular context.

Table 1. Contexts for the assessment of energy literacy of preservice physics teachers

	Personal	Local/National	Global
Environment	Environmental impact of energy use	Renewable energy technologies	Climate change
Economics	Energy efficiency	Energy policy	Energy resources and global development
Ethics	Green lifestyle, energy conservation	Energy exploration and production	Global consumption of energy

3.3 Thinking System and Competencies

Competencies are defined as clusters of skills and abilities that may be called upon and expressed in real-world and assessment settings for a specific purpose [27]. Table 2 describes the competencies of energy literate person relate to the six levels of thinking system in The New Taxonomy.

Table 2. The six levels of thinking and competencies relate to each level

System of thinking	Competencies
Level 1: Retrieval	Recognizing nonrenewable and renewable energy resources.
Level 2: Comprehension	Explaining that energy dissipation occurs in every energy transfer. Counting energy consumption of electrical equipment.
Level 3: Analysis	Identifying logic error of information provided about energy. Analyzing the environmental impact of fossil fuel usage.
Level 4: Knowledge utilization	Using information to decide on energy use and purchase. Using information to solve the problem about energy. Proposing personal action to conserve energy.
Level 5. Metacognition	Specifying goals of conserving energy. Specifying the learning objective of the energy concept.
Level 6. Self-system	Examining the importance of energy conservation. Identifying beliefs about one ability to conserve energy. Identifying own emotional response related to energy use. Identifying the overall level of motivation to take action in energy conservation.

4. SAMPLE ITEMS

In this section, examples of the item of energy literacy assessment for pre-service physics teachers are presented.

Question 1: Air Conditioner (AC)

I feel annoyed to find AC in the classroom is on whereas no people there.

A. Always B. Often C. Sometimes C. Never

The categorization for sample Question 1 is presented in Table 3.

Table 3. Framework categorization for sample Question 1

Categories	Framework
Knowledge type	Action-related knowledge.
Competency	Identifying own emotional response related to energy use.
Context	Personal, economics.

Question 2: Air Conditioner (AC)

The human body uses energy at the rate of approximately 100 W when at rest. From chemical energy in our body's stores, this energy is ultimately converted entirely to thermal energy, which is then transferred as heat to the environment. Estimate what BTU/hour of AC you need for a lecture room if its capacity is about a hundred people to take account of transferred thermal energy.

The categorization for sample Question 2 is presented in Table 4.

Table 4. Framework categorization for sample Question 2

Categories	Framework
Knowledge type	System knowledge.
Competency	Using information to decide on energy use and purchase.
Context	Personal, economics.

Question 3: Air Conditioner (AC)

One day, you are asked by your father, who is with no science background, to accompanying him to buy an AC that will be used in the small guest room of your home. He tells you that he wants to buy it cash and he has IDR 3.000.000 for its budget. At the electronic store, you find many kinds of AC with a similar specification but differ in power consumption and price, as shown in the table below.

Brand	Power (watts)	Price (IDR)
A	795	2.900.000
B	840	2.700.000
C	900	2.600.000
D	925	2.500.000

Based on the table above, and only consider both its power consumption and price, which brand of AC will you recommend your father to buy? Give your reason.

The categorization for sample Question 3 above is presented in Table 5.

Table 5. Framework categorization for sample Question 3

Categories	Framework
Knowledge type	Effectiveness knowledge
Competency	Using information to decide on energy use and purchase.
Context	Personal, Economics

5. SUMMARY

The purpose of this paper is to develop an assessment framework to measure prospective physics teachers' energy literacy. Due to an energy literate person who has energy knowledge and can use his/her knowledge, we chose The New Taxonomy of Educational Objectives [20], which satisfied our criteria, as a basis for the framework. The framework comprises knowledge domain, context, and three systems thinking. For the knowledge domain, we substituted the original in The New Taxonomy with system knowledge, action-related knowledge, and effectiveness knowledge, which is akin to declarative knowledge. Assessment items are constructed in the personal, local/national, and global context related to the environment, economics, and ethical aspects. Competencies are assessed with relation to the six levels of the thinking system (i.e., self-system, metacognition, knowledge utilization, analysis, comprehension, and retrieval). Sample items show that the framework developed applicable for assessment items to measure the energy literacy of prospective physics teachers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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