

Developing a Framework For The Assessment Of Pre-Service Physics Teachers' Energy Literacy

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Abstract. Energy concept is one key component in physics education. Pre-service physics teachers are expected have energy literacy as their learning experience and for preparing their professional teaching. Measuring their energy literacy is therefore very important and its results are useful not only for faculty but also for national curriculum developers and policy makers. Yet there is no assessment instrument to measure how literate they are. In this paper, we develop an assessment framework to measure pre-service physics teachers' energy literacy.

1. Introduction

Energy literacy is a topic in science education research that has been risen over the last few decades. Most of the research have focused either on determining attitudes toward energy conservation and education or on trying to effect a change in attitude toward energy conservation and education through courses and workshops [1]. Reseachers then broadened the domain of energy literacy. DeWaters, Powers, and Graham [2] developed energy literacy scale for a written survey, named Energy Literacy Qusetionnaire, The scale measures energy literacy in three domain: cognitive, affective, and behavioral outcomes. This scale used by many reseachers in different country [3–7].

By adopting and extending the framework from DeWaters and Powers [3], other researchers [8] developed framework for energy literacy in four domain: energy concepts, reasoning of energy issues, low carbon lifesyle, and civic responsibility for sustainable society. Similar to the former, this frameworks were intended use adequately for the assessment of energy literacy among middle and high school students. So far, we have not found a assessment framework to assess energy literacy of physics pre-service teacher.

Pre-service teachers is a key intervention into the future generation of citizens facing sustainability challenges [9]. Therefore, addressing energy literacy as part of preparation of future teachers is important. Teacher preparation education can transform human behavior towards the rational use of energy and increase energy literacy [10]. Pre-service teacher education is a promising means to achieve this transformation [9].

The National Science Teachers' Association outlined standards for Science Teacher Preparation [11]. One of the standards stated that teachers of science should recognize that informed citizens must be prepared to make decisions and take action on contemporary science-and-technology-related issues of interest to the general society. For this reason, we viewed that assessment framework to measure



physics pre-service teacher energy literacy is needed. The existing frameworks are not adequate to be used for this purpose because of their intended purpose for middle and high school students.

2. Method

We developed the framework assessment in the following steps. Firstly, we started with determining definition of energy literacy and individual characteristics who has it. In developing a working definition of energy literacy that can be used as the basis for designing an assessment, we used definitions of literacy, several national frameworks for energy education, and pertinent research. Secondly, we developed a model of framework by matching the criteria with a model of 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 appropriate to be applied for energy literacy assessment.

3. Energy Education and Energy Literacy

Energy education receives much attention for its importance in instilling knowledge, making connections with environment and society, developing responsibility, and shaping behavior regarding energy issues [5]. There is no agreement among researchers or curriculum developers about energy education definition. One definition of energy education stated as a vehicle to help students respond to present and future energy-related concerns, which include the political, social, economics, and environmental dimension [1]. The broad objectives of energy-education for students are as follows [21-22].

- a) Becoming acquainted with various forms of energy and their interconversion.
- b) Learning about the role of energy in their daily lives.
- c) Becoming aware that energy is not infinitely available—through this the methods of conserving energy, augmenting it.
- d) Developing an awareness about the nature, cause of energy crises and methods of overcoming it.
- e) Making aware of various types of nonrenewable and renewable sources of energy, their resource potential, existing technologies to harness them, 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 in our lives. Energy literacy is also the ability to apply this understanding to answer questions and solve problem [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) is able to 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.

4. Choosing an appropriate taxonomy for assessment framework

We did not use those aforementioned energy literacy-related assessment framework [8], [12], because of three reason. Firstly, they did not represent a model or a theory of human thought as opposed to a taxonomy [24]. Secondly, they did not give clear information about in what level of thinking the item of assessment would be addressed. Thirdly, they did not clear about how knowledge type and context are integrated in assesment item.

We examined among the taxonomies [14–20] that could be categorized as framework, because of their broad in 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 a 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, that 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, that is akin to information knowledge in The New Taxonomy. We included PCK in this framework because PCK is a type of knowledge that is unique to teachers, as this framework is intended. The elaboration of these systems of thinking and types of knowledge are presented in the following section.

5. 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. Figure 1 presents these components.

5.1. Knowledge domain

Knowledge is needed to solve certain 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 system operate or knowledge about energy issues. A typical example is knowledge of the relationship between carbon dioxide (CO₂) 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, if people know that CO₂ contributes to global warming, they may still not know what actions they can take to reduce their CO₂ emissions. The

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

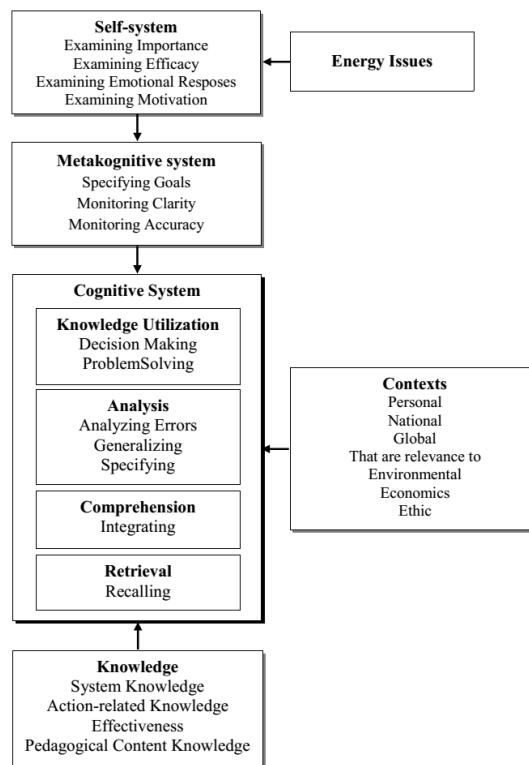


Figure 1. A framework for assessing energy literacy of pre-service physics teachers (adapted from [20]). Some components from the original framework are excluded due to the purpose of our framework.

5.2. 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, that are combined with environmental, economics, and ethics aspects. The combinations are shown in the Table 1. Energy literacy assessment does not assess contexts; rather, it assesses competencies and knowledge in particular contexts.

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

5.3. 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]. Tabel 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 occur in every energy transfer.
Level 3: Analysis	Counting energy consumption of electrical equipment. Identifying logic error of an information provided about energy. Analyzing the environmental impact of fossil fuel usage.
Level 4: Knowledge utilization	Using information to make a decision about energy use and purchase. Using information to solve problem about energy. Proposing personal action to conserve energy.
Level 5. Metacognition	Specifying goals of conserving energy. Specifying learning objective of energy concept.
Level 6. Self-system	Examining importance of energy conservation. Identifying beliefs about one ability to conserve energy. Identifying own emotional response related energy use. Identifying overall level of motivation to take action in energy conservation.

6. Sample items

In this section, examples of item of energy literacy assessment for pre-service physics teachers is 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 above 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 energy use.
Context	Personal, economics.

Question 2 : Air Conditioner (AC)

Human body uses energy at the rate of approximately 100 W when at rest. This energy, from chemical energy in our body's stores, 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 about a hundred people in order to 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 make a decision about 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 tell you that he want to buy it cash and he has IDR 3.000.000,- for its budget. At electronic store, you find there are many kind of AC with 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 table above, and only consider on both its power consumption and price, which one brand of AC you will recommend to your father to buy? Give your consideration.

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 make a decision about energy use and purchase.
Context	Personal, Economics

7. Conclusion

The purpose of this paper is to develop an assessment framework to measure pre-service physics teachers' energy literacy. Due to an energy literate person is who not only has energy knowledge but also is be able to 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 of thinking. For knowledge domain, we substituted the original in The New Taxonomy with system knowledge, action-related knowledge, and effectiveness knowledge, that are akin to declarative knowledge. Assessment items are constructed in the personal, local/national, and global context related to environment, economics, and ethics aspect. Competencies are assessed with relation to the six levels of thinking system (i.e., self-system thinking, metacognition, knowledge utilization, analysis, comprehension, and retrieval). Sample items show that the framework developed applicable for assessment item to measure energy literacy of pre-service physics teachers.

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