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Investigating energy literacy of pre-service primary school teachers in Greece

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ABSTRACT

Today, the notion of energy has never been more critical, such that it's become a major environmental, economic, and political issue. Education has a key role to play in cultivating the energy literacy of citizens and therefore encouraging wise and sustainable-driven decisions toward energy transition. Considering teachers are the instigators of this transition, this study investigates the level of energy literacy among 408 Greek pre-service primary school teachers using the energy literacy questionnaire (ELQ). The results indicated that pre-service teachers have low-to-moderate knowledge of energy concepts and challenges, however, show a rather satisfactory level in affect and behavior. Still, they express caution over the potential costs of renewable energy and the shift away from the prevailing energy use model. Women performed better than men in the affective and behavioral dimensions of ELQ and pre-service teachers who opted for a science or technology major in high school performed better in the cognitive and affective dimensions than those who had pursued the humanities. Finally, a correlation analysis revealed that attitude has a significant effect on behavior.

Keywords: energy literacy, students, pre-service teachers, primary school

INTRODUCTION

Modern societies are strongly dependent on energy to achieve technological progress and improve quality of life (Langfitt et al., 2014). At the same time, energy has become one of the most essential concerns of the 21st century (Armaroli & Balzani, 2007; Das & Richman, 2022; Martins et al., 2019a; Stylos & Kotsis, 2023) because of finite conventional energy resources (i.e., fossil fuels) and the increasing environmental consequences of their use, (i.e., air pollution, greenhouse effect, and climate change) (International Energy Agency, 2019). To mitigate energy-driven environmental problems and provide people with sufficient energy resources, societies at large are called on to reflect on their needs and habits and adopt sustainable energy production and management systems (Faria et al., 2015; Steg et al., 2015). Such a reorientation requires energy-literate citizens able to make responsible choices and decisions (Brounen et al., 2012; DeWaters & Powers, 2011; Karpudewan et al., 2016; Martins et al., 2020a; Yeh at al., 2017). According to Yeh et al. (2017, p. 423) "well-informed and well-educated citizens are the basis for the design and implementation of smart and forward-looking policies".

Building on the notion of energy literacy, Van den Broek (2019) proposed four types of energy literacy: knowledge about the energy consumption of appliances, the ability to evaluate the effect of personal actions on home energy conservation, financial literacy, which reflects the ability to make financially efficient energy decisions and multifaceted energy literacy, which in addition to the above includes the attitudes, values and behaviors associated with energy saving.

Among the several definitions of energy literacy (U.S. Department of Energy, 2013), DeWaters and Powers (2013, p. 38) argue that energy literacy embodies more than just content knowledge, it also includes "citizenship understanding of energy that encompasses affective and behavioral aspects". More specifically, the authors define an energy-literate person as someone who in addition to having sufficient knowledge and understanding of the overall energy production-consumption system and its environmental-social impact, is also sympathetic to energy conservation and the use of alternative resources, aware of how his/her decisions affect the global community, exhibits environmentally-conscious behaviors, and undertakes actions that reflect these attitudes towards energy conservation (DeWaters & Powers, 2011). In this context, energy literacy consists of cognitive, affective, and behavioral dimensions, and comprises competences that allow individuals to make informed and wise choices toward energy use and conservation (DeWaters et al., 2013; Martins et al., 2022; Lay et al., 2013; Lee et al., 2015). Such choices and actions, personal or collective, on a local or global scale, agree

with all sustainable development goals (SDGs) but especially the 7th SDG; to ensure access to affordable, reliable, sustainable and modern energy for all (United Nations, 2015).

LITERATURE REVIEW

Over the last two decades several studies, using different scales and research instruments, have investigated energy literacy, mainly among students, both in developed and developing countries.

Energy Literacy of Secondary School Students

The energy literacy questionnaire (ELQ) is a coherent and worldwide instrument developed by DeWaters and Powers (2008, 2011, 2013) and DeWaters et al. (2013) to examine energy literacy and has been mainly administered to secondary students in various countries. In New York State, for example, DeWaters and Powers (2011) showed low cognitive and behavioral scores among middle and high school students even though their student sample expressed a high concern over current events (i.e., identification of coal as the primary source of electricity), home energy use, and energy conservation. In their study, the affective and behavioral subscales showed the strongest correlation. A modified version of ELQ was used by Lay et al. (2013) in Malaysia, which revealed low levels of energy literacy among secondary students. Namely, although students showed concern over energy challenges, as reflected in the affective subscale, they presented a weak cognitive understanding. The analysis also confirmed a high correlation between the affective and behavioral dimensions but a low correlation between the cognitive and behavioral dimensions.

Other studies in energy literacy were conducted in Taiwan. One study that administered ELQ to Taiwanese school students showed that energy literacy tends to be high and positive across all three subscales (Lee et al., 2015). In this study, socio-demographic characteristics, such as grade, age, gender, family income and parents' highest education level proved to be important factors in determining student scores on the knowledge, affective, and behavior subscales. Moreover, energy-saving behavior was better predicted by affect rather than knowledge, gender, or socioeconomic status. The high school students who participated in the study of Chen et al. (2015a) completed the Chinese version of ELQ. The student sample was quite knowledgeable of the energy scientific basics, and impact of energy use but less knowledgeable about issues of energy resources. Once again, students' energy-related knowledge exhibited no effect on behavior whereas attitude was most critical in activating energy-conscientious behaviors. Regarding gender, while males indicated better cognition, their attitude toward energy issues was less positive than their female counterparts. Furthermore, females performed better on energy-conscientious behaviors such as walking or cycling short distances. On the contrary, Chen et al. (2015b), using a research tool consisting of items that measured perceptions of energy conservation, carbon reduction and a series of contextualized test units on real-life problems, showed that the energy literacy level of Taiwanese secondary students was unsatisfactory. In particular their ability to assess information about global energy issues as well as their knowledge of new energy resources were limited. The behavioral aspect in this study was therefore more closely correlated with the cognitive rather than the affective dimension. Another relevant research study performed in Taiwan (Lee et al., 2017) showed that the energy-related knowledge of students studying in vocational high schools was acceptable, affect was considered good however students' behavioral performance needed further development. Gender differences were not observed but students majoring in agriculture exceeded other students in the cognitive, affective, and behavioral dimensions, however students majoring in electrical and electronic engineering produced the highest scores among respondents. Again, in Taiwan, Yeh et al. (2017) assessed the energy literacy of junior high school students in five regions through a questionnaire comprised of three components, i.e., energy knowledge, energy & life, citizen responsibility & action, which were further divided into subcomponents and indicators. This study revealed that although respondents were relatively familiar with the energy areas taught in schools, their knowledge of in-depth scientific issues (e.g., principles of the greenhouse effect, nuclear power generation) was quite poor. Nevertheless, they had a positive attitude toward the development of renewable energy sources and expressed their intention to perform environmentally friendly actions. Students whose parents had a higher education level or worked in education had a considerably better cognitive understanding than other students. A difference in their intention to perform energy conservation actions was also obvious between younger and older junior high school students. Specifically, 8th grade students showed a greater positive attitude and behavioral intention than their 9th grade peers.

ELQ has also been modified and employed in Japan (Akitsu et al., 2017) to investigate secondary students' literacy level. The results indicated that females and students who discussed energy issues with their family possessed higher scores on all dimensions than males and those who didn't have relevant discussions in the family. Additionally, their energy literacy structural model revealed that students' awareness of consequences and ascription of responsibility predicted their behavior. Finally, a moderation analysis showed an effect of gender, grade, and region on components of the energy literacy model.

More recently, Bahrami and Mohammadi (2021) modified ELQ and measured Iranian high school students' energy literacy along the cognitive, affective, and behavioral dimensions. The authors' results demonstrated low levels of knowledge and awareness of energy-saving behaviors although students expressed relatively positive attitudes and values toward energy issues. Factors such as gender, school location and parents' education level impacted the energy literacy of students. For instance, males performed better than females on the behavioral dimension.

Energy Literacy of University Students

Aside from secondary education, some studies have also investigated energy literacy at the higher education level. For example, Van Treuren and Gravagne (2008, p. 3) argued that "the state of energy education in higher education is dismal"

since most curricula do not cover the topic of energy holistically, i.e., course units only include advanced technical engineering areas or the purely social dimension. Although several studies in the UK (Kagawa, 2007; Winter & Cotton, 2012) have shown student strength on energy issues awareness, they have also revealed areas for improvement in energy use knowledge and further clarity on energy-efficient behavioral choices.

Cotton et al. (2015) attempted to document students' energy knowledge, attitudes and behaviors to subsequently promote energy literacy by developing tertiary education curricula in the UK. They used a mixed-methods approach comprising an online survey and focus-group interviews. They found that different factors (i.e., demographics, prior experiences) interact with formal curricula and informal sources, which then influence students' energy literacy, knowledge, attitudes, and energy-conscientious behaviors.

Focusing on students from different engineering departments in state and private universities in Jordan, Jaber et al. (2017) investigated the extent of knowledge and awareness in two areas (a) the existing energy situation and (b) renewable energy potential. Significant differences among students were reported, explained by the type of university in both areas and by the department students were enrolled as well as their gender in the second area. Additionally, research by Alawin et al. (2016) conducted with senior students in various faculties of engineering demonstrated a lack of awareness and relatively poor knowledge.

Recently, Alghamdi and El-Hassan (2019), using a revised version of ELQ in Saudi Arabia revealed low levels of knowledge among undergraduate students in a public university, even if they demonstrated positive attitudes and will in addressing energy issues e.g., clean energy and energy conservation. The authors also found a moderate degree of performing energy conservation behaviors. In Kuwait, El-Kanj et al. (2022), assessed and compared the energy literacy of university students, faculty, and staff. Attitude and intention seemed to affect the behavior of students and faculty. The faculty's attitude had a greater influence on their energy literacy intention than students, reason being that faculty members were highly educated engineers.

Finally, in Poland, Białynicki-Birula et al. (2022) based on the proposal of DeWaters and Powers (2011), presented the results of a survey administered to undergraduate students in economics, which set out to measure their energy literacy levels. The students achieved very low energy knowledge scores, but their level of energy knowledge was independent of the other dimensions of energy literacy.

Present Study

Undoubtedly, it is encouraging that over the last several years an increasing number of studies have focused on students' i.e., future citizens' energy literacy. However, it is also essential to examine in service teachers as well as pre-service teachers' energy literacy levels, given that this target group will be responsible for younger students' literacy. As pre-service teachers are key players in educating future generation, who will inevitably encounter sustainability challenges (Yusup et al., 2017), energy literacy needs to be part of teacher preparation programs (Zografakis et al., 2008).

Despite the argument for energy literate teachers, departments of education still lack a holistic and integrated tertiary energy curriculum (Van Treuren & Gravagne, 2008). Such a curriculum would include the cognitive side of energy concepts and issues, but more so highlight the values that influence attitudes and affect in general, as well as key competences (e.g., critical thinking, problem-solving, etc.). Along with the physical and environmental dimensions of energy, such a curriculum would also emphasize the interactions among the social, economic, political, and cultural dimensions of energy use, but through a lens of systems thinking.

This paper presents the results of a study that measured the energy literacy of pre-service teachers enrolled in the Department of Primary Education of the University of Ioannina, Greece. This is one out of nine tertiary education institutions that prepare the future teachers of Greek primary schools.

The study set out to answer three research questions:

1. How do pre-service teachers perform on the cognitive, affective, and behavioral dimensions of energy literacy?
2. Do differences exist among pre-service teachers' performance on the three subscales, which may be due to their gender or senior high school course specialization?
3. How are the cognitive, affective, and behavior dimensions correlated?

METHOD

Adaptation of A Research Instrument

ELQ of DeWaters et al. (2013) was the survey instrument in this study. Although ELQ was mainly developed for students of American middle and high school students, it nevertheless provides a holistic and appropriate framework for student teachers studying in any Department of Primary Education. Pre-service teachers in training are not expected to become environmental scientists but need to understand the basic elements (i.e., knowledge, attitudes, and competences) of energy literacy and the pedagogical tools suitable for environmental and sustainability education (ESE) and science education (SE). ELQ is a questionnaire consisting of closed multiple choice questions for all three energy literacy dimensions: the cognitive, the affective and the behavioral. ELQ was translated into Greek following the International Test Commission (ITC) guidelines for test adaptation (Hambleton, 2001) and the Beaton et al. (2000) recommendations. The original items were deliberated in detail by the authors to verify their suitability, partially revise them if needed, or remove those deemed not relevant. Two translators, experienced in ESE, separately translated the questionnaire into Greek. A comparison between the two translations showed no significant differences. The final Greek questionnaire was then given to a third translator who back translated it into English. The English back translation presented slight differences in wording compared to its original.

Table 1. Number of items for pilot and final study

Subscale	Pilot study	Final study
Cognitive	36/36	28/36
Affective	17/17	14/17
Behavioral	10/10	10/10
Total	63/63	52/63

Next, a pilot study was conducted, where following discrimination indices and internal reliability coefficients certain items presenting low scores were removed (cognitive dimension: items 5,17, 19, 24, 30, 40, 41, 44; affective dimension: items, 65, 67, 73) (DeWaters et al., 2013). Participants in the pilot study were asked whether they had difficulties understanding the items listed in the questionnaire and in the end fifty-two out of the 63 initial items constituted the final instrument (**Table 1**). The 52-item ELQ included three subscales: cognitive (28 items), affective (14 items), and behavioral (10 items) (**Table 1**).

In the cognitive subscale, students had to answer 5-option multiple choice questions, which were divided into eight components, i.e., saving energy, energy forms, conversions and units, home energy use, basic energy concepts, energy resources, critical analysis about renewable resources, environmental impact, and energy-related societal issues. The affective and behavioral subscales used 5-point Likert-type scales ranging from 1 to 5 (i.e., affective: 1='strongly disagree'–5='strongly agree' and behavioral: 1='hardly ever or never'–5= 'always'). The internal consistency reliability of the final subscales, as per their respective Cronbach's alpha, was 0.69 (cognitive), 0.70 (affective), and 0.76 (behavioral).

The final instrument also included several independent variables such as students' demographic and educational characteristics, e.g., gender, year of study, parents' educational level, and the discipline they had focused on during their final secondary school studies (i.e., High school - Lyceum- course specialization options: sciences, humanities, or technology).

Sample

Purposive sampling was used to select participants. In particular, the sample consisted of 408 students studying in the Department of Primary Education of the University of Ioannina, Greece, which makes up 41% of the total number of students enrolled in this department.

Table 2 summarizes the basic demographic and academic characteristics of the participants.

In most departments of early childhood and primary education in Greece, ESE was introduced nearly two decades ago. The vast majority of the pre-service teachers in the study sample pursued a high school course specialization in humanities in their final high school years. This means that, unlike their classmates who chose the sciences and technology options, those who opted for humanities hadn't systematically attended science courses before their university entry. Upon enrollment in higher education and throughout their studies, which indeed included ESE courses such as the "theoretical framework of ESE", "teaching methods in ESE", "environmental and sustainability concepts & issues" and science education courses such as "basic physics", "physics in everyday life" and "physics didactics", trainee teachers are introduced to basic environmental and sustainability concepts, including energy concepts and issues (Gavrilakis et al., 2017).

Table 2. Sample characteristics

Variable	Frequencies (%)
Gender	
Male	16
Female	84
Year of studies	
Year 1	32
Year 2	18
Year 3	25
Year 4	25
High school course specialization	
Sciences	11
Technology	14
Humanities	75

Data Collection & Analysis

Student teachers were informed about the scope of this survey and voluntarily answered the questionnaire during a lecture period.

The data were analyzed using the SPSS software package (version 28). Descriptive statistics were calculated for the energy literacy dimensions. Moreover, statistical analyses were used to determine any significant differences in pre-service teachers' energy literacy due to the independent variables, such as year of undergraduate study and high school course specialization via nonparametric statistical analyses since the data was not normally distributed. The predetermined significance level was 0.05. Relationships between knowledge, affect, and behavior were determined by Spearman correlation.

RESULTS & DISCUSSION

Pre-Service Teachers' Self-Evaluation of Their Knowledge on Energy Issues

About two-thirds of pre-service teachers (63%) assessed their energy knowledge as moderate. Only 14.5% considered they have "quite a bit" or "a lot" of knowledge while one-fifth of the sample stated their level was low or very low (**Figure 1**). Such rather low percentages of perceived knowledge of energy issues are in line with recent studies conducted both at universities (Alghamdi & El-Hassan, 2019) and high schools (Bahrami & Mohammadi, 2021; Guven et al., 2019) and underline the need for a more effective introduction of energy concepts and issues in both school and university curricula so that students feel well prepared to make conscientious decisions.

Pre-Service Teachers' Behavior Toward Saving Energy

The data on pre-service teachers' efforts to save energy also indicate a rather moderate level. A fifth of the sample (21%) considered themselves moderate to high-energy users, whilst 36.3% stated they were moderate energy users. This overall trend also converges with the findings of some of the

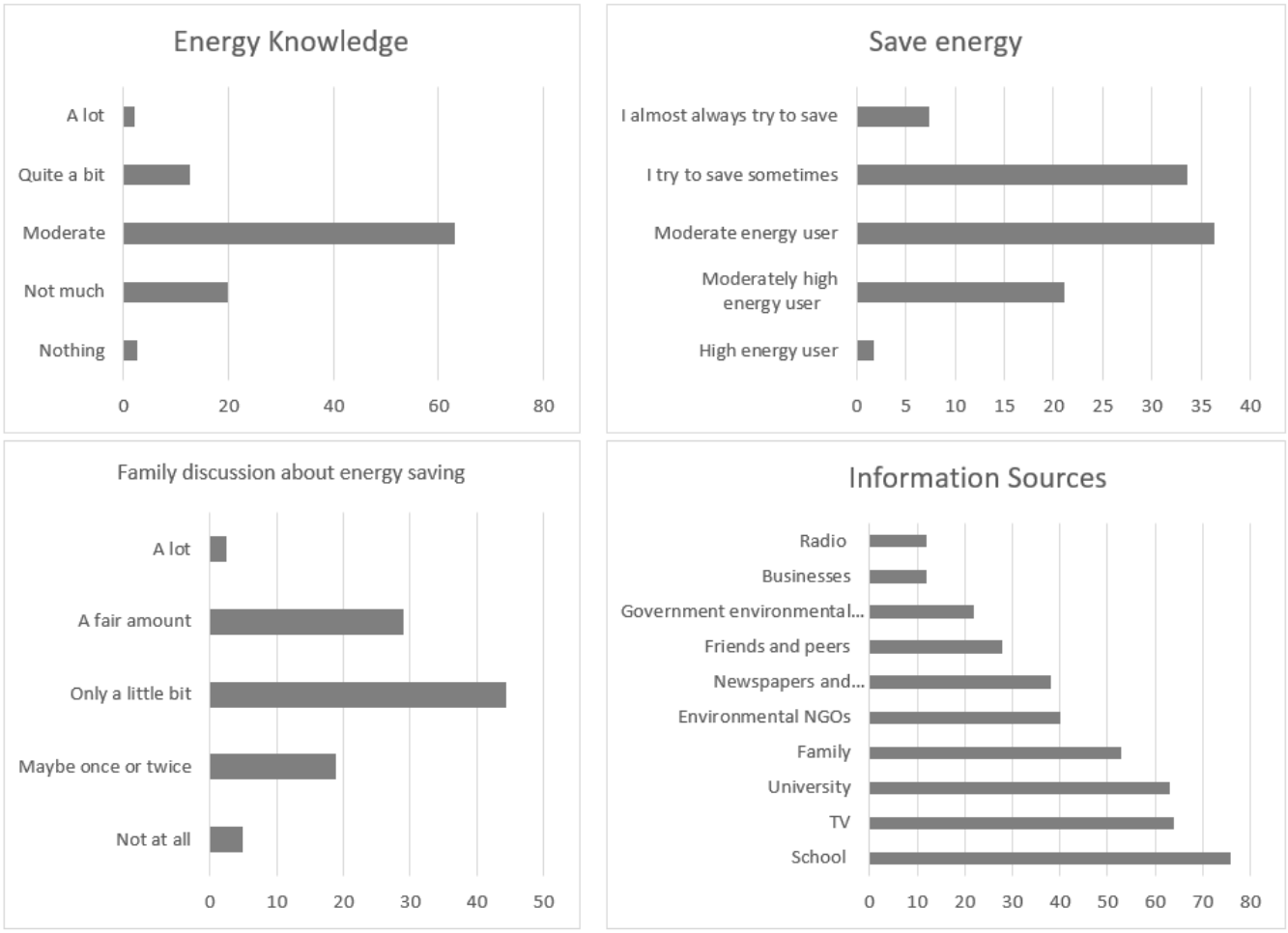

Figure 1. Pre-service teachers' self-evaluations of energy literacy (Source: Authors' own elaboration)

above-mentioned studies (e.g., Alghamdi & El-Hassan, 2019; DeWaters & Powers, 2011; Winter & Cotton, 2012). Although only 7.4% of participants claimed they always tried to save energy, also hopeful is the one-third (33.6%) that sometimes tried to do so (**Figure 1**).

Pre-Service Teachers' Discussions With Their Families About Ways to Save Energy

Although many of the study participants lived away from their parental homes, it was worthwhile knowing if they regularly held discussions with their family given that parents are critical role models for children who often influence their environmental behaviors (Chawla & Flanders Cushing, 2007). According to the data collected, almost one-third of the student teacher sample (29.1%) held a fair amount of energy saving discussions with their families. The largest proportion of participants (44.5%) discussed energy saving only a little, and 18.9% stated that their parents may have mentioned something about energy saving on a few occasions (**Figure 1**).

Information Sources

Pre-service teachers are often presented with formal, non-formal and informal education opportunities to develop energy literacy in their everyday lives. All information sources are expected to form knowledge and influence attitudes and behaviors around energy and its use. The study sample's responses reveal that indeed a mix of formal and informal sources rank at the top of the list. School, television, university, and the family are the dominant information sources for student teachers (**Figure 1**). Our findings converge with some earlier studies and suggest that although formal education institutions, such as school and higher education establishments have a principal role in providing information about energy issues (see also Alghamdi & El-Hassan, 2019), informal sources, such as television and the family also play a significant role in energy education (see also Bahrami & Mohammadi, 2021). In the context of constructivism, it's critical therefore for curriculum designers to take informal sources of information into consideration when preparing educational programs and materials about energy.

Cognitive, Affective, & Behavioral Performance of Pre-Service Teachers

A summary of pre-service teachers' performance on the cognitive, affective, and behavioral subscales is presented in **Table 3**. The average of correct answers to the knowledge questions was 56.04% and attitudes toward energy-saving tended to be positive (mean [M]=3.91) and slightly higher than behaviors (M=3.80). Such trends, i.e., low or moderate levels of knowledge but greater positive attitudes and behavior are in line with recent studies (e.g., Bahrami & Mohammadi, 2021; Lee et al., 2022), which creates a clear and predictable pattern. The overall performance indicates that pre-service teachers care about energy problems and are familiar with the skills needed for energy-wise choices and behaviors, although they lack the relevant knowledge (see also Bahrami & Mohammadi,

Table 3. Overall survey results

	Cognitive	Affective	Behavioral
n	408	408	408
Mean±standard deviation (%)[a]	56.04±14.53	79.43±7.44	76.04±11.98
Average mean response±standard deviation[b]	-	3.97±0.37	3.80±0.60
Average item difficulty	0.56	-	-
Average discrimination index	0.34	-	-
Reliability[c]	.69	.70	.76

Note. [a]Cognitive, affective, & behavioral scores were converted to percent; [b]Affective & behavioral items were measured by 5-point Likert scales; & [c]Kuder-Richardson 20 (KR-20) internal reliability coefficient

Table 4. Correct answers on the cognitive subscale items

Statements (correct multiple-choice answers in *italics*)	Correct (%)
Topic: Forms, conversions, & units	
When you turn on a light bulb, following energy conversions take place: *Electrical energy to radiant energy (light) & thermal energy (heat).*	74
Amount of electricity we use is measured in a unit called … *Kilowatt-hours (kWh).*	53
We know that a piece of wood has stored chemical potential energy because… *it releases heat when burned*.	53
The energy conversion for a battery powered flashlight is… *chemical energy - electrical energy - light energy*.	50
Topic: Basic energy concepts	
All the following are forms of energy except for … *coal.*	81
Every action on Earth involves … *energy.*	78
The original source of energy for almost all living things is … *the sun.*	64
What does it mean if an electric power plant is 35% efficient? *For every 100 units of energy that go into the plant, 35 units are converted into electrical energy.*	63
Energy is defined as … *the ability to do work.*	45
It is impossible to … *build a machine that produces more energy than it uses.*	39
Topic: Energy resources	
The term "renewable energy resources" means … *Resources that can be replenished by nature in a short period of time.*	80
Which of the following energy resources is not renewable? *Coal.*	68
Which is the most abundant fossil fuel found in Greece? *Lignite.*	55
Most of the electricity produced in Greece comes from … *Burning lignite.*	47
Renewable energy resources provided approximately [*between 14% &d 23%*] of total energy consumption in Greece at end of 2017.	39
Which resource provides most of the energy used in Greece each year? *Petroleum.*	38
Most of the renewable energy used in Greece comes from … *biomass.*	7
Topic: Critical analysis on renewable resources	
Some people think that if we run out of fossil fuels we can just switch over to electric cars. What is wrong with this idea? *Most electricity is currently produced from fossil fuels (coal, oil, & natural gas).*	48
Select option that makes following statement true: Renewable energy resources like wind & solar are still harmful to human health & environment because … *it takes a lot of energy and materials to manufacture wind turbines and photovoltaic (solar) cells.*	20
Topic: Home energy use	
Which of following options use up the most energy in an average Greek household in a given year? *Heating & cooling rooms.*	36
Which of the following items uses up the most electricity in an average Greek household in a given year? *Oven*	23
Topic: Environmental impacts	
Many scientists say the Earth's average temperature is increasing. They say that one important cause is … *increasing carbon dioxide concentrations from burning fossil fuels.*	74
Which of the following energy-related activities is least harmful to human health and the environment? *Generating electricity with photovoltaic (solar) cells.*	60
One advantage in using nuclear power instead of coal or petroleum to produce energy is that … *it produces less air pollution.*	40
Topic: Energy conservation	
The best reason to buy an energy star© appliance is … *energy star© appliances use less energy.*	83
Which of the following options always save energy? *Turning off the car engine when the car is at a standstill for 15 seconds or more.*	40
Scientists say the single fastest and most cost-effective way to address our energy needs is to… *promote energy conservation.*	27
If a single person had a 50 km commute to work every day and wanted to save on gasoline, which of the following options would save the most gasoline? *Carpooling to and from work with one other person.*	27

2021). Hence, whereas pre-service teachers present a rather low score in the cognitive dimension, they score higher in the affective and behavioral dimensions.

Cognitive Dimension

Table 4 summarizes the findings of the cognitive dimension items as presented and discussed in a previous study (Stylos et al., 2017). Additionally, two more areas with items measuring the knowledge of basic energy concepts and that of forms, conversions and units are included in this article.

In summary, although the correct answers differed throughout the cognitive subscale, knowledge on forms,

Table 5. Pre-service teachers' responses to affective subscale items

Affective items	% PR
Saving energy is important.	98.0
I do not need to worry about turning the lights off in the classroom because the university pays for the electricity.*	89.7
We do not have to worry about conserving energy, because new technologies will be developed to solve any energy problems for future generations.*	87.7
Energy education should be an important part of every school curricula.	86.0
We should produce more electricity from renewable resources.	85.3
I would do more to save energy if I knew how.	83.1
Greeks should conserve more energy.	82.3
All electrical appliances should have a label showing resources used in manufacturing them, their energy requirements, & operating costs.	79.6
I believe I can contribute to solving energy challenges through appropriate energy-conscious choices and actions.	79.5
The government should impose stronger restrictions on the gas mileage of new cars.	78.2
More oil fields should be developed once discovered, even if located in areas protected by environmental laws.*	58.5
The way I personally use energy does not really make a difference to the energy problems our nation is encountering.*	56.4
Greece should develop more ways of using renewable energy, even if this means that energy will cost more.	51.5
Efforts to develop renewable energy technologies are more important than efforts to find and develop new sources of fossil fuels.	45.6

Note. PR: Positive response & *These items were reverse scored to ensure directional value is consistent with rest of subscale

conversions and units was consistently moderate (i.e., 52% correct answers). There was however an obvious and better understanding of energy conversion, as it occurs for example when a light bulb turns on while correct answers of basic energy concepts were not uniform.

While participants were familiar with energy forms and the fact that every action involves energy they failed to select the right definition of energy or provide the correct answer on the first law of thermodynamics. Student teachers were also moderately aware of energy resources in general but significantly less aware of the energy resources used in Greece. Moreover, the analysis revealed that pre-service teachers were not familiar with specific types of renewable energy sources, such as hydropower or biomass, even though they are used in Greece at a noteworthy level. Despite the rather high scores on the general statements regarding renewables, participants failed to respond to a satisfying degree to their critical analysis, indicating that the sole transfer of knowledge, or the basic understanding of some concepts, does not suffice to develop critical thinking.

Furthermore, it's safe to assume that everyday life would allow someone to become aware of their energy-demanding practices. However, the findings on the home energy use statements raise doubt over this assumption, indicating the difficulty of participants to recognize the energy demands of their everyday habits on the one hand, thus demonstrating ignorance on the basic elements of the home energy footprint (DeWaters & Poweers, 2011; Fell & Chiou, 2013) on the other. These findings underline the value and the need for more participatory and experiential learning approaches (Flogaiti et al., 2021). With regards to the environmental impact of energy use, most student teachers recognize the contribution of fossil fuels combustion in the increase of atmospheric CO_2 and the earth's temperature as well as the role of photovoltaic cells in the production of clean energy. Finally, participants' score on the energy conservation items was very low given that less than half gave correct answers on three out of four questions (Stylos et al., 2017). Overall, cognitive findings reveal that the sampled future teachers possess a low-to-moderate level of knowledge on energy-related topics with some exceptions in specific areas.

Affective Dimension

Table 5 presents the percentages of pre-service teachers whose answers indicate pro-environmental attitudes. These percentages sum up the positive responses, i.e., 'strongly disagree' + 'disagree' or 'strongly agree' + 'agree' depending on the item. Pre-service teachers' scores in the affective dimension were clearly higher in comparison to the cognitive dimension, reconfirming a pattern already reported in several studies (e.g., DeWaters & Powers, 2011; Lay et al., 2013; Bahrami & Mohammadi, 2021; Białynicki-Birula et al., 2022). However, a closer look into attitudes reveals some points that need careful consideration.

Almost all participants consider that saving energy is important (98.0% 'strongly agree' or 'agree'). Moreover, in line with earlier findings from Taiwanese (Chen et al., 2015a) and Malaysian (Lay et al., 2013) secondary school students, a high percentage of the future teachers in our sample believe that Greeks should conserve more energy (82.3%) and expressed their personal willingness to do more to save energy on condition that they knew how to (83.1%). These findings indicate the need for an effective, wider, and more systematic dissemination of energy-related tips, through formal, non-formal, and informal educational sources.

Indeed, with regards to specific statements testing individuals' awareness of simple energy conservation behaviors and everyday habits, a strong majority of respondents expressed the need to turn off the lights in the classroom, even if the institution was paying for the electricity (89.7%) and considered that people should care about conserving energy regardless of technological progress that might protect future generations from energy problems (87.7%). Both these cases indicate a high level of personal responsibility over one's everyday habits to reduce energy consumption, and the simultaneous impact on the public purse and future generations, i.e., see intergenerational solidarity.

Additionally, a large percentage of respondents also believe that stronger restrictions should be set on the gas mileage of new cars (78.2%) and that labeling should apply to all electrical appliances to ensure that resources used during

Table 6. Pre-service teachers' responses to behavioral subscale items

Behavioral items	% PR
When I leave a room, I turn off the lights.	90.7
I turn off the computer when not in use.	80.4
My family turns the heating down at night when away from home to save energy.	80.4
I am willing to encourage my family to buy energy efficient compact fluorescent light bulbs.	74.3
I am willing to encourage my family to turn heating down at night or increase air conditioner temperature when away from home to save energy.	68.9
My family buys energy-efficient compact fluorescent light bulbs.	65.4
I walk or cycle short distances, instead of driving a car or asking for a ride.	61.4
I try to save water.	53.4
I am willing to buy fewer things to save energy.	37.9
Many of my everyday decisions are affected by my thoughts on energy use.	26.2

Note. PR: Positive response

their production, as well as energy requirements and operating costs are transparent (79.6%). The above-mentioned percentages are notably higher than those of similar studies (DeWaters & Powers, 2011; Lay et al., 2013).

However, participants' self-efficacy belief was weaker than their strong positive attitudes towards saving energy. Self-efficacy is defined as an individual's confidence in her/his ability to organize and execute a course of action to solve a problem or accomplish a task (Bandura, 1977). Although 79.5% of participants believed that their energy-related choices and actions could contribute to solving energy problems, only 56.4% were convinced that their personal contribution, i.e., the ways in which they use energy, really can mitigate energy problems on a national level. Studies having evaluated high school students' self-efficacy demonstrated similar results (Chen et al., 2015a; DeWaters & Powers, 2011; Lay et al., 2013).

It is worth mentioning that although a strong majority of respondents (85.3%) believe that renewable resources should be the main source of electricity production, most participants become very cautious over the potential costs of renewable energy investments and the essential shift away from the prevailing model of energy use, findings, which converge with those of Chen et al. (2015a) and DeWaters & Powers (2011). Only half the respondents (51.5%) support the development of renewable energy when initial and operational costs are higher, thus highlighting the fact that the financial argument of energy policies are able to obstruct critical transformations in the existing energy model. Even more alarming is the low percentage of respondents (45.6%) who believe that the development of renewable energy technologies should be a priority as opposed to finding and developing new sources of fossil fuels, a finding that also confirms that of other researchers (DeWaters & Powers, 2011; Lay et al., 2013). Furthermore, it is quite worrying, and maybe a paradox, that only 58.5% of the pre-service teachers in the sample were against the development of new oil fields, knowing that protected areas would be sacrificed. These findings should concern environmental and energy policymakers, especially as critical decisions are being taken on energy investments in Greece, a member state of the European Union currently undergoing a considerable effort to urgently promote renewable sources. In any case, the above-mentioned findings confirm the argument that shifting from one energy model to another, i.e., from our dependence on fossil fuels toward a reliance on energy efficiency and renewable energy, needs about 50 years (Miller & Spoolman, 2016, p. 415).

Finally, a strong majority of participants (86.0%) stated that energy education should be an important part of the school's curriculum (see also Chen et al., 2015a). This is a critical finding given that the study's participants are future teachers who are going to implement, and to some extent enrich the primary school curriculum in Greece. Meanwhile, new books are being prepared for Greek schools, which is a great opportunity for energy education to get more attention.

Behavioral Dimension

Table 6 shows the percentages of pre-service teachers' whose answers indicate pro-environmental behaviors, in terms of personal or their families' everyday energy decisions and behaviors. These percentages reflect the sum of positive responses, i.e., 'never' + 'not very often' or 'quite frequently' + 'almost always or always' depending on the item. In the behavioral dimension, respondents showed a rather moderate energy conservation profile. Findings can be divided into three levels of concern. First, pre-service teachers and their families were very likely to execute simple everyday behaviors, such as turning off the lights when leaving a room (90.7%), turning off the computer when not in use (80.4%), and turning the heat down at night when away from home (80.4%). A noteworthy percentage of respondents mentioned indirect (Jensen & Schnack, 1997) environmental behaviors, namely willingness to encourage their families to buy energy-efficient light bulbs (74.3%) and adjust the heat or air conditioner temperature (68.9%). About two-thirds of the sample stated that their families buy energy-efficient light bulbs (65.4%). Given that in the last decade school curricula (mainly in the sciences) in Greece combine several units on the importance of energy conservation, and that NGOs and the mass media consistently promote behaviors and approaches to save energy through targeted campaigns, higher percentages were expected in endorsing the above-mentioned decisions.

It is also interesting to note that pre-service teachers were clearly reluctant to make decisions and currently do not adopt behaviors that would essentially modify their life habits, stressing the difficulty to make second-order changes - see Cuban's (1988) terminology. For example, only 61.4% of respondents chose to walk or cycle short distances instead of driving a car. Moreover, only about half of the respondents (53.4%) tried to save water, and one-third (37.9%) were willing to change their shopping habits to save energy. Overall, it was

Table 7. Results of gender differences in knowledge, affective, & behavioral dimensions

Dimension	Gender	Mean	Standard deviation	Mean rank	Mann-Whitney U test
Cognitive	Male	58.14	15.85	220.80	9,467.000
	Female	55.68	14.31	200.44	
Affective	Male	76.16	10.20	166.22	7,988.000**
	Female	79.41	6.74	203.30	
Behavior	Male	72.61	14.53	167.03	8,084.500**
	Female	76.60	11.42	202.29	

Note. **p<.05

Table 8. Results of high school specialization differences in knowledge, affective, & behavioral dimensions

Dimension	High school specialization	Mean	Standard deviation	Mean rank	Mann-Whitney U test
Cognitive	Science & technology	61.76	14.92	241.58	7,307.000*
	Humanities	55.33	13.91	183.76	
Affective	Science & technology	80.28	10.75	219.79	7,699.000**
	Humanities	79.39	6.64	182.44	
Behavior	Science & technology	76.29	13.75	191.55	9,596.500
	Humanities	76.03	11.23	186.06	

Note. *p<.001 & **p<.05

Table 9. Spearman's rho coefficients between knowledge, affect, & behavior

		Affective	Behavioral
Cognitive	Correlation coefficient	.281*	.172*
	Sig. (2-tailed)	.000	.001
Affective	Correlation coefficient		.362*
	Sig. (2-tailed)		.000

Note. *Correlation is significant at 0.01 level (2-tailed)

rather disappointing that only a quarter of respondents (26.2%) stated that their concerns about energy use influence many of their everyday decisions, a finding that indicates an energy culture that is inapt to positively influence pre-service teachers' everyday actions or encourage them to make informed and conscientious decisions (**Table 6**). Nevertheless, pre-service teachers' responses in our study indicate a slightly greater awareness of pro-environmental behaviors in relation to similar studies (Chen et al., 2015b; DeWaters & Powers, 2011; Lay et al., 2013).

Response Patterns by Student Gender & Studies in High School

Pre-service teachers' responses differed according to gender and high school course specialization for all three dimensions. Results are presented in **Table 7** and **Table 8**. Women performed better than men in two dimensions, affective (U=7,988.000, p<.05) and behavioral (U=8,084.500, p<.05) however the gender effect was not significant in energy-related knowledge. This finding converges with those of earlier studies (e.g., Dopelt et al., 2019; Martins et al., 2019b) although cannot clearly support studies claiming that men demonstrate higher levels of knowledge than women (Abdullah, 2021; Chen et al., 2015b; Cotton et al., 2015; 2018) or vice versa (Akitsu & Ishihara, 2019; Akitsu et al., 2017). Our results confirm the impact of gender on energy literacy confirming that women demonstrate a more positive attitude and greater energy-friendly behaviors than men, a finding already highlighted by recent research (Bahrami & Mohammadi, 2021; Cotton et al., 2018; Dopelt et al. 2019; Martins et al., 2020b, 2021, 2022). This result may be attributed to women's social and structural position in society (Blocker & Eckberg, 1997), although according to Hayes (2001, p. 670), differences in attitudes *"are simply a by-product of gender disparities in scientific literacy"*.

Students majoring in Science and Technology performed better than those in the Humanities in the cognitive (U=7,307.000, p<.001) and affective (U=7,699.000, p<.05) dimensions. This result is in line with Gambro and Switzky (1999) who suggested that the number of science classes students enrolled in could increase their knowledge about environmental issues.

Relationship Between Knowledge, Affect, & Behavior

The correlation coefficients between knowledge, affect, and behavior are presented in **Table 9**. Although all were significant (p<.01), the affective/behavioral and cognitive/affective magnitudes were greater than the cognitive/behavioral one. Similarly to other studies (Bahrami & Mohammadi, 2021; DeWaters & Powers, 2011; Dopelt et al., 2019; Lee et al., 2022), findings demonstrate the significant role of students' affect in establishing responsible energy-related behavior. The weak correlation between the cognitive and behavioral dimensions declares that knowledge doesn't impact decision-making processes on energy conservation (Alghmamdi & Hassan, 2019; Białynicki-Birula et al., 2022; Demeo et al., 2013).

Table 9 highlights the inadequacy of the traditional model that links knowledge, attitudes and behavior in a linear way (Hungerford & Volk, 1990) and, once again, suggests that this 3-component relationship is complex and likely influenced by other factors (values, beliefs, socioeconomic factors, etc.) (DeWates & Powers, 2011; Owens & Driffill, 2008). Furthermore, it underlines that curriculum-based cognitive overload has no effect on addressing energy issues.

CONCLUSIONS AND IMPLICATIONS

The present study aimed to investigate the level of Greek pre-service teachers' energy literacy in the cognitive, affective, and behavioral dimensions. Overall, their scores on the

affective and behavioral subscales were remarkably better as opposed to their moderate scores on the cognitive subscale. The sampled pre-service teachers seem to successfully understand basic concepts and issues related to energy. However, their knowledge is considered limited, even very limited, on the energy resources utilized in their country, domestic energy consumption, energy-saving actions, and their ability to critically assess renewable as well as non-renewable energy sources (Stylos et al., 2017). The satisfactory score of pre-service teachers on pro-environmental attitudes and behaviors cannot obscure their skepticism over potential investment costs and the challenge in shifting away from the conventional energy model, as well as their everyday habits and lifestyle. Significant differences in the affective and behavioral dimensions were due to gender with women performing better than men. Significant differences in the cognitive and affective dimensions were due to high school course specialization with students having majored in Science or Technology performing better than Humanities-oriented students. Finally, the results of correlational analyses revealed that behavior is strongly correlated to affect, more so than the energy knowledge.

According to the results, implications and recommendations emerge for educators, researchers, teachers, and policymakers. Energy education should be considered a critical subject area in both schools and the future training of teachers. A better (i.e., holistic and critical) integration of energy concepts and issues into curricula or the adoption of energy curricula in line with the trends of global energy education could contribute to this direction (Alghamdi & El-Hassan, 2019; Lay et al., 2013; Lee et al., 2022). The association between affect and behavior reveals that energy education programs should strive to influence attitudes, values, and beliefs toward energy conservation (DeWaters & Powers, 2011; Lee et al., 2022) through participatory, holistic and experiential approaches, instead of simply delivering content knowledge. Furthermore, the implementation of teaching strategies that develop critical thinking, apply energy concepts to real contexts, and foster decision-making skills can enhance students' energy literacy levels (Lee et al., 2019, 2022; Martins et al., 2019). The positive attitude expressed by future teachers toward the integration of energy education into the school curriculum is obviously an optimistic message.

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