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Research Article

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Acceptance of nuclear energy by pre-service teachers in Greece

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ABSTRACT

Nuclear energy is required to provide a reliable, sustainable, and environmentally friendly energy source. Its use, however, receives limited public support, mainly because of the nuclear disasters that have occurred in the past. People perceive it as more dangerous than it really is and does not consider its multiple benefits. In addition to their concerns about the consequences of a nuclear explosion, there are many other factors that affect their acceptance or non-acceptance of nuclear energy. In this research, pre-service teachers' perceptions of Department of Primary Education at University of Ioannina regarding factors such as the proximity of nuclear power plants, social trust, safety perception, perceived benefits, environmental awareness, and perceived nuclear knowledge are being examined. The sample consisted of 500 persons, and a questionnaire was distributed for data collection, which included demographic questions and 29 questions related to acceptance of nuclear energy. Understanding the public perceptions and identifying the determinants of their acceptance is vital to establishing nuclear energy.

Keywords: public acceptance, pre-service teachers, nuclear energy, Greece

INTRODUCTION

During the first decade of this millennium, nuclear energy was of particular concern to governments and international organizations for its use in electricity generation. Their interest in nuclear energy came from the fact that it is considered "green" and "clean" energy (Findlay, 2011). The first nuclear reactor was commissioned in 1942 in Chicago,IL, USA (Karakosta et al., 2013). In 2019 there were 449 reactors in operation, distributed in 31 countries, and another 55 reactors under construction (World Nuclear Association [WNA], 2020). There are three main sources of energy on the planet: fossil fuels, renewable energy sources, and nuclear energy. The aim is to avoid climate change and to replace traditional crude oil as the basis of the transport system with other alternative energy sources (Forsberg, 2008; Verbruggen, 2008). Nuclear energy and renewable energy sources (hydroelectric, wind, solar, biomass, and geothermal) are the two most powerful tools for meeting the energy needs of countries, but at the same time, for reducing carbon dioxide emissions on the planet. Most global electricity in 2010 was produced through fossil fuels (coal, natural gas, and oil), while renewables accounted for 18% and nuclear power for just 14% (Dittmar, 2012; Karakosta et al., 2013). In 2020, however, the percentage corresponding to renewable energies was 14.5%, and nuclear energy to 4.8% (Halkos & Gkampoura, 2020). Carbon dioxide (CO_2), which is being talked about, is one of the major contributors to global warming. Efforts to combat global warming require finding alternative energy sources to fossil fuels (such as renewable energy and nuclear energy) that are safe and sustainable (Menyah & Wolde-Rufael, 2010). The operation of nuclear power plants contributes significantly to reducing greenhouse gas (GHG) emissions, currently saving about 10% of CO_2 emissions from global energy use (Apergis et al., 2010; Sims et al., 2003). With the use of nuclear energy, two billion tons of GHGs are reduced each year (Duffey, 2005). The introduction of these energy sources into the total electricity can help a country achieve its CO_2 emission reduction targets and, at the same time, meet its electricity demand (Goh & Ang, 2018). According to Baek (2016), nuclear energy reduces CO_2 emissions in both the short and long term, while using energy is produced through renewable sources only in the short term. Therefore, nuclear energy is an alternative to fossil fuels. Its development is increasingly seen as an appropriate international sustainable development strategy option. Its main advantage is its ability to produce large amounts of energy continuously from a small number of initial resources (Vaillancourt et al., 2008). It is also an economical energy source that can compete with all existing or emerging renewable energy technologies (Kessler, 2002). Therefore, nuclear energy covers both the social, economic, and environmental needs of the states that use it (Duffey, 2005). But while nuclear energy is a reliable, sustainable, and environmentally friendly energy source, it is controversial in public. There is a wide gap in the perception of the risk of its

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use between the public and the scientific community. The Fukushima nuclear accident and subsequent debates about nuclear power affected its public acceptance because the potential risks associated with its establishment were perceived (Kim et al., 2013; Siegrist et al., 2014). A number of studies have focused on investigating public perceptions before and after the Fukushima nuclear accident in various countries (Bird et al., 2016; Latré et al., 2017; Park & Ohm, 2014; Roh &Kim, 2017; Visschers& Siegrist, 2013; Yeo et al., 2014). In the above-mentioned surveys, a significant change in the attitude of public opinion toward nuclear energy was observed. Acceptance, perceptions, feelings of safety, and trust in governments were more negative after the nuclear accident. In contrast, the benefits of nuclear power did not show significant changes before and after the accident. Prati and Zani's (2012) research also studied the environmental beliefs factor in which greater environmental concerns were presented by citizens after the Fukushima nuclear accident. A general explanation of the current public perception of the risk of nuclear facilities is that the public is negatively biased and poorly informed (Yim & Vaganov, 2003). The nuclear accident in Fukushima was a turning point in public perceptions of nuclear energy. Understanding public perceptions of nuclear power and identifying its acceptance determinants is crucial to establishing nuclear power upon which countries' energy futures are based. The most important acceptance factor is knowledge. Inadequate knowledge of energy issues hinders the development of both renewable and nuclear energy (Kardooni et al., 2016). Many studies have been conducted regarding the factors influencing the acceptance of nuclear power in various countries worldwide. In the research by Wang et al. (2019) examined public perceptions and acceptance of nuclear power and explored the effects on public knowledge of nuclear power, perceived benefits (PB), perceived risk, and public involvement in its acceptance. It has been found that when the public understands the benefits of nuclear power and knows about it, they are more likely to accept it. However, when the public realizes the dangers of nuclear power, they are less likely to accept it. By having knowledge about nuclear power, the benefits of building nuclear power plants are understood, and thus the acceptance of nuclear power is more likely (McComas et al., 2016). In the research by Hao et al. (2019), six factors influencing acceptance of nuclear energy (ANE) in students were studied. It was confirmed that proximity (P) to nuclear plants had a negative effect on its acceptance, while the remaining factors (social trust [ST], knowledge about nuclear energy, benefits, environmental sensitivity, and sense of security) had a positive effect. Education plays a vital role in the development of a sustainable society. It is a powerful agent of social change and increases sensitivity to issues related to the environment (Jennings, 2009). Regarding nuclear energy, education has been considered a key means of changing people's perceptions or attitudes. The research of Yim and Vaganov (2003) examined the effectiveness of education in changing people's perceptions based on a review of theories about how people perceive risk and form corresponding attitudes. It was found that following information and education on nuclear power issues, the public tended to be more supportive of it (Yim & Vaganov, 2003). Since the public ANE can be positively influenced through education, it is necessary to establish nuclear energy education programs in respective governments if they wish to establish nuclear energy (Kim et al., 2014). Only through discussions and targeted programs related to the benefits of nuclear power can it influence public opinion about nuclear plants (Visschers & Siegrist, 2013). This quantitative research studies the factors influencing students' ANE in Greece. Its theoretical contribution is particularly important, as it examines these factors in a country, where nuclear energy has not yet been established. For the first time, a survey is being conducted in Greece focusing on pre-service teachers' ANE. Undergraduate students have a relatively high cognitive background and are expected to play a key role in the future development of the Greek economy and society. The acceptance or not of nuclear energy by them reflects some extent, the attitude of society towards nuclear energy. Therefore, this paper aims to identify the main factors that influence ANE so that they can be considered when planning programs that will inform and promote nuclear energy establishment.

RESEARCH METHODOLOGY

Sample and Tool

500 pre-service teachers, students of Pedagogical Department of Primary Education at University of Ioannina who came from all years of study participated in this research. There were 106 men and 394 women.

The survey was conducted with a questionnaire consisting of closed-ended questions examining demographics (gender, year of study, parental education level, general energy-related questions) and 29 closed-ended questions examining ANE (**Table 1**) based on six factors.

Safety perception (SP) factor corresponded to questions SP1-SP3, environmental awareness (EA) factor questions EA1-EA, PB factor questions PB1-PB5, ST factor questions ST1-ST4, P factor questions P1-P3, factor perceived nuclear knowledge (PNK) about nuclear energy the questions PNK1-PNK5 and finally in the factor ANE the questions ANE1-ANE4. The questions were answered using a 5-point Likert scale (1-strongly disagree, 2-disagree, 3-neutral, 4-agree, and 5-strongly agree). The Likert scale measures respondents' attitudes regarding how much they agree or disagree with a particular question statement. The first two questions are indicative:

(1) "I support the development of nuclear energy in my country" and

(2) "Nuclear energy is a source of energy that does not produce carbon dioxide".

The response category "3-neutral" used on the Likert scale is a response that reflects ignorance on issues related to nuclear energy. The creation of the questionnaire followed a series of steps before its final form. First, corresponding research tools designed to examine the acceptability of nuclear power were collected. An important role in the final selection was the fact that these tools should be modern and simultaneously examine as many factors as possible for the ANE. The 29 questions were derived from the tool developed in the survey studying six factors of ANE (Hao et al., 2019). This research aimed to identify the factors that positively or

Table 1. Questionnaire

Q	Code	Variables
SP	SP1	The use of nuclear energy is safe.
	SP2	I believe that the possibility of a radioactive leak at the nuclear facilities is high.
	SP3	Modern technology has reduced the likelihood of serious accidents at nuclear power plants compared to the past.
EA	EA1	Due to high rate of coal-fired power generation & harmful local smog, people will have to accept electricity generated in an environmentally friendly way.
	EA2	I believe that developing nuclear power will prevent the depletion of natural resources.
	EA3	The operation of nuclear plants favors the reduction of atmospheric pollution caused by thermal plants.
	EA4	The world's carbon dioxide emissions are huge. To combat global warming and meet international commitments to reduce emissions, people must embrace the kind of energy that can contribute to the above goals.
	EA5	Radioactive waste can be disposed of safely.
PB	PB1	Nuclear power generation is an important factor in the long-term sustainable development of the world economy.
	PB2	Development of nuclear power increases overall national power (e.g., geostrategic, political, military, economic) of country that produces it.
	PB3	Nuclear energy contributes to the economic development of the country that produces it.
	PB4	A country's use of nuclear energy increases its standard of living.
	PB5	Developing nuclear power can help reduce the electricity bill on household tariffs.
ST	ST1	The nuclear safety system of the countries is ensured by the governments.
	ST2	Governments have established comprehensive nuclear safety monitoring and management systems at nuclear plants.
	ST3	Even if a nuclear accident occurs, governments can deal with its effects.
	ST4	The proper use of nuclear energy is adequately ensured by governments.
P	P1	The operation of a nuclear plant hurts the environment of the surrounding area.
	P2	If there was a nuclear power plant where I live, I would consider moving to another area.
	P3	I do not want a nuclear power plant to be built near my workplace or where I live.
PNK	PNK1	Nuclear energy is an energy source that does not produce carbon dioxide.
	PNK2	Nuclear energy is the energy released from the nucleus of atoms through nuclear reactions.
	PNK3	Nuclear energy is divided into nuclear fission and nuclear fusion.
	PNK4	Nuclear power is produced through controlled nuclear fusion.
	PNK5	Uranium is today the most important nuclear fuel.
ANE	ANE1	I support the development of nuclear energy in my country.
	ANE2	I would support Greece's investment in nuclear research and development.
	ANE3	The advantages of nuclear power outweigh the disadvantages.
	ANE4	Greece must develop nuclear energy at a rapid pace.

negatively affect ANE. The next stage in creating the questionnaire was translating the research questions of Hao et al. (2019) into Greek.

The questionnaire was translated into Greek for content and conceptual equivalence according to the International Test Commission (ITC) guidelines for test adaptation (Hambleton, 2001) and the suggestions of Beaton et al. (2000). The questions of the original version of the questionnaire were translated into Greek by two bilingual speakers, where discrepancies in the translation were examined and the necessary vocabulary adjustments were made. They were then translated from Greek to English and no semantic errors were detected. Finally, the final questionnaire was checked by teachers familiar with the literature to establish its validity, content and cultural appropriateness. These questions were then given to small groups of students who were not included in the final sample of the survey, in order to identify possible points that create questions or difficulty in understanding. After feedback, the questions remained as they were because no ambiguities were found.

Procedure

Initially, a pilot survey was conducted with 100 participants who were not included in the final survey sample. Upon its completion, no ambiguities were identified in the questions, and therefore no changes were made to the data collection instrument used (questionnaire). The questionnaires of the main research were distributed to the students at the beginning of lectures in the auditorium of Pedagogical Department of Elementary Education at University of Ioannina. Before completing the questionnaire, it was made clear that completion is anonymous and participation in the survey is voluntary. The students were asked to read the questions carefully and answer according to their knowledge, without any kind of intervention, either to explain the questions or for clarification. There was also no time limit for completing the questionnaire, although it was completed by everyone in less than 15 minutes. After the process was completed, some students expressed concern about nuclear energy because, as they reported, they did not know basic concepts, which did not help them complete the questionnaire.

RESULTS

The data obtained from the questionnaires were recorded and then processed with SPSS statistical package. Specifically, most of the sample is women (78.8%). Most participants (77.4%) followed a non-science course in the 6th grade of High School. From the 1st year of studies, 147 students participated (29.4%); from the 2nd, 95 (19%); from the 3rd, 111 (22.2%); from the 4th, 134 (26.8%) and the 5th year, and above only 13 persons (2.6%). And regarding the place of residence examined, more than half of the respondents live in a city (57.8%).

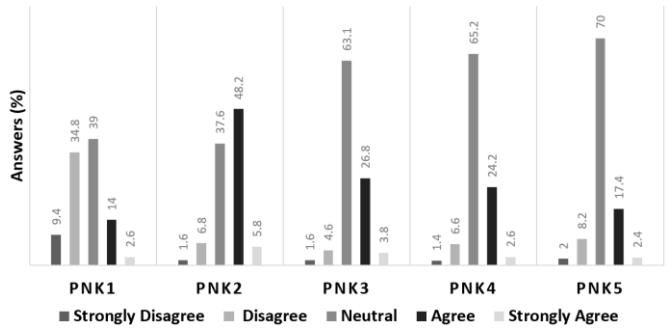

Figure 1. Response rates for PNK factor (Source: Authors)

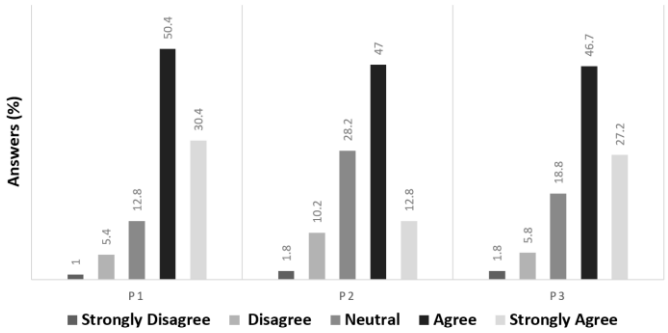

Figure 2. Response rates for P factor (Source: Authors)

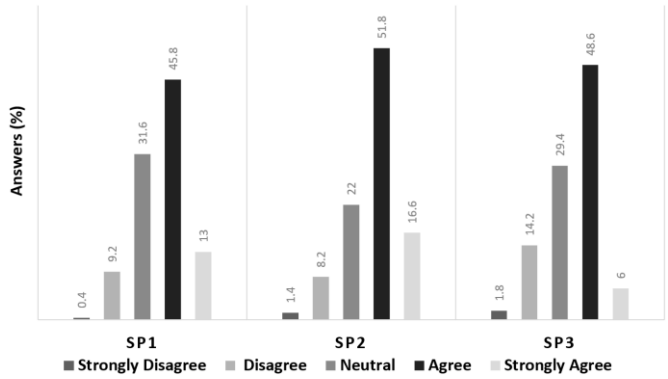

Figure 3. Response rates for SP factor (Source: Authors)

PNK factor corresponded to five questions of the questionnaire. As shown in **Figure 1**, four of five questions gathered the highest percentage of the neutral answer, which in question PNK5 was 70%. Only in question PNK2 was there a higher percentage of strongly agree-agree responses than neutral response.

Regarding P factor (**Figure 2**), agree-strongly agree answers predominate in all three questions. In these two responses, 59.8%-80.8% of respondents do not wish to be near nuclear facilities. On the contrary, only 6.4%-12.0% of respondents want it.

Regarding SP factor (**Figure 3**), most respondents consider nuclear energy unsafe, and the possibility of leakage in nuclear facilities is high (questions SP1 and SP2). Nevertheless, about 50% consider that modern technology makes nuclear energy safer than before, and only 16% disagree with this proposition (question SP3).

Figure 4 shows that in the first two questions (ST1 and ST2), at a percentage of 43.8% for the first question and 45.2% for the second question, the neutral answer gathered the most answers. Only 22.4% of respondents to question ST1 and 21.8% to question ST2 stated that they trust governments. In questions ST3 and ST4 a percentage of 47-68.4% stated that they do not trust governments, and less than 15% trust them.

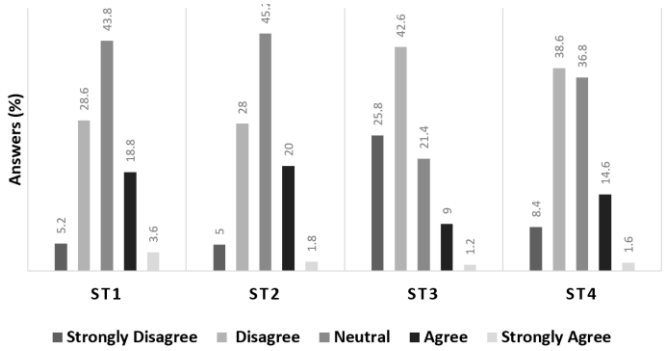

Figure 4. Response rates for ST factor (Source: Authors)

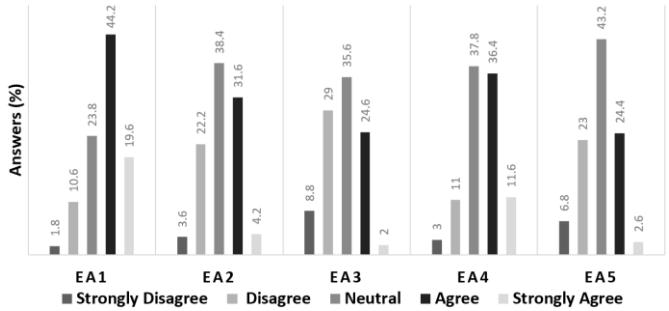

Figure 5. Response rates for EA factor (Source: Authors)

EA factor (**Figure 5**) examines issues surrounding nuclear energy and more general perceptions of the participants on environmental issues. In these more general topics to which questions EA1 and EA4 refer, the existence of environmental sensitivity is observed, as the percentage of agreement vs. the percentage of disagreement is 48% vs. 14% in the first question and 63.8% vs. 12.4% in the second question. In the questions referring to the extent to which nuclear energy can contribute to reducing environmental problems, the largest percentage is occupied by neutral answer (questions EA2, EA3, and EA5) and immediately followed by options disagree-strongly disagree that nuclear energy is environmentally friendly energy.

PB factor was examined through five questions (**Figure 6**), which referred to the extent to which the economy, citizens, and national power of the country producing nuclear energy would benefit. 44.2%-59.1% of the participants agreed that developing nuclear power would benefit the country producing it economically, while only 8.8%-19.4% disagreed (questions PB1 and PB3). The majority, i.e., 49.6%, answered that the country's national power would increase with the use of nuclear energy, and 32.1% answered neutrally to this question (question PB2). In the question regarding the increase in the standard of living with the use of nuclear energy, 44.2% of the respondents answered neutral, and the percentage for the answers agree and disagree was about the same.

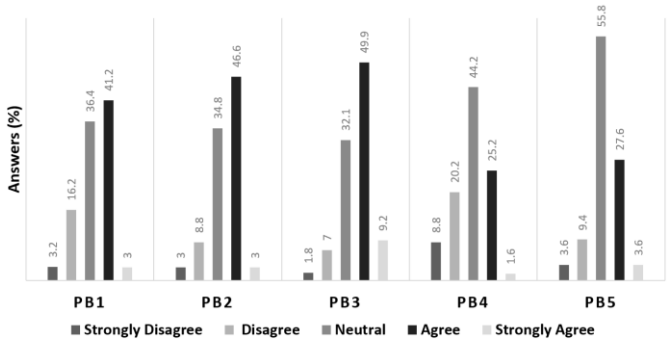

Figure 6. Response rates for PB factor (Source: Authors)

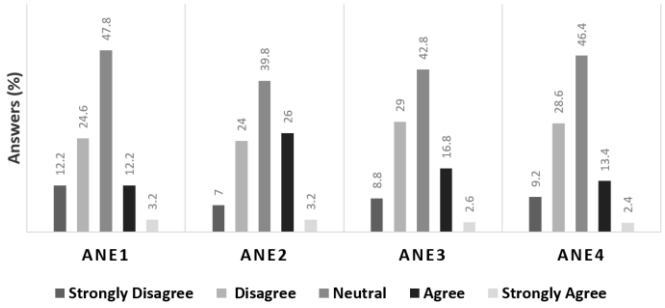

Figure 7. Response rates for ANE factor (Source: Authors)

Figure 7 shows four questions regarding ANE in Greece. All questions gathered the largest percentage in the neutral response (40%-47%). The next largest percentage was collected by the disagree-strongly disagree answers (31%-37.8%), that is, they stated that they do not wish to develop nuclear energy in Greece.

DISCUSSION-CONCLUSIONS

Despite the fact that social acceptance plays an important role in the establishment and development of nuclear energy, research examining the factors influencing social acceptance is scarce. For this reason, this research examines the six main factors that influence ANE by students at University of Ioannina. The research results confirm that the general group of students' nuclear energy knowledge is extremely low (Yim & Vaganov, 2003). In all the questions that examined their knowledge, the largest percentage answered "neutral". Consistent with previous research, P factor has a negative effect on the acceptance of nuclear power, as eight out of 10 participants stated that they do not wish to be near a nuclear power plant (Hao et al., 2019). Only knowledge about nuclear energy can effectively influence its acceptance because, in this way, its benefits and the necessity of its establishment will be highlighted. Aware of the necessity of establishing nuclear energy, for the energy future of both Greece and worldwide, governments need to focus on effective communication and education about nuclear energy. It is necessary to understand the cognitive deficiencies and the opinions of the citizens that influence them regarding the acceptance or not of nuclear energy so that programs designed in this direction can be implemented. For example, it would be possible to hold lectures on nuclear energy in schools, organizations, and businesses so that students and the general public are informed about the mechanism of nuclear energy production and the operation of nuclear power plants. In addition, governments must reassure citizens about the safe operation of nuclear power plants because nuclear accidents have alarmed citizens, making them feel unsafe. It is obvious that further research is necessary as far as social acceptance is concerned, but also the improvement of public policy for nuclear energy. It is also deemed necessary to include chapters or sections related to nuclear energy in school textbooks. From elementary to high school, references to nuclear energy issues are minimal. Therefore, students graduating from school do not have sufficient knowledge of the importance of nuclear energy and its benefits.

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Ethics approval and consent to participate: The authors declared that the study did not require formal ethics approval since the data was completely anonymous, with no personal information collected (apart from age and sex).

Availability of data and materials: All data generated or analyzed during this study are available for sharing when appropriate request is directed to corresponding author.

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