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HOW SSI-BASED INSTRUCTION INFLUENCED PRE-SERVICE SCIENCE TEACHERS' AWARENESS OF ALTERNATIVE ENERGY SOURCES[1]

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Abstract

The purpose of this study is to explore how pre-service science teachers' awareness of alternative energy sources developed after participating in socioscientific issues-based (SSI-based) instruction focusing on alternative energy sources. This study was designed as a case study. The participants were selected by using the convenience sampling method and consisted of a total of 12 (10 female, two male) pre-service science teachers enrolling at a state university in Aydın province during the 2023-2024 academic year. The researchers designed an SSI-based alternative energy course. The data were collected by interviews using an alternative energy sources opinion form developed by the researchers before and after the SSI-based course. The results revealed that participants' awareness of alternative energy sources was quite low, they were partially knowledgeable about the types, potential use of energy sources, and their potential to cover Türkiye's energy demand before the instruction. The SSI-based course improved participants' knowledge and awareness about the advantages and disadvantages of alternative energy sources.

Key Words: Alternative energy sources, awareness, preservice science teachers, SSI-based instruction.

SOSYOBİLİMSEL KONULAR TEMELLİ ÖĞRETİM, FEN BİLGİSİ ÖĞRETMEN ADAYLARININ ALTERNATİF ENERJİ KAYNAKLARI KONUSUNDAKİ FARKINDALIKLARINI NASIL ETKİLER?

Özet

Bu çalışmanın amacı, alternatif enerji kaynakları temelli sosyobilimsel konular temelli öğretiminin, fen bilgisi öğretmen adaylarının alternatif enerji kaynakları konusundaki farkındalıklarının nasıl geliştirdiğini araştırmaktır. Bu çalışma bir durum çalışması olarak tasarlanmıştır. Kolay örnekleme yöntemi kullanılarak seçilen katılımcılar, 2023-2024 akademik yılında Aydın ilindeki bir devlet üniversitesinde öğrenim gören toplam 12 (10 kadın, iki erkek) fen bilgisi öğretmen adayından oluşmaktadır. Araştırmacılar sosyobilimsel (SBK) temelli bir alternatif enerji dersi tasarlamıştır. Veriler, sosyobilimsel konulara dayalı öğretim öncesinde ve sonrasında araştırmacılar tarafından geliştirilen alternatif enerji kaynakları görüş formu kullanılarak görüşmeler yoluyla toplanmıştır. Sonuçlar, uygulama öncesinde katılımcıların alternatif enerji kaynakları hakkındaki farkındalıklarının oldukça düşük olduğunu, enerji kaynaklarının türleri, potansiyel kullanımları ve Türkiye'nin enerji ihtiyacını karşılama potansiyelleri hakkında kısmen bilgi sahibi olduklarını ortaya koymuştur. Sosyobilimsel konular temelli öğretim,

[1] [1] Preliminary findings of this study was presented as oral presentation on IIIrd International Congress on Exellence in Education in 2023.

katılımcıların alternatif enerji kaynaklarının avantaj ve dezavantajları hakkındaki bilgi ve farkındalıklarını artırmıştır.

Anahtar kelimeler: Alternatif enerji kaynakları, farkındalık, fen bilgisi öğretmen adayları, sosyobilimsel konular temelli öğretim.

INTRODUCTION

Türkiye is one of the growing economies that needs increasing energy demand (Satman, 2007). Growing economies are dependent upon fossil fuels and reoccurring oil crises show this dependency (Koroneos et al. 2003). However, this dependency introduces a major problem: Greenhouse gases. These gases include carbon dioxide (CO_2), carbon monoxide (CO), ozone (O_3), nitrogen gas derivatives (NO, NO_2, and N_2O), and chlorofluorocarbon (CFC) (Cebesoy, 2016). The increasing amount of greenhouse gases in the atmosphere brings important global problems: global warming, climate change, natural disasters such as floods or hurricanes along with an unstoppable wave of migration (Cebesoy, 2016; Karisan & Topcu, 2016). Alternative energy could be an alternative to fossil fuels as they are inexhaustible and harm the environment less than fossil fuels (Koroneos et al., 2003). Alternative energy sources (AES, hereafter) are naturally found in nature and are renewed constantly. Common AES sources are hydraulic, wind, solar, geothermal, biomass, biogas, wave, hydrogen, and tidal energy (Ministry of Energy and Natural Sources [MENS], 2019). AES are considered an alternative to fossil fuels as they cause less carbon emission to the atmosphere (Liarakou et al., 2009).

The recent strategy report published by the Ministry of Energy and Natural Sources (MENS) (2019) states that Türkiye aims to increase the use of AES from 59% to 65% in the following five years (2019-2023). Consequently, we can assume AES is important for the Turkish Republic. This importance was also recognized by the curriculum designers and the Turkish elementary science curriculum which was renewed in 2018. AES has become an important topic of the curriculum and 6th-grade students are expected to understand the difference between the AES and non-AES at the end of the fuels topic (Ministry of National Education [MoNE], 2018). A major issue was raised at that point: How aware are science teachers of the potential of AES? Teachers' and preservice science teachers' opinions, views, and perceptions about AES have been an important topic for investigation for over a decade by both national (Açışlı Çelik, 2021; Cebesoy & Karışan, 2017; Çelikler, 2013; Doğru & Çelik, 2019; Genç & Akıllı, 2019; Güven & Sülün, 2017; Şen & Temel, 2023) and international scholars (Liarakou et al., 2009, 2021; Lowan Trudeau & Fowler, 2022; Zyadin et al., 2014).

The reviewed literature mostly focused on determining preservice teachers' opinions, awareness, and knowledge levels of AES. In an earlier study, Çelikler (2013) investigated preservice science teachers' awareness of AES. While the study did not reveal any significant gender difference, it revealed grade-level differences (i.e., third-grade preservice teachers' awareness was statistically significant than their counterparts in different grades). In a more recent study, Doğru and Çelik (2019) investigated preservice science and primary teachers' knowledge about AES and revealed that both groups did not have enough knowledge about AES. In another study by Genç and Akıllı (2019), the authors investigated the relationship between preservice teachers' knowledge of AES and their attitudes toward AES by using structural equation modeling. The study revealed there was a positive relationship between the two constructs. In Açışlı Çelik's (2021) study, the researcher examined preservice teachers' attitudes towards AES and reported positive attitudes towards AES. In the international context, Liarakou et al. (2009) investigated Greek secondary school teachers' perceptions and attitudes towards AES, particularly wind and solar energy. The results revealed that the participants were knowledgeable about AES in general but unaware of how particular sources such as wind or solar energy could be used. In another study by Zyadin et al. (2014), Jordanian secondary school teachers' knowledge, perceptions, and attitudes toward AES were investigated. The authors revealed that while teachers had relatively limited knowledge of AES, they held positive attitudes towards AES.

The aforementioned studies were usually descriptive in nature. Only a few studies explored the effectiveness of an intervention. In such a study, Cebesoy and Karışan (2017) designed a case study to develop preservice science teachers' knowledge and attitudes toward AES. The participants joined a twelve-hour teaching session on AES

by using multiple teaching methods. The results revealed that participants' knowledge of AES was insufficient. Moreover, their attitudes were shaped by economic, ecological, political, technical, geographical, and sociological factors. In addition, their self-efficacy perceptions towards the teaching of AES were low. As seen, there is a gap in how to develop, preservice teachers' knowledge of AES by using intervention studies.

Energy issues, on the other hand, have been used as a socioscientific issue (SSI) due to their ill-structured, ethically complex, and controversial nature (Martín-Gámez & Erduran, 2018; McKinzie Sutter et al., 2019; Sakschewski et al., 2014; Zeidler et al., 2005). To make informed decisions on energy-related SSI, students need to ecological, economic, and social dimensions by integrating the demands of both the current and future generations (Sakschewski et al., 2014). Investigating middle school students' reasoning in a wind energy SSI, McKinzie Sutter et al. (2019) found out that students could identify the possible and negative aspects of wind farms while making decisions. However, they indicated the need for more research on how middle school students understand AES. If we aim to raise our students to be well-informed about the possible consequences of AES as well as weigh different dimensions such as economic, environmental, and social aspects, we then need to include the controversial nature of SSI into our teacher education programs. However, to the best of our knowledge, there is no study exploring how SSI-focused AES courses affect preservice teachers' awareness of AES. To fill this gap, the present study explored the effectiveness of an SSI-based AES course on preservice teachers' awareness. Based on this aim, we sought answers to the research questions below:

1. To what degree does enrollment in an SSI-based AES course influence the proficiency of preservice teachers in recognizing and describing various AES?
2. How does participation in an SSI-based AES course affect preservice teachers' perspectives regarding the potential of alternative energy sources to meet Türkiye's energy demand?
3. How does participation in an SSI-based AES course affect preservice teachers' perspectives regarding the advantages and disadvantages of AES?

METHOD

This study is guided by a qualitative case study design to investigate how SSI-based instruction influences the awareness of alternative energy sources among preservice science teachers. The case study approach provides a comprehensive exploration of the phenomenon within its real-life context, allowing for an in-depth understanding of the complex interplay of factors influencing the participants (Yin, 2009).

Participants:
The participants for this study were selected through convenience sampling. Convenience sampling is a non-probability sampling technique in research where participants are selected based on their ease of availability or accessibility to the researcher (Trochim & Donnelly, 2008). Convenience sampling is commonly used in situations where time, resources, or access to participants are limited. A total of 12 preservice science teachers (10 female, two male) enrolled at a state university in Aydın province during the 2023-2024 academic year were included in the study. The choice of participants from a specific university and academic year aims to provide a focused and contextualized analysis of the impact of SSI-based instruction on this particular group.

Participants consist of second-grade preservice science teachers. These students have chosen the course voluntarily, and they have not taken any previous courses on energy or SSI. Furthermore, this course represents the students' initial exposure to both alternative energy and SSI topics. The fact that students have previously taken general education science courses (such as philosophy of education, sociology of education, and educational psychology) and foundational courses in specific fields (physics, chemistry, biology) in previous years focuses the research on the participants' prior knowledge levels.

SSI-Based Alternative Energy Course
In the research, the SSI-based AES course provided to the students encompasses a curriculum that delves into both energy-related topics and socio-scientific dimensions. Throughout the implementation process, close monitoring of students' in-class interactions, learning processes, and awareness of alternative energy topics has

been maintained. During the initial week of the course, students were introduced to the concept of SSI. They were given the opportunity to engage in scientific argumentation through an example topic. As the weeks progressed, students were informed that they would need to engage in scientific discussions related to the respective alternative energy sources.

Throughout the course, a diverse range of energy sources has been covered. From fossil fuels to hydroelectric power plants, geothermal energy to solar power, wind energy to biogas, and wave energy, various energy resources were examined. Each energy source has been thoroughly analyzed in terms of both its benefits and drawbacks. The aim of this dual-sided analysis was to provide students with a comprehensive perspective.

The environmental impacts and limited nature of fossil fuels, the contributions of hydroelectric power plants to energy production and water resource management, the utilization and potential risks of geothermal energy from underground sources, the advantages and cost factors of solar energy as an alternative source, the advantages and aesthetic effects of wind energy as an environmentally friendly alternative, the sustainability and energy production benefits of biogas from organic waste, and the potential energy source obtained from seas through wave energy were thoroughly explored.

In this way, students had the opportunity to gain a deeper understanding of both the technical aspects of each energy source and their impacts on society, the environment, and the economy. This dual-sided critical perspective empowered participants to approach various issues in the energy sector with a more informed and balanced outlook.

For each alternative energy source, weekly activities were designed, including watching documentaries, compiling newspaper articles, and participating in in-class scientific discussions. In the week dedicated to geothermal energy, a field trip to a commonly found geothermal energy facility in the region was organized. During the field trip, engineers explained all stages of the geothermal energy production process, providing on-site observations and insights. The field trip lasted approximately 3 hours.

Figure 1. Güriş-Mogan Geothermal Energy Central Field Trip

Similarly, during the week focused on biogas, another field trip was organized. Students had the opportunity to observe firsthand all processes related to energy production at the biogas facility. This hands-on experience allowed them to deepen their understanding of biogas as an alternative energy source.

After the course, students utilized Web 2.0 tools to create posters for each energy source. These posters encapsulated the knowledge gained throughout the weeks dedicated to various alternative energy topics. The students then presented their posters to fellow faculty members, showcasing their comprehensive understanding of each energy source. This interactive and technology-infused approach not only allowed students to creatively synthesize the information but also provided them with the opportunity to effectively communicate their findings to their peers and faculty members. The use of web 2.0 tools added a dynamic and engaging element to the presentation, fostering digital literacy skills among the preservice science teachers.

Data Collection and Analysis

We conducted individual interviews with students before and after the implementation and transcribed the interview records. Subsequently, these written transcripts underwent content analysis. Content analysis is a research method that involves systematically examining and interpreting the content of textual, visual, or multimedia materials to identify patterns, themes, and meanings (Krippendorff, 2018). It is often used to analyze and quantify the presence of specific words, phrases, themes, or symbols within a given set of data, providing insights into communication patterns, attitudes, and behaviors.

Two researchers independently evaluated the responses of the same students, generating codes. This process was repeated for five students. Later, the two researchers compared their codes in a collaborative session. Similarities and differences in the generated codes were identified. Discussions addressing the differences led to a consensus, resulting in the final set of codes.

Following this, the two researchers reanalyzed the responses of the same students during a joint session. The reliability of the analyses was calculated according to Miles and Huberman (1994), yielding a 95% agreement, a generally accepted level of reliability in the literature. The remaining analyses were carried out by the second researcher.

Ethical considerations

The research was conducted in accordance with ethical principles. Written consent was obtained from the participants, and principles of confidentiality and privacy were strictly adhered to. Throughout the research process, respect for participants' rights was maintained, and care was taken in sharing information. When presenting findings, participant identities were kept confidential by assigning numerical identifiers such as PT-1 and PT-2.

FINDINGS

Findings about Recognition and Description of Various AES

The first research question explored how enrolling in an SSI-based AES course influenced preservice teachers' recognition and description of various AES. Table 1 shows the pre-test and post-test codes derived from students' answers:

Table 1: Comparison of Pretest and Post-Test Responses of Preservice Teachers' AES Perceptions

Category (Pre-test)	Code	Frequency
Environmental Attributes	Natural and sustainable source of energy	3
	Does not harm the environment	2
	Environmentally friendly	3
	Renewable, protects nature	3
	Low carbon emissions	1
	Inexhaustible	1
Economic and Sustainability Attributes	Economic (decrease energy dependence)	2
	Natural	3
	Sustainable	3
Category (Post-test)	**Code**	**Frequency**
Environmental Attributes	Environmentally friendly, sustainable (compared to fossil)	3
	Low environmental impact	4
	Natural	1
	Not very harmful to the environment	2
Economic Attributes	Decrease energy dependence	1

The post-test shows a shift in emphasis from general environmentally friendly characteristics to specific considerations such as sustainability compared to fossil fuels and low environmental impact. In the pretest, participants associated economic and sustainability attributes more broadly. In the post-test, there is a specific mention of decreasing energy dependence. For instance:

> *"The fact that our energy needs are met by foreign countries shows that we are dependent on foreign countries for energy. if we use alternative energy sources, we will get rid of this dependence." (PT-8)*

> *"Alternative energy sources are environmentally friendly and sustainable. In my perspective, when compared to fossil fuels, these sources are seen as less harmful to the environment." (PT-1*)

The responses of preservice teachers to the pretest and posttest on their recognition of different alternative energy sources are shown in Table 2.

Table 2: Comparison of Preservice Teachers' Recognition of AES In Pre-test and Post-Test

Alternative Energy sources	Pre-test (f)	Post-test (f)
Solar Energy	9	10
Wind energy	9	10
Hydroelectric Energy	5	10
Geothermal Energy	5	19
Wave Energy	1	1
Biomass energy	1	7
Tidal energy	0	1
Magnetic Energy	0	1

The following are some examples of alternative energy sources: solar, wind, hydroelectric, geothermal, wave, biomass, and tidal energy. The frequency of mentions of each energy source before and after the SSI-based training is represented by the numerical values. Notable changes include increased frequencies in the post-test for geothermal energy, biomass energy, and tidal energy, indicating a potential positive impact of the course on the participants' awareness of a broader range of alternative energy sources. One of the participants reported Magnetic Energy as a type of alternative energy. Although the term "magnetic energy" is not commonly recognized as a standalone form of alternative energy it's possible that the student was referring to certain concepts related to magnetism being explored for energy generation. PT-1 explained it as:

> *"Alternative energy sources are solar, wind, hydroelectric, geothermal, wave, biomass, tidal energy, and magnetic energy. there are experimental technologies and research projects that explore the potential use of magnetic fields in power generation, such as in magnetic generators or magnetic induction. We may take it as an alternative energy type."*

Findings about Preservice Teachers' Perspectives regarding AES Meeting Türkiye's Energy Demand

In the second research question, we aimed to explore how preservice teachers' perspectives regarding AES meet Türkiye's energy demand. Participants' responses to pre-test and post-test were grouped under categories and presented in Table 3:

Table 3: Comparative Overview of Preservice Teachers' Perspectives on AES For Türkiye's Energy Demand

Category (Pre-test)	Code	Frequency
Environmental and Sustainability Considerations	Fossil fuels are running out, alternative energy is a must	2
	Critical role in terms of sustainability	1
Potential and Capacity	Meets most of the requirements	2
	Very high potential	3
Current Status and Action Items	Currently 5%, capacity needs to be increased	1
	Budget should be allocated; public awareness should be raised	1
	I think it will not be enough	1
Energy security	Needed for energy security	1
Category (Pre-test)	**Code**	**Frequency**
Environmental and Sustainable Attributes	Has great potential	5
	Sustainable, potential must be explored	3
	Not reliable/intermittency issues with certain sources	2
	Clean energy	1
Economic Considerations	Cost reduction through technological progress	1

	Initial cost of installation	1
	Technological advancements needed	
Energy Security and Future Demand	Energy security	1
	Fossil fuels are running out	4
	Alternative energy is not a choice, it is a must	3
Policy	Depends on the government's policy	1

According to Table 3, the pre-test responses indicated a baseline understanding among preservice teachers, emphasizing the urgency of transitioning from fossil fuels due to the acknowledgment that "Fossil Fuels are Running Out" and recognizing the "Critical Role in Sustainability." Additionally, concerns were raised about the current energy status, with the belief that "Currently 5% of capacity needs to be increased," and calls for action through "Budget Allocation" and "Raising Public Awareness."

Following the SSI-based course, notable shifts in perspectives emerged in the post-test responses. Preservice teachers exhibited an enhanced appreciation for the potential of alternative energy sources, with a heightened emphasis on their positive environmental and sustainable attributes. Specifically, they recognized the "Great Potential" and advocated for further exploration of the "Sustainable" aspects of alternative energy. However, concerns were raised about the reliability and intermittency issues associated with certain sources, indicating a nuanced understanding of the challenges. Moreover, post-test responses underscored a strengthened awareness of the economic considerations, including the need for "Cost Reduction Through Technological Progress" and the importance of addressing the "Initial Cost of Installation" through technological advancements. Energy security remained a consistent concern, with an increased emphasis on the indispensability of alternative energy sources, reflected in the sentiment that "Alternative Energy is not a Choice, it is a must." Sample excerpts are provided below:

> *"With fossil fuels running on empty, it's pretty obvious we can't stick with them forever. it's like a no-brainer now – we need to switch to alternative energy. It's not just a suggestion; it's a must to keep things going sustainably." (PT-8, post-test)*

> *"It's clear that cost reduction through technological progress is a game-changer. With advancements in tech, we're seeing a real opportunity to make alternative energy more affordable. It's like a win-win – cleaner energy and saving some cash in the long run." (PT-6, post-test)*

> *"It's pretty straightforward – if we want to make a serious shift to alternative energy, we need the funds to back it up. Allocating a budget for this cause is a must. Public awareness needs a boost so that everyone knows why investing in alternative energy is so crucial." (PT- 7, pre-test)*

> *"Counting on other countries or messing with nuclear stuff can be sketchy. Feels like we're handing over our energy future or playing with fire safety-wise. But hey, that's where alternative energy steps in – seems like a way safer move for our own energy security." (PT-1, post-test)*

Findings about the Perspectives of Preservice Teachers regarding the Advantages and Disadvantages of AES

In last research question, we explored how an SSI-based AES course affects the perspectives of preservice teachers regarding the advantages and disadvantages of AES. Table 4 provides a comparison of pre-test and post-test responses from preservice teachers regarding the advantages of RES.

Table 4: Comparison of Pre-test and Post-test Responses on the Advantages of AES

Categories	Codes	Pre-test (f)	Post-test (f)
Environmental Benefits	Environmentally Friendly	6	6
	Sustainable	6	5
	Energy Security	2	3
	Reduced Air and Water Pollution	1	0
	Less Harmful to Nature	3	1

Resource Characteristics	Inexhaustible	4	5
Security	Energy Security	2	3
Economic and Job-Related	Reduced Cost	1	0
	Jobs	0	1
	Price Stability	0	1
	Independence	0	1
	Economic Viability	0	1
	Economical Even with High Installation Cost	0	1
Technological and Innovation	Technological Progress	0	1
	Innovation	1	0
Long-Term Considerations	Long Term Use	0	1
	Long-lasting	1	1
	Clean	0	2
Social and Global Concerns	Low Carbon	0	1
	Clean	0	2
	Reliable	0	2
	Reduces Dependency	0	1
	Reduced Greenhouse Gas Emissions	0	1
	No Greenhouse Gases	0	1
	Evaluates Separately	0	1
	Reduces Environmental Pollution	0	1
	Does Not Deplete Resources	0	1
	Does Not Cause Global Warming	0	1

Perceptions of alternative energy among preservice teachers underwent notable changes from the pre-test to the post-test, particularly within key categories. Environmental considerations, such as being "Environmentally Friendly" and "Sustainable," remained consistent, showcasing an enduring environmental awareness. Notably, the post-test indicated a heightened emphasis on recognizing resource characteristics, particularly the perception of alternatives as "Inexhaustible," suggesting a deepening comprehension. A significant shift unfolded in economic and job-related considerations, with an increased focus on "Jobs," "Price Stability," and "Economical Even with High Installation Cost" in the post-test. This shift signifies an enhanced understanding of the economic feasibility and employment potential linked to alternative energy. Collectively, these responses illuminate the improved understanding students gained regarding the multifaceted benefits of alternative energy, encompassing environmental, economic, and societal dimensions. Sample excerpts exemplifying these aspects are provided below:

> *"It's friendly to the environment, keeps things sustainable, and even boosts our energy security. But the coolest part? It helps cut down on air and water pollution. So, we're not just getting power – we're getting cleaner, healthier air and water." (PT-7, post-test)*

> *"It's not just about going green; it's about creating jobs, ensuring stability in prices, and making alternative energy economical even with those upfront costs." (PT-1, post-test)*

Similarly, we created Table 5 to explore how participants' perceptions changed about the disadvantages of AES after the SSI-based course:

Table 5. Comparison of Pre-Test and Post-Test Responses on the Disadvantages of AES

Categories	Codes	Pre-test (f)	Post-test (f)
Technical Challenges	Storage difficulties	1	1
	Space constraints	0	1

	First aid cost	1	0
	Technological dependency	1	0
	Discontinuous	1	0
	The amount of energy produced	2	1
	Unstable energy	0	1
Economic Factors	High cost	3	3
	Installation cost	2	4
	Shortage of land to install	0	2
	Not possible to benefit from the percentage	1	0
	Efficiency problems	1	0
	Storage spurns	1	2
Environmental Impact	Damages the ecosystem and biodiversity	1	8
	Land disturbs natural environment	0	1
	Location problems	0	2
	Weather conditions are variable	0	3
Miscellaneous	All evaluated separately	0	1
	Solar panels are chemical	0	1

Table 5 provides a comparison of pre-test and post-test responses from participants regarding the disadvantages of AES. Changes in students' perspectives on the disadvantages of alternative energy emerged distinctly from the pretest to the posttest, showcasing shifts in various categories. Technical challenges, such as "Storage Difficulties" and "Technological Dependency," were decreased in mentions in the post-test, suggesting a potential reassessment of these issues. Economic factors like "High Cost" remained concerns, with an increased focus on "Shortage of Land to Install" and "Installation Cost" in the post-test, indicating an evolving understanding of the economic implications. Environmental impacts gained prominence in the post-test, particularly concerns about "Damaging the Ecosystem and Biodiversity". Participants highlighted '*Land Disturbing Natural Environment*', and '*Dams as a Nuisance to Aquatic Environment*' showing their increased environmental awareness about the effects of RES. Miscellaneous concerns, including "All Evaluated Separately", "Solar Panels are Chemical" surfaced in the post-test, revealing additional dimensions of consideration. Collectively, the participants' perspectives indicate an evolving awareness of the multifaceted challenges associated with alternative energy. Sample excerpts delineating the challenges associated with AES are provided below:

> *"Storage difficulties and technological dependency are real challenges. It's not just about the sources; it's about how we store and manage that energy. It's making me think more about the practical side of things." (PT-4, post-test)*

> *"Alternative energy sounds awesome, but you need to consider the real deal. The costs can get pretty high, and when we set up those energy systems, it can mess with nature, disturb the land, and even damage ecosystems. Dams, which give us energy, can also be a hassle for aquatic environments. It's like this tricky balance between getting clean energy and making sure we're not messing up the planet at the same time." (PT-2, post-test)*

To sum up, the study's findings, taken together, provide insight into the effectiveness of an SSI-based AES course on preservice teachers' understanding, viewpoints, and considerations of AES. The course affected participants' ability to identify and characterize a range of AES, as demonstrated by the significant changes in focus from broad environmental friendliness to more focused factors like sustainability and low environmental impact. The participants' viewpoints on the ability of AES to meet Türkiye's energy demand also were significantly changed, with a greater respect for the sustainable, economic, and environmental qualities of AES. The study also demonstrated a sophisticated comprehension of the difficulties posed by alternative energy, as evidenced by how issues like economic viability, intermittency, and reliability were examined. Overall, the results showed that the participants' awareness was successfully expanded by the SSI-based AES course, promoting a comprehensive understanding of the advantages and disadvantages presented by AES.

DISCUSSION

This study explored how SSI-based AES course helped to develop preservice teachers' understanding, viewpoints, and considerations of AES. In this respect, our study revealed that participants were able to identify and characterize a range of AES at the end of the course. This finding, in fact, is promising as the relevant literature reported mixed results about teachers' knowledge of AES (Doğru & Çelik, 2019, Liarakou et al., 2009; Stylos et al., 2023; Zyadin et al., 2014). While Doğru and Çelik (2019) reported preservice science and primary teachers' knowledge of AES was insufficient, Liarakou et al. (2009) reported that Greek teachers were knowledgeable about AES however, their awareness about particular AES (wind or solar energy) was low. In contrast, Stylos et al. (2023) reported that Greek preservice teachers held a low to moderate understanding of energy concepts. In another study, Kara (2015) reported that preservice teachers were more knowledgeable about solar, wind, and hydroelectric energy while a few participants mentioned geothermal, biomass, wave, and hydrogen energy as AES. In addition, participants had alternative conceptions (such as mentioning nuclear power as an AES). Zyadin et al. (2014) also reported that Jordanian secondary teachers had limited knowledge of alternative energy. While these studies were descriptive and did not include any intervention, intervention studies, as in this study, were proven to be successful in terms of developing participants' understanding of relevant AES (Cebesoy & Karisan, 2017; Karpudewan et al., 2013; Levine Rose & Calabrese Barton, 2012; Mckinzie Sutter et al, 2019). Our participants were able to identify more AES as well as demonstrate sophistical comprehension of the difficulties posed by alternative energy, as evidenced by how issues like economic viability, intermittency, and reliability of AES should be handled while discussing these issues. These aspects are important as Sakschewski et al. (2014) indicated that students need to comprehend ecological, economic, and social dimensions of energy-related SSI. The intervention study conducted by Cebesoy and Karişan (2017) revealed similar findings as preservice teachers were able to consider economic, ecological, political, technical, geographical, and sociological factors associated with the use of AES. Similarly, McKinzie Sutter et al. (2019) found out that students could identify the possible and negative aspects of wind farms while making decisions after participating in an instructional module. However, Cebesoy and Karisan (2017) revealed that participating teachers' knowledge was lower than expected at the end of the course. This might be related to the length of the course. While Cebesoy and Karisan's (2017) intervention lasted for a twelve-hour teaching session, our study lasted for a semester. Thus, it might be the reason that the more the preservice teachers interacted with the controversial nature of energy-related SSI, the more sophisticated understanding they might develop at the end of the course. Another possible explanation for reporting a low level of knowledge of AES after the intervention could be that there was no data collection before the intervention in Cebesoy and Karisan's (2017) study. we collected data twice (before and after the SSI-based course) and were able to compare the frequencies of the pre-test and post-test.

Another significant finding was that the participants' viewpoints on the ability of AES to meet Türkiye's energy demand also were significantly changed, with greater respect for the sustainable, economic, and environmental qualities of RES. This finding clearly diverges from Cebesoy and Karisan's (2017) study. As the authors only reported that preservice teachers were able to identify certain types of alternative energy found in Türkiye, in our study, we found that participants were able to assess the ability of AES to meet Türkiye's energy demand meaning they were more critical in terms of sustainable, economic and environmental consequences of AES. Overall, the results showed that the participants' awareness was successfully expanded by the SSI-based AES course, promoting a comprehensive understanding of the advantages and disadvantages presented by AES.

This finding is significant in terms of providing evidence as the participating preservice teachers were more able to consider the pros and cons of energy-related SSI. In line with our findings, Sakschewski et al. (2014) argue that students need to comprehend the ecological, economic, and social dimensions of energy-related SSI while making decisions. SSI-based AES course helped participants to consider different aspects of alternative energy. Supporting this finding, Stylos et al. (2023) reported that preservice teachers were able to be cautious about the potential benefits and costs of alternative energy. In line with our findings, developing a 13-week unit over an energy-related SSI, Levine Rose and Calabrese Barton (2012) reported that participants enhanced their understanding and knowledge about the complexity of the issue being discussed by recognizing the multi-dimensional nature of the problem and proposed more complex solutions for the problem. On the other hand, Martín-Gámez and Erduran (2018) reported that preservice teachers had difficulties while making arguments

about energy-related SSI. It shows the relevance of intervention studies to develop preservice teachers' argumentation skills in energy-related SSI. Supporting this, our study reveals that SSI-based AES course could improve participants' weighting of the multi-dimensional nature of alternative energy issues.

Limitations and Future Directions

This intervention study has promising evidence while holding limitations that can direct future studies. First of all, this study was conducted with preservice science teachers enrolling in an elective course about AES. The enrolling students might be more interested in alternative energy and it might be the reason why we revealed a more sophisticated understanding of alternative energy at the end of course. It will be feasible to conduct a similar intervention study in a compulsory course with a larger number of participants. The second issue is that we only collected qualitative data and renumerated the interview transcripts into quantitative forms. Future studies might adopt multiple data collection tools such as classroom participation or classroom discussions. Thus, it might be useful to use video analysis or voice records of small-group and whole-group discussions. A third issue might be creating gender-balanced classes. As the literature reveals gender differences (Stylos et al., 2023; Zyadin et al., 2014) about knowledge and attitudes toward AES, it could be feasible to create a more gender-balanced class to conduct intervention studies.

Araştırma ve Yayın Etiği

In this study, all rules specified in the "Directive on Scientific Research and Publication Ethics of Higher Education Institutions" were followed. None of the actions specified under the second part of the Directive, "Actions Contrary to Scientific Research and Publication Ethics" have been carried out. (Mandatory declaration)

Disclosure Statements

1. Contribution rate statement of researchers: First author % 50, Second author % 50

2. No potential conflict of interest was reported by the authors.

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