



Indonesian Society for Science Educators

# Journal of Science Learning

journal homepage: [ejournal.upi.edu/index.php/jslearning](http://ejournal.upi.edu/index.php/jslearning)

## Improving Pre-Service Science Teachers' Content Knowledge and Argumentation Quality through Socio-Scientific Issues-Based Modules: An Action Research Study

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**ABSTRACT** This paper aimed to assess improvements in content knowledge and argumentation quality of pre-service science teachers (PST) through a socio-scientific issues-based (SSI-based) module course. The study was designed as action research with 25 PSTs. Data collection instruments were an energy-related content knowledge questionnaire and video recordings. An energy-related content knowledge rubric was used to evaluate the content knowledge of PSTs, while their argumentation quality was analyzed using a video analysis inventory. The module course was completed in eight weeks. Findings showed that the SSI-based teaching modules course improved energy-related content knowledge with all PSTs increasing by a minimum of one criterion on the rubric. Although the number of arguments decreased weekly, the argumentation quality also increased. Thus, it can be inferred that SSI-based module teaching is a practical tool to teach energy-related content knowledge and argumentation qualities. The study suggests that action research can contribute to developing an effective learning environment. Further studies that include the actual practices of PSTs as they reflect and revise their learning are indicated.

**Keywords** Argumentation quality; Content knowledge; Socio-scientific issues-based teaching

### 1. INTRODUCTION

In recent decades, commentators have opined that science should better match society's requirements and that science is related to the environment and technology (Topçu, 2008). Socio-scientific issues (SSIs) give the idea that there are moral principles in students' physical, social, and personal lives. Moreover, these issues provide students with a healthy perspective on how to think about science-based issues (Topçu, 2015). According to Zeidler, Sadler, Simmons, & Howes (2005), SSIs impact individuals' intellectual development in terms of their personal and social context. This result is provided by using controversial issues and dilemmas, which activate how to think about these kinds of issues. Thus, SSIs can be regarded as a context to learn science and as a pedagogical strategy that has clear objectives.

SSIs are scientific-related social issues with ethical-moral, political, and religious contents (Borgerding & Dagistan, 2018). Also, SSIs can be regarded as a complement of scientific products or processes that can bring about social debates. Sadler & Zeidler (2005)

indicated SSIs' features: they are based on scientific concepts and have controversial nature, and they are discussed in public usually and subject to political and social influences (e.g., nuclear power plants). A few of the most typical SSIs are cloning stem cells and genetically modified foods, biotechnological outputs, and implementations (Sadler & Zeidler, 2005).

Because SSIs are open to argument on the topics held during the learning process, these issues are integral parts of the curriculums in most countries (Council of Ministers of Education, Canada [CMEC], 1997; Western Australia Curriculum Council [WACC], 1998). According to the Ministry of National Education (MoNE) (2013), SSIs involve scientific and moral discernment for socio-scientific problems about science and technology.

Received: 23 February 2020

Revised: 12 November 2020

Published: 28 November 2020



## 1.1 Teaching socio-scientific issues

SSIs, which contribute to students' science literacy, should not be seen as a magic-bullet solution (Sadler, 2011a). Several studies have pointed out that SSI-based teaching practices struggle teachers in a science course (Hanley, Ratcliffe, & Osborne, 2007). According to Windschitl, Thompson, Braaten, & Stroupe (2012), science teachers struggle to include students in lessons as a social aspect of learning. For instance, Simon & Amos (2011) reported that the teacher struggled to recognize students participating in the instructional process and argumentation practices. Besides, Pitipornatapin, Yutakom, & Sadler (2016) emphasized that pre-service science teachers struggle with a lack of integration of SSIs to their lessons, difficulties linking SSIs to scientific concepts, and difficulties in eliciting students' prior knowledge of SSIs.

A literature review suggests that it is challenging to use SSIs in the classroom, but teachers from different backgrounds can succeed with appropriate support (Sadler, 2011a). For this purpose, teachers should be supported as professionals to be more experienced in teaching SSIs. To successfully integrate SSI-based instruction in the classroom, teachers must provide scaffolding for students to engage in higher-order thinking processes, reflect learning, argumentation processes, reasoning, and decision-making (Presley et al., 2013). Besides, teachers can use newspapers, interviews, reports (Klosterman, Sadler, & Brown, 2012), and technological materials (Evagorou, 2011) to promote SSI-based practices in the classrooms. If they can put this approach into practice, students can deeply understand SSIs' place in scientific content (Sadler, 2011a). Thus, teachers should guide students during lessons and evaluate whether the students can make a proper claim or not (Nielsen, 2012). According to Ratcliffe & Grace (2003), practices including learning strategies are crucial, as they make the learning goals and structure of the practice clearer, make the learning process visible, and define the teacher's role during the discussion. Besides, Bencze (2000) indicated that students should engage in student-directed, open-ended investigation processes, which lead them to reach their conclusions about socio-political issues. Moreover, because partnerships between researchers and teachers constitute another significant issue, it needs to be defined whether university-based education helps classroom-based education or not (Sadler, 2011a). It is also important to remember that teachers need both subject-matter knowledge and pedagogical-content knowledge (Magnusson, Krajcik, & Borko, 1999) to teach SSIs effectively.

### 1.1.1 Socio-scientific issues teaching frameworks

Different models have been developed for SSI-based teaching include a model for decision-making (Keefer, 2003), a model for bioethics (Dawson, 2001), and SSI-based teaching frameworks (Presley et al., 2013; Sadler, 2011b). Sadler (2011b) has drawn a frame to teach SSIs,

which includes four aspects: (a) designing elements, (b) learner experiences, (c) classroom environment, and (d) teacher attributes. Designing elements and learner experiences as core features of the framework are shown in the figure's center. The other dimensions (classroom environment and teacher attributes) are seen as peripheral contributions to shape the core aspects. In contrast, Presley et al. (2013) presented a framework that puts the aspect of teacher attributes in the central region. Some modules have been designed to teach SSIs by using different models (Evagorou, Guven, & Mugaloglu, 2014). For example, three modules have been developed in Preparing Elementary and Secondary Pre-Service Teachers for Everyday Science (Evagorou, Guven, & Mugaloglu, 2014). Here the main aim was to improve teachers' content knowledge, pedagogical knowledge, and skills to teach SSIs with seven participant countries (Topçu, Muğaloğlu, & Güven, 2014).

### 1.1.2 Argumentation for teaching socio-scientific issues

In science education, it is crucial to learn well-accepted scientific practices, including making a claim and providing an argument to make a claim clear (Andrews, Costello, & Clarke 1993). SSIs are contradictory by nature (Sadler & Zeidler, 2005), and this nature makes SSIs debatable. Therefore, argumentation can be one of the best strategies to meet SSI teaching needs (Osborne, Erduran, & Simon, 2004).

Multiple studies have been published (Dawson & Carson, 2017; Erduran, Simon, & Osborne, 2004; Zohar & Nemet, 2002) related to argumentation, which is seen as a critical factor of SSI teaching (Osborne, Erduran, & Simon, 2004; Presley et al., 2013). According to Duschl, Schweingruber, & Shouse (2007), argumentation is a sound practice to teach how to learn about the natural world, how to produce and evaluate scientific evidence and explanations, how to understand the epistemic nature of scientific knowledge, and how to participate in scientific practices and discussions.

The most widely used model about argumentation is Toulmin's Argument Pattern (TAP). While using TAP to analyze arguments focuses on small-group discussions among students in science education (Erduran, Simon, & Osborne, 2004). TAP defines argumentation as a series of claims that are mutually related. According to this pattern, data supports a claim, a warrant connects data to the claim, backing supports the warrant, and rebuttal shows that the claim may not be valid in certain situations.

### 1.1.3 Teaching energy-related socio-scientific issues

Energy is a concept used to explain scientific phenomena among different disciplines (Eisenkraft et al., 2014). Students should be encouraged to be engaged citizens to learn energy-related SSIs (Sakschewski, Eggert, Schneider, & Bögeholz, 2014). Thus, energy should be seen

not only as a concept but as an educational opportunity in terms of SSIs, citizenship education, and sustainable development (Sakschewski, Eggert, Schneider, & Bögeholz, 2014). Science education curriculums are also extensively related to energy and students' misconceptions about this concept. In a similar vein, energy topics are an essential consideration in Turkey (MoNE, 2013).

However, it is not sufficient to learn concept-based knowledge to make decisions to evaluate energy technologies critically. Although energy is a crucial concept having rich connections among disciplines, the issues that include this concept are difficult for students. For example, students struggled with the long-term process of defining a problem about energy issues (Bartosch, 2018). According to Sadler (2009), energy storage technologies, the construction of offshore wind power systems, or energy-efficient buildings as ill-structured problems encounter students in their daily lives. These problems are not only scientific or engineering-related issues but also ethical or political social-related controversial issues (Bartosch, 2018). Moreover, people have a significant and quick response to these issues because they have limited time and information to decision energy-related issues (Lee, 2015).

Energy-related SSIs provide a multidisciplinary approach and a decision-making process, producing engaged social debates and improved citizenship consciousness, which are reasons to select this issue in this study. Besides this, this topic reflects our domestic agenda. Furthermore, there are many design model/module studies for SSIs in terms of climate change (Klosterman & Sadler, 2010), biotechnology (Presley et al., 2013), ecology (Sadler et al., 2015), and natural selection (Friedrichsen, Sadler, Graham, & Brown, 2016). Hence, we believe that this study contributes to the literature on module usage related to energy-related SSIs.

Other studies related to SSIs have investigated argumentation practices (Venville & Dawson, 2010), teacher experiences (Ekborg, Ottander, Silfver, E., & Simon, 2013), decision-making skills (Gresch, Hasselhorn, & Bögeholz, 2013), and learning the nature of science (Lederman, Antink, & Bartos, 2014). In these studies, SSIs were used as a context. Also, in studies related to designing modules, most have not focused directly on SSIs. In this study, SSIs are used not as context but as content to learn.

Participatory action research (PAR) studies are deal with both empirical research findings that obtained classroom activities and the development of innovative, evidence-based curricula, pedagogies, and teaching materials (Eilks, 2018). In PAR model, it aimed five areas of objectives in practical science education: (1) new concepts and materials for teaching, (2) knowledge about teaching and learning, (3) developed practice, (4) trained teachers, and (5) documentation of teaching practice (Eilks, 2018). Energy-related SSIs-based module used in this study as a guide for teachers in teaching SSIs. We intend to both

develop teaching practices that pre-service science teachers will use in their courses and encourage them professional development.

This study aimed to evaluate what improvements the pre-service science teachers' (PSTs) content knowledge and argumentation quality in socio-scientific issues-based module used courses. The research questions are (1) What improvements are in the content knowledge level of PSTs when implementing socio-scientific issues-based module used courses? Moreover, (2) What improvements in the argumentation quality of implementing socio-scientific issues-based module used courses?

## 2. METHOD

### 2.1. Study Design

This study was designed based on action research. Action research aims to study a social situation to improve the quality of action (Elliot, 1991). In this case, an action study is studying a school or class situation to understand and improve the quality of education (McTaggart, 1997). Action research is often used to design curriculum, advance professional development, or undertake systematic planning or policymaking in education. Eilks and Ralle's (2002) Participatory action research (PAR) project for chemistry education is an example of action research related to science education. PAR is a collaborative strategy for curriculum and classroom-based studies (Eilks & Ralle, 2002) because this approach provides collaboration among researchers and teachers. As universities and schools have their advantages and limitations (McIntyre, 2005), PAR aims to show that both universities and schools can benefit from each other's strengths and address their missions collaboratively.

In the current study, the role of the researcher was a "participatory observer". The researcher helped the PSTs during the distribution of materials, giving information about the scenarios and activities and explaining the subjects, so the researcher was a participant during these processes. On the other hand, the researcher was a passive observer during conduct activities and the argumentation process.

### 2.2 Participants

In this study, criterion sampling, one of the purposeful sampling methods, was used to create the participant group. Criterion sampling provides researchers the opportunity to deeply study a situation by providing a vast amount of related data (Creswell, 2009). Purposeful sampling is a crucial method to collect open-ended data (Creswell, 2009). This study's participants were 18 women and 7 men who were studied in science teaching with grade three pre-service teachers in Turkey, individuals who want to become teacher, and they enter the university entrance exams after 12 years compulsory education. After matriculation of Education Faculty, pre-service teachers whom trainee four years qualify for a teacher. If they wish, graduated teachers can be appointed as a teacher to schools

by taking a new exam. Therefore in this study, the expression ‘pre-service science teachers’ refers to students studying at the Education Faculty. The selection criteria were that the PSTs were grade three, they knew the basic concepts, and they had not taken a course about energy-related SSIs, and they had not attended any program about teaching SSIs. Although PSTs who participated in this study knew fundamental physics and chemistry concepts (e.g., dynamic, electricity, optic, energy conversions) and general science education knowledge (e.g., general educational sciences, science curriculum), most PSTs did not have prior knowledge on SSIs, and they did not learn argumentation process and skills at the level of their education.

### 2.3 Instruments

Two types of instruments—open-ended questions and video recordings—were used to collect data. First, questions based on energy-related content knowledge were used to understand the knowledge level of PSTs. Open-ended Content Knowledge Questions about Energy (CKQEs) were prepared by the researchers based on a Turkish science education curriculum (MoNE, 2013). The questions' themes were determined based on the dimensions of energy literacy defined by DeWaters & Powers (2013). The themes were basic conceptual knowledge, energy sources, energy needs and management, social effects of energy, global energy, and energy's environmental effect. CKQEs examples are presented in Table 1.

CKQEs were reviewed by three experts, two of whom are professors of science education and a physics professor. After expert views corresponded, the final form of questions created. The final form of CKQEs consists of 15 open-ended questions. To ensure study accuracy and credibility, criteria suggested by Johnson (2012) were taken into consideration. Therefore, the researcher took notes when necessary, describing the instruments' design process in detail and creating a table of specifications to evaluate and confirm the content validity.

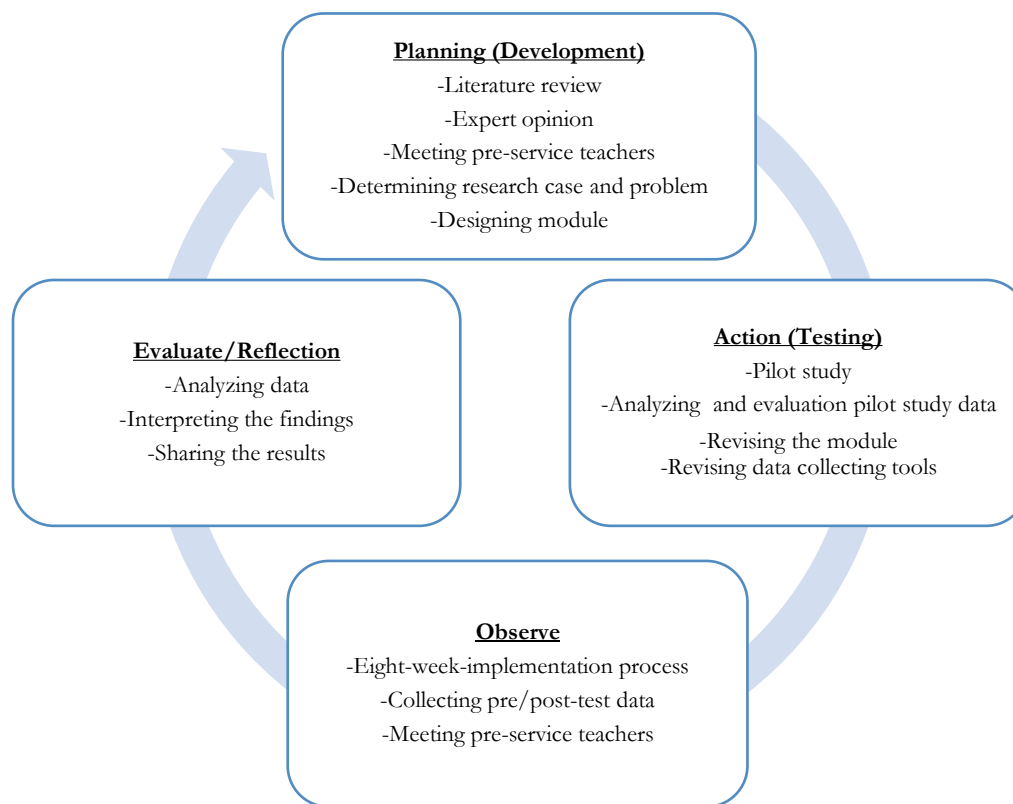
Secondly, argumentation videos were recorded by four groups in the argumentation process. Videos were recorded for four weeks, and each week had its topic. The researchers decided on energy-related argumentation topics based on the learning outcomes of a Turkish science education curriculum (MoNE, 2013) as CKQEs. For the first week, power plants were held as an argumentation topic (for 12–24 minutes in different groups). For the second week, the topic was heat insulation (13–28 minutes). Solar energy was discussed in the third week (11–20 minutes), and in the last week, the topic was recycling-energy scenarios (14–29 minutes).

### 2.4 Process

In this research, the researchers developed a teaching module for use in their course. The researchers grounded their module based on Sadler's (2011b) framework and Presley et al. (2013). The module was designed based on the Turkish science education curriculum (MoNE, 2013). The module had three parts, covering eight weeks. The first part of the module (two weeks) included activities based on

**Table 1** CKQEs examples according to learning outcomes and energy literacy dimensions

CKQEs examples	Learning outcomes	Energy literacy dimensions
Briefly describe how energy is produced in hydroelectric power plants, thermal power plants, wind power plans, geothermal power plants and nuclear power plants (Q <sub>1</sub> ).	Investigate and present how electricity is generated in power plants (LO <sub>7.6.2.4</sub> )	Energy sources
You've learned that illegal electricity use is high in the area where your school is appointed. You want to give your students a few suggestions to share with their parents. What advice would you give them to prohibit the use of illegal electricity? Offer 4 suggestions. (Q <sub>2</sub> )	Discuss the importance of conscious and efficient use of electrical energy in terms of family and country economy (LO <sub>7.6.2.5</sub> )	Energy needs and management
Which criteria are used for the heat insulation materials? Why? (Q <sub>8</sub> )	Determines the selection criteria of heat insulation materials used in buildings (LO <sub>6.6.1.3</sub> )	Basic conceptual knowledge
As residents of the site, you would like to have a meeting about whether to have heat insulation. But the apartment superintendent says it will be costly and nobody will take a positive decision. How do you convince the apartment superintendent in terms of the contribution of heat insulation to energy savings for the family and the national economy? (Q <sub>9-10</sub> )	Discuss the importance of thermal insulation in buildings in terms of family and country economy and effective use of resources (LO <sub>6.6.1.2</sub> )	Social effects of energy



**Figure 1** Action research cycle

plays about SSIs' nature and features. The second part (four weeks) consisted of energy-related SSI argumentation scenarios (power plants, heat insulation, solar energy, and recycling energy). In this part, PSTs worked in four groups. In each group, PSTs were assigned certain roles (e.g., scientist, industrialist, father, environmentalist, and apartment superintendent) as in the study by Evagorou,

Güven, & Mugaloğlu, (2014). One of the PSTs in each group took notes to support the video recordings. For the last two weeks, PSTs prepared a lesson plan about SSIs. According to Eilks & Ralle (2002), PAR can improve educational strategies and development curriculum. The implementation of the SSI-based module was carried out in a single cycle as the researchers aimed to improve the

**Table 2** Action plan

Action plan steps	Process
Development of teaching strategies and materials	Literature review (studies about teaching SSIs, designing module and energy-related topics) Expert opinions (expert opinion about the subject of the module and activities to be used during implementation) Meeting pre-service teachers (collecting ideas of pre-service teachers about the SSIs and module) Describing research study case (defining and classifying the objectives in the curriculum whether they are related with SSIs or not, and also defining energy-related objectives) Looking through the studies related with the research problem (problem situation was defined as energy-related topics and the studies related with it were analyzed) Designing module to teach SSI-based on research questions (determining the framework of the module, deciding on the topics and activities for the process and schedule for the module)
Testing in practices	Pilot study Revising the module after pilot study Revising data collecting tools after pilot study Collecting pre-test data according to research questions Eight-week-implementation process (play activities, argumentation process and designing lesson plans) Collecting post-test data according to research questions
Evaluation	Analyzing data Interpreting the findings
Reflection and revision	Sharing the results

content knowledge and argumentation quality of PSTs. This cycle consists of four-part: Planning (development), action (testing), observe and evaluation/reflection (Figure 1). In broad terms, the action plan designed according to Eilks & Ralle's (2002) "PAR model for science education" for the research process is presented in Table 2. According to Table 2, literature review, expert and PST's opinion studies, determination of research problem and study case, Design of SSI-based module were carried out in the development of teaching strategies and materials step. In the second step, testing in practices, pilot study, revision of module and data collection tools, pre/post-test collect, and eight-week implementation was done. In the last steps, evaluation, reflection, and revision analyzing data, interpreting the findings, and sharing the results were carried out.

## 2.5 Data Analysis

Two instruments, a rubric, and an inventory were used in the data analysis. Firstly, an Energy-related Content Knowledge Rubric (ECKR) developed by the researchers was used to analyze data related to content knowledge about energy. The criteria were determined according to the themes used in CKQE. The rubric was designed with a review of three measurement and evaluation experts and three science and physics experts. The reliability was determined using kappa reliability coefficients. The reliability value based on the formula defined by Fleiss

(1971) was calculated as 0.68, which means that "substantial". According to Landis and Koch (1977), the extent of the agreement is perfect if the Kappa values fall between (.81) and (1.00); substantial if they fall between (.61) and (.80); moderate if they fall between (.41) and (.60); fair if they fall between (.40) and (.21); slight if they fall between (.00) and (.20); and poor if they are less than (.00). This result indicates that the agreement value between the six raters was enough to use the analysis tool for the data related to content knowledge about energy. ECKR was an analytical rubric defining four levels: "inadequate (1), developable (2), acceptable (3) and exemplary (4)" and the category names were "basic conceptual knowledge, energy sources, energy needs and management, social effects of energy, a global energy, and the environmental effect of energy." Data were analyzed by two researchers based on ECKR. The inter-rater reliability was determined using kappa reliability coefficients. The reliability value based on the formula defined by Cohen (1960) was calculated as 0.69, which means that "substantial". This result indicates that the agreement value between the two raters was enough to categorize the findings.

Secondly, to define the argumentation quality, the Argumentation Quality Video Analysis Inventory (AQVAI) was used. This inventory was based on TAP and designed by Erduran, Simon, & Osborne, (2004). In this study, AQVAI was preferred because it is both comprehensive and appropriate for the subject of argumentation. AQVAI defines the levels of arguments regarding elements like claims, data, reasoning, and rebuttal (See levels in Table 3). Level 1 defines the argument comprising the claim or claim with counterclaims; level 2 defines arguments including the claim with data, warrant, and backing; level 3 describes claims with data, warrant, backing, weak rebuttal, and counterclaims; level 4 defines arguments with a strong rebuttal, and level 5 is defined by more than one rebuttal or arguments with all elements of argumentation. The argumentation videos of each group were analyzed by two researchers, according to AQVAI. The inter-rater reliability was determined using kappa reliability coefficients. The reliability value based on the formula defined by Cohen (1960) was calculated as 0.71, which means that "substantial". This result indicates that the analyses of both researchers have corresponded; the findings were obtained.

## 3. RESULT AND DISCUSSION

The results below comprise PSTs' knowledge level about energy-related content knowledge and their argumentation quality.

### 3.1 PSTs' knowledge about energy-related content

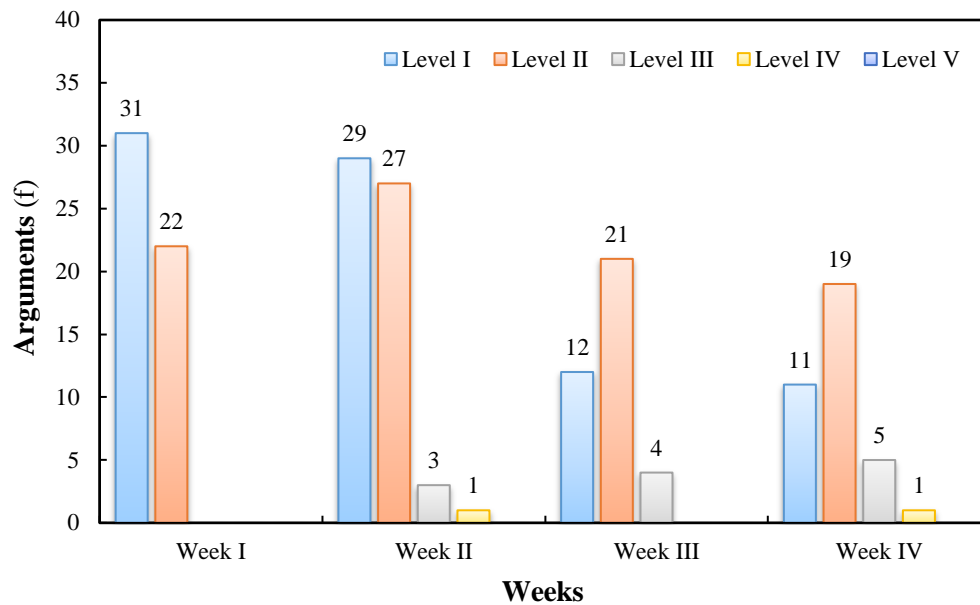
The knowledge level of PSTs was determined by using the same questions before and after the argumentation process, established by six criteria: Basic conceptual knowledge (BCK), energy sources (ES), energy needs and

**Table 3** Argumentation Quality Video Analysis Inventory (Adapted from Erduran et al., 2004)

AQL	Criteria
Level 1	Claim or claim with counterclaim (not include data, warrant, backing and rebuttal)
Level 2	Claim with data, warrant or backing (not include rebuttal)
Level 3	Claim or counterclaims with data, warrant, backing and weak rebuttal
Level 4	Strong rebuttal
Level 5	More than one rebuttal and all elements of argumentation

**Table 4** PSTs' scores according to ECKR

Criteria	Test	Scores ( $\bar{X}$ )
Basic Conceptual Knowledge	Pre-test	2.07
	Post-test	3.10
Energy Sources	Pre-test	1.64
	Post-test	2.89
Energy Needs and Management	Pre-test	2.46
	Post-test	3.26
Social Effects of Energy	Pre-test	1.93
	Post-test	3.00
Global Energy	Pre-test	1.57
	Post-test	2.63
Environmental Effect of Energy	Pre-test	1.71
	Post-test	3.21



**Figure 2** Argumentation quality of PSTs according to AQVAI

management (ENM), social effects of energy (SEE), global energy (GE), and environmental effect of energy (EEE).

The pre-test score of PSTs on BCK was 2.07 (level 2), and the post-test score was 3.10 (level 3); for ES, the pre-test score was 1.64 (level 1), and the post-test score was 2.89 (level 3); the pre-test score for the criterion ENM was 2.46 and the post-test score was 3.26; for SEE, the pre-test score was 1.93 (level 2), and the post-test score was 3.00 (level 3); the pre-test score of the criterion GE was 1.57 (level 1) and the post-test score was 2.63 (level 3); and the pre-test score of the last criterion, EEE, was 1.71 (level 1) and the post-test score was 3.21 (level 3). These findings are shown in Table 4. According to the findings, the module improved PSTs' energy-related content knowledge, as it stepped up each criterion by a minimum of one level.

### 3.2 PSTs' argumentation quality

The findings of the argumentation quality of PSTs according to AQVAI over four weeks are shown in Figure 2. According to Figure 2, it can be seen that arguments of PSTs in the first week (power plant-related argumentation) were at level 1 and 2; in the second week (heat insulation-related argumentation), all levels of arguments were voiced, but levels 1 and 2 were more intensely voiced; in the third week (solar energy-related argumentation), arguments from levels 1 to 3 were expressed and levels 1 and 2 were dramatically decreased compared to the first two weeks; and in the fourth week (recycling energy-related argumentation), when all levels of arguments were expressed, the amount of level 3 and level 4 arguments increased. Moreover, although the number of arguments decreased weekly, the argumentation quality increased. For

**Table 5** PSTs' argumentation samples (Heat insulation-related argumentation samples)

Argumentation samples	Criteria	Level
Heat insulation should not be done. Because the materials used there are damaged after some time and they become garbage. Furthermore they become carcinogen (PST <sub>3</sub> )	Claim with warrant	Level 2
We have no data effect of these materials on human health and I didn't see anyone with cancer due to heat insulation (PST <sub>1</sub> )	Counterclaim to claim	Level 1
As heat insulation is newly applied in our country, we may not have encountered such effects yet (PST <sub>3</sub> )	Claim with backing	Level 2
Heat insulation is not new in our country. Applied since 2001. Heat insulation also prevents mould growth. Growth moulds can affect airways in uninsulated houses. In addition to, 5% heat loss through the window, 6% from ground, 17% thorough doors and 23% through roof in uninsulated houses. This leads to loss of energy and economy (PST <sub>4</sub> )	Claim with data, warrant, backing and counterclaim to claim	Level 3
Ok. Materials used in heat insulation will quickly flash and flash-over in a fire (PST <sub>2</sub> )	Counterclaim to claim	Level 1
What you say is banned in 2007. Since the materials used for heat insulation are covered with stone does not damage in case of fire. Lastly, use of fossil fuels decreases by 50% with heat insulations (PST <sub>4</sub> )	Rebuttal	Level 4

detailed argumentation, samples of PSTs, according to AQVAI, are shown in Table 5.

At the end of the SSI-based module implementation, we can say that the module included SSI-based activities that improved PSTs' energy-related content knowledge. Based on their studies, Çetin (2014) inferred that participating in the argumentation process positively affects the content knowledge level of PSTs. Other studies have reached the same inference (Venille & Dawson, 2010; Zohar & Nemet, 2002). According to Zohar & Nemet (2002), teaching argumentation skills improves argument skills in the context of SSI and enables participants to understand science. Von Aufschnaiter, Erduran, Osborne, & Simon (2008) indicated the reason for this situation as that participants spend more time on the topic during argumentation practice. In this study's teaching module, four weeks were spent with argumentation practice. After two weeks of play activities about SSIs, the argumentation process was held, aiming to prepare PSTs for topics. After the argumentation process, PSTs formed their argumentation lesson plan over two weeks. Thus, overall the argumentation process was intensely experienced by PSTs, which can be one reason for their improved content knowledge level, as seen in other studies. For example, Jimenez-Aleixandre & Pereiro-Munoz (2002) indicated that participating in the argumentation process advances knowledge about the topic practiced during argumentation implementation.

Additionally, PSTs might state more accurate knowledge during the argumentation process because they are far less uneasy about failing to use an argument's components. For example, at the beginning of the implementation process, PSTs were hesitant while expressing their ideas, and they used sentences like "What I am saying now is a claim or data component for my argument". Within weeks, PSTs were confident in expressing their ideas because they learned the components of an argument. This situation may cause an improvement in their content knowledge level.

Additionally, Jho, Yoon, & Kim (2014) indicated that SSI-based teaching practices step up content knowledge of PSTs, as SSI-based education requires understanding and reflecting knowledge. In our study, the questions used to understand PSTs' content knowledge were versatile, comprising skills such as creating projects, designing concept maps, reading graphs, and decision-making, which triggers the use of diverse skills. Therefore, the improvement in PSTs' content knowledge level in our study should not be seen as a one-dimensional improvement but an improvement that includes different skills.

Another remarkable finding based on ECKR is that the module mostly affected the environmental effects of PSTs' content knowledge's energy dimension. According to Sandell, Öhman, & Östman (2003), when individuals

participate in an SSI-based decision-making process, they have the chance to evaluate the information that has effects both on their individual and their social lives, which represents excellent progress in terms of education for sustainable development. Moreover, Simonneaux & Simonneaux (2012) defined sustainable development issues as SSIs. Ratcliff & Grace (2003) defined environmental topics as SSIs. Argumentation topics held in the module (power plants, solar energy, and the relation between recycling and energy) were positively related to environmental issues. During the weeks, these topics were debated, some of the PSTs played environmentalists' role, and they got involved in the decision-making process to refute counterarguments. This result can be the reason for the improvement in environmental issues-related energy topics. Jegstad & Sinnes (2015) concluded that dealing with green chemistry topics, which are chemistry topics based on environmental issues, may increase pupils' understanding of the scientific process. Similarly, sustainable development-related topics in our module may bring about an improvement in energy-related content knowledge.

Our study's argumentation quality dimension shows that the arguments with elements like data, warrant, and rebuttal increased in number when the number of arguments expressed by PSTs decreased. Thus, it can be inferred that the module enhanced the argumentation quality of PSTs. The inventory used in this study has two methodological approaches while the arguments are evaluated, which are the number of arguments and rebuttal of the counterargument based on TAP (Erduran, Simon, & Osborne, 2004). It can be said that argumentation quality can be defined by the number of arguments and a rebuttal and the nature of the rebuttal. In other words, the amount of argumentation does not guarantee its quality; rebuttal is a crucial criterion to evaluate the argumentation quality. Therefore, our study's decreased number of arguments should not be evaluated as a degradation in argumentation quality.

According to Jimenez-Aleixandre & Pereiro-Munoz (2002), the argumentation process enhances knowledge about argumentation practice. For the same reason, PSTs might use a reduced number of claims and many other argumentation elements. In our study, the more they learned about argumentation practice, the less they tended to produce level 1 and level 2 claims. Although the number of claims was reduced, the last weeks' claims were more substantial than in previous weeks. Moreover, warrant, backing, and rebuttal elements of argumentation were more evident, defined as an advancement of argumentation. An improvement in content knowledge can also cause this situation. According to Sampson & Clark (2011), content knowledge is an essential factor in argumentation quality. Thus, the improvement in PSTs'



content knowledge within weeks could also have affected their argumentation quality.

During the module design, the researchers recognized five learning outcomes about SSIs or argumentation topics that could be used as SSIs in the Turkish science education curriculum (MoNE, 2013), even though there are many learning outcomes about energy topics, which are generally about energy usage. Besides, SSIs are only mentioned in the goals of the renewed curriculum (2017). In the 21st century, energy is one of the factors that define countries' development level, and it is an essential part of their budgets, which is significant for citizens. Besides, citizenship consciousness is emphasized in science literacy (Sakschewski, Eggert, Schneider, & Bögeholz, 2014). In this situation, energy-related SSIs can be the intersection topic of both citizenship consciousness and science literacy. Thus, it can be essential to rank this topic higher in the curriculum. When this is done, individuals will be supported in terms of decision-making, evaluating issues in the media or daily life, speaking knowledgeably about world affairs, being open to new ideas, listening to different views, and showing respect for different ideas. Therefore, SSIs should be covered in the curriculum. This module, whose aim was to test energy-related SSIs, can be used as a guide for future SSI modules. Also, the similarities and differences can be presented among SSI-based modules.

#### 4. CONCLUSION

It can be an inference from this study that SSI-based teaching modules can use practical tools to improve energy content knowledge and enhance the argumentation quality of PSTs'. Besides, it is essential to bear in mind that this study was designed as an action research study. Action research studies are used to fill the gap between the practical world and the research literature and help teachers create effective learning environments (Johnson, 2012). Action research studies do not require experimental and control groups, dependent and independent variables, or hypotheses. The action study aims to take a snapshot of the situation to understand it (Johnson, 2012). In this study, the researcher was a participant-observer, and the subject was created by purposive sampling. Thus, the results are limited concerning PSTs. However, the study could be adapted for teachers and students, and other experimental studies could be implemented to understand the module's impact better. In our study, we aimed to improve energy content knowledge and the quality of argumentation of PSTs. Since we achieved our aim in the first cycle, we completed the study in one cycle. Action research could complete two or more cycles in action research. This result can be a limitation of this study that we will explore further. It can be suggested that participants' practices could include in the "reflection and revision" step of the action plan and the practices could compare with different cycles of action research. Since action research provides one-to-one solutions to problems encountered in schools, we need to

pay attention to promoting SSIs in participants' classrooms. The other limitation is argumentation contents discussed in four weeks are different from each other, although all are energy-related SSIs. This situation may have affected the results of PSTs' content knowledge and argumentation qualities. Thus, other studies could be practiced on focusing on one issue.

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