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Preservice Science Teachers' Informal Reasoning about Hydroelectric Power Issue: The Effect of Attitudes towards Socio-scientific Issues and Media Literacy

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Abstract

The purpose of this paper is to examine the role of media literacy and attitudes towards socioscientific issues as two major predictors of informal reasoning. A sample of 208 preservice science teachers completed an open-ended informal reasoning questionnaire on hydroelectric power plant issue, media literacy level determination scale, and attitudes towards socio-scientific issues scale. In this study, descriptive research method was used. We used both qualitative and quantitative methods to analyze the data. Results indicated that the participants frequently used ecological-oriented arguments. The participants least used health-oriented arguments. Regarding reasoning qualities, the participants typically created supportive arguments, rather than counterarguments and rebuttals. Confirmatory factor analysis revealed validity and reliability evidence consistent with previous research. Multiple regression analyses revealed that perceived level of media literacy predicted informal reasoning. However, attitudes towards socioscientific issues did not explain informal reasoning. We offer implications for science teacher education programs.

Introduction

With scientific advancements and an increase in environmental challenges, socio-scientific issues (SSI) draw more media attention and are more frequently debated (Klosterman, Sadler, & Brown, 2012). Incorporation of controversial, open-ended issues with multiple solutions such as genetically modified organisms, cloning, and nuclear energy have been advocated globally in national curricula. These issues are believed to provide contexts for teaching science content knowledge (Zeidler & Nichols, 2009) and to engage individuals in decision-making processes about daily life issues related to politics, economics, and ethics, as well as scientific concepts (Roberts, 2007). Individuals, then, are expected to base their decisions on available evidence, negotiate conflicting views, and weigh the trustworthiness of the claims associated with these issues through reasoning (Lee & Grace, 2012).

Reasoning refers to the processes of constructing and evaluating arguments (Walton, 1990), while scientific reasoning involves individuals in using deductive patterns of logic and mathematics to solve explicit problems of science. Informal reasoning is a reasoning process through which individuals reason for complex problems without clear-cut solutions (Sadler, 2004). Therefore, in socioscientific decision making processes, in which the problems are prone to multiple solutions, individuals use informal reasoning patterns to evaluate advantages and disadvantages, causes and effects of these complex issues (Means & Voss, 1996; Zohar & Nemet, 2002). To become informed about SSI and make well informed decisions, students are expected to engage in high-quality informal reasoning processes (Acar, Turkmen, & Roychoudhury, 2010).

With the emergence of information communication technologies opinions and information about complex SSI are more accessible than ever before in several media outlets. This in turn could have an influence on individuals' informal reasoning and thus their decisions on contemporary SSI (Klosterman et al., 2012). First, the way that information is presented in the media and hidden messages that it incorporates could have an influence on people's attitudes about these issues. Research indicates that individuals with positive attitudes towards SSI are more likely to engage in informal reasoning processes and justify their decisions about these complex issues (Sürmeli & Şahin, 2012; Yerdelen, Cansiz, Cansiz, & Akcay, 2018). Second, it is important that individuals avoid directly adopting arguments from mass media and evaluate the available information to make their own arguments through informal reasoning (Simmoneaux, 2007), a process that is critical to media literacy (ML). A limited number of studies indicated that preservice teachers recognize different and often conflicting views of different stakeholders reflected in the media, their informal reasoning involved the use of high-quality argument elements, and they tend to make decisions based on the credibility of the source instead of interpreting the evidence in the media (Toth & Graham, 2016). Yet, ML and attitudes towards SSI are still unaccounted for, specifically in teacher education.

Central to high-quality informal reasoning, we identify ML and attitudes towards SSI as important predictors. As teachers can deeply affect their students' informal reasoning on socioscientific issues (Cetin, Dogan, & Kutluca, 2014), we investigate a sample of preservice teachers' perceptions of ML and attitudes towards socioscientific issues as predictors for informal reasoning. The following research questions guided our inquiry:

1. What type and quality of informal reasoning do preservice science teachers demonstrate as they make a decision on an SSI?
2. What is the association between preservice science teachers' informal reasoning and their attitudes towards SSI and perceived level of media literacy?

Informal Reasoning

Contrary to the notion that science is the accumulation of facts, scientific knowledge is prone to change and discussion (National Research Council, [NRC], 1996). Therefore, contemporary science education should equip students with skills to engage in meaningful discussions about the technological and societal concerns of today's controversial problems through critical reasoning (Lemke, 1990; Sadler, Barab, & Scott, 2007). In the international science education reform initiatives, this goal is considered to be fulfilled by including real-life problems in science education curricula (Ministry of National Education [MoNE], 2018; NRC, 2000). Thus, incorporation of SSI not only makes science relevant to students but also supports students to acquire cognitive and social skills to engage in decision making processes of modern scientific problems.

In decision making processes students are expected to engage in inquiry, consider competing claims and social and scientific evidence, and search for relevant information, which could be achieved through reasoning. In science, formal reasoning refers to a process of creating and evaluating arguments characterized by symbolic logic and mathematics (Sadler, 2004). This leads individuals to impersonal conclusions in problems with clear-cut solutions. In other words, formal reasoning is a deductive process in which individuals are expected to generate valid conclusions from given promises (Evans, 2002). Conversely, informal reasoning is used to generate opinions or solve complex problems, in which premises and conclusions change as additional information becomes available (Sadler, 2004). As SSI are controversial problems, informal reasoning is used to make well-informed decisions about these issues (Sadler, 2004). During this process, individuals consider the pros and cons, risks and benefits, and opinions about a given SSI (Means & Voss, 1996). Therefore, it is an inductive process that highlights the opinions and attitudes of the reasoner (Zohar & Nemet, 2002).

Socioscientific informal reasoning demands high-level processing as it requires reasoners to consider different options and exhibiting skepticism for biased information. "Therefore, in order to successfully support students' learning of socioscientific decision making, it is a prerequisite to provide a well-designed curriculum, appropriate teaching and learning materials, and thorough instruction" (Fang, Hsu, & Lin, 2019, p. 428). Hence, for meaningful engagement of students in socioscientific decision making and teachers to model and teach this important skill, teachers need to understand and use appropriate decision making strategies (Kim, Anthony, & Blades, 2014). In order to support this process, there needs to be better laid out the factors affecting this important process.

Informal reasoning has been approached from different perspectives. For example, Sadler and Zeidler (2005a) defined informal reasoning patterns as emotive, intuitive, rationalistic, and a combination of these three. Emotive reasoning represents the expression of emotions such as empathy towards others, intuitive reasoning represents immediate reactions to a given issue, and rationalistic reasoning patterns represents reasoning based on data. Other approaches classify informal reasoning under reasoning modes. These represent the aspects used to reason about a given issue. In their study, Yang and Anderson (2003) identified three reasoning modes: scientifically oriented reasoning refers to reasoning based on scientific information, socially oriented reasoning refers to reasoning based on social factors, and equally disposed reasoning refers to reasoning based on both scientific information and social factors. In a more holistic approach, Wu and Tsai (2007) provide both qualitative and quantitative indicators. Qualitative indicators include (a) Decision-making mode: Intuitive or evidence-based reasoning, (b) Reasoning mode: Perspectives that individuals base their reasoning on such as social, economy, ecology, science or technology-oriented aspects. Quantitative measures include (a) number of social-oriented arguments, (b) number of ecological-oriented arguments, (c) number of economic-oriented arguments, (d) number of science or technology oriented arguments, (e) the total number of reasoning modes, (f) number of supportive arguments, (g) number of counterarguments, (h) number of rebuttals, and (i) the total number of arguments.

Factors Affecting Informal Reasoning

There are several factors affecting informal reasoning on socioscientific issues. Most research in this area studied school students' informal reasoning in different SSI contexts. They identified the nature of science conceptualizations (Bell & Lederman, 2003), content knowledge (Albe, 2008; Hogan, 2002; Lewis & Leach, 2007), and moral perspectives (Sadler & Zeidler, 2005a) as factors affecting informal reasoning. Yet, a limited number of studies have been conducted with preservice and in-service teachers (Ozturk & Yilmaz-Tuzun, 2017; Sadler, 2006; Topçu, Yılmaz-Tüzün, & Sadler, 2011). Investigating factors influencing informal reasoning of the next generation of science teachers, preservice science teachers (PSTs), is particularly important as to design meaningful SSI content and courses at the college level (Topcu et al. 2011). We discuss the literature on the effects of attitudes towards SSI and media literacy (ML) on preservice teachers' informal reasoning. In each section, we discuss the relationship between each factor with informal reasoning in preservice teacher education and give examples from teacher education literature.

Attitudes towards Socioscientific Issues

PSTs' attitudes towards SSI are important because preservice teachers with increased positive attitudes towards SSI will be more likely to engage in argumentation about these issues and in return could be more interested in implementing socioscientific decision making in their future classrooms (Yerdelen et al., 2018). There are several studies conducted with preservice teachers and aimed at increasing their attitudes towards SSI. For instance, in their study with preservice teachers Bozdogan (2011) found visual materials as effective tools to increase their attitudes towards global warming issues. Ercan, Ural, and Tekbıyık (2015) found that preservice teachers had negative attitudes towards nuclear energy in terms of their environmental effects, worldwide nuclear armament, and energy politics.

In another study, Prokop, Lešková, Kubiatko, and Diran (2007) found that Slovakian preservice teachers had negative attitudes towards the technology of genetic engineering and neutral attitudes towards genetically engineered products and their marketing. Chabalengula, Mumba, and Chitiyo (2011) indicated that American preservice teachers had positive attitudes towards modifying microorganisms and plants genetically but showed negative attitudes towards modifying human and animal genes. Kapici and Ilhan (2016) found that although preservice teachers were open to learning about SSI, they had anxiety when learning about these issues due to religious and moral considerations.

One perspective on PSTs' attitudes toward socio-scientific issues (ATSIS) categorizes these attitudes into four subcategories. Topcu (2010), drawing on Osborne, Simon, Christodoulou, Howell-Richardson, and Richardson's (2013) definition of attitudes toward science and Sadler's (2004) definition of SSI, designed a study to explore students' attitudes toward SSI using these four affective domains. Each subcategory is defined as follows: "(1) Liking SSI: students' feelings of enjoyment of socially relevant scientific issues; (2) Anxiety towards SSI: what extent students have concerns about science-related social issues; (3) Usefulness of SSI: students' attitudes towards how scientific issues are important and useful for society; and (4) Interest of SSI: positive attitudes to investigations, science, and its social context" (Topcu, 2010, p. 55).

As with other researchers who have investigated PSTs, we used this approach to identify attitudes towards SSI. While limited studies using the ATSIS approach have been implemented, Topcu (2010), for instance, found that students with greater content knowledge (science majors versus non-science majors) are more likely to have a more positive view of SSI. In another study, Cebesoy and Dönmez Şahin (2013) investigated Turkish PSTs' attitudes towards socioscientific issues in terms of gender and class level. They found no statistically significant effect of gender and class level on attitudes towards SSI. More recently, Yerdelen et al. (2018) investigated the effect of an SSI course on Turkish PSTs' attitudes towards SSI. Using ATSIS as pre-and posttest, they found that the course contributed positively to PSTs' interests and usefulness of SSI and liking of these issues, but the anxiety scores remained the same. However, to our knowledge, there have been no quantitative studies related to PSTs' attitudes towards SSI and informal reasoning.

Media Literacy

Students obtain information from different sources such as peers (Garcia-Mila & Andersen, 2007) and mass media, including newspapers, books, television, and online information (Maloney, 2007; Osborne, Erduran, & Simon, 2004). Media literate individuals are expected to access, analyze, evaluate, and communicate media messages provided in different formats (Aufderheide, 1993). The main skills involved in media literacy are access, analyze, evaluate, and communicate (Eristi & Erdem, 2017). *Access* refers to locating and using proper tools when using media for different purposes (Hobbs, 2010) and understanding the content of the messages (Thoman & Jolls, 2003). *Analyze* includes examining the messages in-depth by dividing the messages into sections, critically evaluating the structure, content, design of the messages, and analyzing context (Lewis & Jhally, 1998), and perceiving hidden messages in the media (Volvic, 2003). *Evaluate* refers to a process of making judgments about the quality, objectivity, relativity, and validity of messages. *Communicate* refers to skills to create and share media with others (Schmidt, 2013). Livingstone (2004) suggests that "learning to create content helps one to analyze that produced professionally by others; skills in analysis and evaluation open the doors to new uses of the internet, expanding access, and so forth" (p. 3).

Although the traditional definition of literacy still prevails in K-12 education, teachers and researchers have begun to expand the definition to include ML. Media is more immediately available and accessible than ever. In this paper, we refer to media as mass media including traditional as well as social media. Students with smartphones have uninterrupted access to media, and with one-to-one technology initiatives in school districts becoming increasingly common, even more students have instantaneous media access. This, in return, affects students' knowledge and attitudes (van Lieshout & Dawson, 2016). Importantly, ML is also inherently connected to both scientific literacy—which we have defined in part as being able to engage in decision-making processes about scientific issues related to politics, economics, morality, and ethics—and decision-making about SSI, which includes being able to assess conflicting views and evaluate the trustworthiness of sources of data (Dani, Wan, & Henning, 2010; Klosterman et al., 2012). Media is at the heart of both of these concepts and therefore we consider ML when assessing students' scientific literacy and decision-making abilities about SSI.

In the context of SSI, a vast amount of counter-information to scientific knowledge exists. The information received from the experts fades in comparison to the volume of information from the media (McBean & Hengeveld, 2000). As a result, people tend towards making decisions quickly and showing gut-level reactions rather than reasoning with scientific knowledge (Nisbet & Scheufele, 2009). Regarding environmental issues, children rely more heavily on the first information they encounter, and they get the most information about environmental issues from media (Stahl, Hynd, Britton, McNish, & Bosquet, 1996). Similarly, adults get their information about complex environmental issues from television. Therefore, it is important to critically read and analyze the information provided by the media before making a decision about complex SSI. ML might have an important effect on individuals' decision-making processes, hence in their informal reasoning.

ML has been only minimally studied in preservice teacher education (Brush & Saye, 2009; Flores‐ Koulish, 2006)—even less so in science-specific contexts. Existing studies suggest potential benefits of incorporating ML into preservice teacher education. For instance, Lee (2008) proposes that critical ML skills assist preservice teachers in developing technological pedagogical content knowledge, while Flores‐ Koulish (2006) found that improved ML can "help to expand their emerging understandings of critical pedagogy" (p. 240). Preservice teachers need ML skills "so that they can communicate and connect with the students of today and the future" (Kumar & Vigil, 2011, p.144).

Method

In this study, we used a descriptive research method (Nassaji, 2015). This method allows researchers to use both qualitative and quantitative data. Researchers can use quantitative methods to analyze qualitative data. The major purpose to use descriptive research is to answer what questions instead of how and why questions (Nassaji, 2015).

Setting and Participants

The study was conducted at a public university in northeast Turkey in late fall 2016. Convenience sampling was used to administer survey instruments. The participants were preservice (grades 5-8) science teachers in their first through the fourth year in the bachelor's program. SSI topics are covered in special topics in biology and chemistry courses in the third and fourth year of studies. There were 266 students enrolled in the program; 214 volunteers were recruited. Six preservice teachers did not answer the questionnaire assessing informal reasoning regarding hydroelectric power; their data was not included in the analysis. Table 1 reports the percentages for students' daily use of the internet and television.

Table 1 shows that 32.7% of the participants use internet 2-4 hours daily, while 87% of the students watch TV 0-2 hours daily. Only 8.2% of the participants reported that they use the internet over 8 hours and 0.5% of the participants reported that they watch TV for over 8 hours. The analytical sample included 208 participants (78% of the total enrollment in the science education undergraduate program). Of them, 147 (70.7%) were female; 71 (34.1%) were in their first year, 51 (24.5%) were in their second, 46 (22.1%) were in their third, and the remaining 40 (19.2%) were in their fourth year. For technology access, 113 (54.3%) possess a computer, and 204 (98.1%) have a smartphone. Students were asked if they keep up with the news on a 1 to 5 scale (0-2, 2-4, 4-6, 6-8, 8+ hours); 1 is never (0%), 2 is seldom (7.7%), 3 is sometimes (39.4%), 4 is often (42.3%), and 5 is always (10.6%). Further, students indicated that they use the following news sources: books (14.9%), magazines (30.3%), web (96.2%), television (73.6%), and radio (5.8%). Lastly, students were asked about their daily usage of internet and television on a 1 to 5 scale; results were reported in Table 1.

Table 1. Percentages for Students' Daily Use of the Internet and Television

	0-2 hours	2-4 hours	4-6 hours	6-8 hours	8+ hours
Internet	30.8	32.7	19.7	8.7	8.2
TV	87.0	10.1	2.4	0.0	0.5

Data Collection Tools

Open-ended Questionnaire to Assess Informal Reasoning

An open-ended questionnaire developed by Wu and Tsai (2007) and translated to Turkish by Ozturk (2011) was modified and used in this study. The original questionnaire includes seven questions focusing on decision-making modes, initial supportive argument or counterargument construction, personal position, generating supportive arguments, counterargument construction, and rebuttal construction. Informal reasoning modes referred to aspects such as economy, politics, health, science and technology that the arguers used to approach the given SSI. Initial supportive arguments are the individuals' initial justifications for the given issue. Supportive arguments refer to additional justifications that would support initial arguments. Counterarguments refer to statements that would challenge the initial argument, while rebuttals refer to the statements that would contradict the counterarguments. A higher number of supportive arguments, counterarguments, and rebuttals used indicate a higher level of reasoning. We merged the questions about the personal position and generating supportive arguments. We chose the hydroelectric power issue because the participants' university is in a mountainous region with multiple water sources. Hydroelectric power plant construction is increasing there and frequently debated. We consulted with an expert in science education, an expert in a measurement program, and a science teacher before making the previously mentioned changes in the questionnaire.

Attitudes towards Socio-scientific Issues Scale (ATSIS)

The ATSIS, developed by Topcu (2010) in Turkish, is a 30-item self-report measure with Likert scale responses ranging from 1 (strongly disagree) to 5 (strongly agree). Three subscales were derived from factor analyses: (1) liking SSI, seven items; (2) anxiety towards SSI, six items; and (3) interest and usefulness of SSI, seventeen items. Inter-item reliability of the subscales ranged from 0.70 to 0.90. Cebesoy and Dönmez Şahin (2013) investigated 169 Turkish PSTs' attitudes towards socio-scientific issues in terms of gender and class level using ATSIS. Analyses demonstrated adequate construct validity. For the current study, we reported factor analysis results and Cronbach alpha values in the following sections.

Media Literacy Level Determination Scale

The ML determination scale is a 17-item self-report measure with Likert scale responses ranging from 1 (never) to 5 (always). The scale was developed by Karaman and Karatas (2009) in Turkish and employed to determine the perceived levels of ML of 495 preservice teachers studying Turkish language teaching, elementary school teaching, and social studies teaching. The authors derived three subscales to measure participants' perception of media literacy levels via factor analyses: (1) knowledge (seven items); (2) analysis (six items); and (3) judgment (four items). Based on the reliability analysis, Cronbach's alpha for the entire scale was calculated as .84 and ranged from .68 to .72 for the subscales. Güven (2014) investigated 107 Turkish preservice teachers' perceived ML levels using ML determination scale and calculated Cronbach's alpha reliability for the scale as .93. For the current study, factor analysis and Cronbach alpha values were also reported for the media literacy scale.

Analysis for Validity Evidence for Media Literacy Level Determination Scale and ATSIS

We examined the construct validity of ML determination scale and ATSIS separately by conducting confirmatory factor analyses (CFA) with Mplus 7.31 (Muthén & Muthén, 2015) and WLSMV estimator (Asparouhov, 2005, 2010; Beauducel & Herzberg, 2006). We declared observed variables as ordered categorical, given they were collected with Likert scales. We evaluated model fit based on chi-square, Comparative Fit Index (CFI), root-mean-squared-error of approximation (RMSEA), and Tucker-Lewis Index (TLI)—the most common measures in CFA studies (Jackson, Gillaspy, & Purc-Stephenson, 2009). The model fit decisions were based on criteria provided by Hu and Bentler (1999) that values under 0.06 for RMSEA and above 0.95 for CFI and TLI indicate adequate fit. We further calculated Cronbach's alpha for each scale and subscale with R (R Core Team, 2017). For the current study, factor analysis and Cronbach alpha values were also reported for the media literacy scale.

Analysis of Preservice Science Teachers' Informal Reasoning

Informal Reasoning Modes

There are several approaches used to analyze informal reasoning in the context of SSI in science education. Informal reasoning modes refer to the frames that represent the aspects of the arguments presented when informally reasoning about an SSI. Yang and Anderson (2003), for example, classified students' reasoning modes in three categories: scientifically oriented, socially oriented, and equally disposed. In another study, Patronis, Potari, and Spiliotopoulou (1999) explored high school students' informal reasoning on a road construction issue and found four reasoning modes: social, ecological, economic, and practical. The number of reasoning modes may indicate that a person considers complex issues from multiple perspectives (Wu & Tsai, 2007).

Informal Reasoning Quality

Although the above-mentioned approaches identify informal reasoning modes, they do not indicate quality; one perspective is not inherently more valuable than another. Reasoning can be defined as the rhetorical, cognitive, and social process of constructing and evaluating arguments (Shaw, 1996; van Eemeren, Grootendorst, & Henkemans, 1996). Therefore, argumentation could be used to identify one's informal reasoning (e.g., Topcu et al., 2010).

Argumentation is the process of connecting claims and evidence through justification (Jiménez-Aleixandre & Erduran, 2008). Although argumentation can reveal some aspects of informal reasoning, there is no direct correspondence between the two. Means and Voss (1996) note that high-quality arguments could be the result of proficient informal reasoning. However, low-quality arguments could be either based on low-quality informal reasoning or proficient but not well-articulated reasoning. Yet, drawing from the work of Toulmin (1958) and (Kuhn, 1991), several researchers use argument structure, evaluating issues from multiple perspectives, and rebuttals and counterargument construction in the reasoning process as the indirect measures for studying informal reasoning (Sadler & Zeidler, 2005b; Zohar & Nemet, 2002). Therefore, similar to previous studies, we adopt the perspective for assessing argumentation quality as an indirect measure to identify informal reasoning quality (Kuhn, 1991; Means & Voss, 1996; Zohar & Nemet, 2002). Individuals' abilities to deal with SSI are dependent on their informal reasoning ability, which is used to support a claim during decision-making (Sadler, 2004).

There are several argumentation frameworks to analyze students' informal reasoning quality in the context of SSI. Based on Toulmin's (1958) argumentation pattern, for instance, Topcu et al. (2010) analyzed Turkish PSTs' informal reasoning on different SSI contexts. In their rubric, they evaluated claims, justifications, counter positions, and rebuttals. Another framework suggested by Tal and Kedmi (2006) uses four criteria to assess argument qualities "as a means of illuminating underlying informal reasoning" (p.2483): number of justifications, use of scientific knowledge, number of aspects incorporated, and synthesizing counterarguments and rebuttals. In the current study, we used an analytical perspective offered by Wu and Tsai (2007) to assess PSTs' reasoning for two purposes. First, Wu and Tsai's (2007) approach is more holistic in that it addresses informal reasoning modes and quality at the same time. In the framework, reasoning modes are categorized as social-oriented, economic-oriented, ecology-oriented, or science/technology-oriented. In terms of quality, Wu and Tsai (2007) identify supportive argument construction, counterargument construction, and rebuttal construction based on earlier studies by Sadler and Zeidler (2005a). Our second motivation for choosing this framework was the cultural issues that affect individuals' socioscientific arguments. The suggested framework has been used in non-Western countries such as Taiwan and recently Turkey for a nuclear power issue (Ozturk & Yilmaz-Tuzun, 2017; Wu & Tsai, 2007)

First, to analyze preservice teachers' responses to five open-ended questions, we used content analysis to determine their informal reasoning modes about hydroelectric power (Yıldırım & Şimşek, 2006). The coding was done with another researcher experienced in qualitative data analysis. Interrater agreement ranged from .76 to .94. Second, to analyze the preservice teachers' informal reasoning quality, we identified the number of justifications participants used in each question. Interrater agreement for the items in the questionnaire ranged from .82 to .91. In peer-debriefing sessions, all inconsistencies in the coding were discussed and resolved.

Analysis of Relationship between Informal Reasoning, Attitudes, and Media Literacy

Consistent with prior studies (e.g. Ozturk & Yilmaz-Tuzun, 2017; Wu & Tsai, 2007), we created two-factor scores by summing subscale scores for each measurement tool. We built and examined two regression models in which the independent variables were total scores of ML level determination questionnaire and ATSIS. Dependent variables were reasoning modes and reasoning qualities scores. The regression model reads:

$$Y_i = \beta_0 + \beta_1 (\text{MLcentered})_i + \beta_2 (\text{ATSIScentered})_i + e_i \qquad (1)$$

In Equation 1, Yi represents the dependent variable for individual i; β_0 represents the intercept; β_1 is the regression coefficient for grand mean centered ML level determination questionnaire, β_2 is grand mean centered ATSIS, In light of our research questions, we tested the null hypotheses of H_0: $\beta_j = 0$ against H_A: $\beta_j \neq 0$ for each predictor. For regression diagnostics, we investigated the distribution of residuals, influence measures (R Core Team, 2017), and calculated the variance inflation factor. Before testing the regression model, we also used R to examine the linear association between the continuous variables and computed Pearson correlation coefficients.

Results

Results of Confirmatory Factor Analysis of the Scales

The measurement model for the ML level determination scale adequately fit the data; with a sample size of 208, the chi-square test statistic for the model fit was significant, $\chi2(116) = 241$, p = .000, the TLI was .957, the CFI was .963, the RMSEA was .072 [.059-.085]. Standardized factor loadings for this model are shown in Table 2. The Cronbach's alpha for the ML determination scale was .86.

Table 2. CFA Factor Loadings for ML Scale

	i1	i2	i3	i4	i5	i6	i7	i8	i9	i10	i11	i12	i13	i14	i15	i16	i17
Knowledge	.65	.75	.73	.78	.62	.75	.72										
Analysis								.61	.57	.72	.64	.70	.77				
Judgement														.79	.79	.67	.81

The measurement model for the ATSIS scale adequately fit the data with two modifications (see discussion section); with a sample size of 208, the chi-square test statistic for the model fit was significant, $\chi2\ (743) = 372$, p = .000, the TLI was .929, the CFI was .922, the RMSEA was .069 [.062-.076]. When calculating the overall ATSIS score, we reverse-coded negatively worded items in the scale. In CFA, we found that item 16 had very low factor loading. Therefore, we excluded item 16 and allowed item 17 and item 28 to cross-load on the anxiety factor; however, these two items contributed once when calculating the overall score. Standardized factor loadings for this model are shown in Table 3. The Cronbach's alpha for the ATSIS scale was .91. Therefore, the two scales were reliable for the current study.

Table 3. CFA Loadings for ATSIS Scale

	I1	I2	I4	I9	I11	I14	I15	I18	I20	I21	I22	I23	I25	I26	I27	I28	I30
Int. & Use.	.77	.78	.58	.75	.80	.84	.82	.47	.66	.71	.64	.72	.64	-.52	.59	-.48	.74
	I6	I7	I8	I10	I13	I17	I24										
L-SSI	.59	.76	.72	.74	.83	-.17	.66										
	I3	I5	I12	I19	I29	I28	i17										
Anxiety	.71	.71	.71	.64	.77	.45	.43										

Results of Preservice Science Teachers' Informal Reasoning Modes

Reasoning mode measures revealed that the participants formulated arguments about hydroelectric power plants using statements oriented in ecology, science/technology, economy, health, social, and politics. As expected, the most used reasoning mode in hydroelectric power arguments were *ecology-oriented* (n=532). The ecology-oriented arguments generated by the preservice teachers included concerns regarding low levels of waters in rivers, the animal population changes in the rivers, deforestation in the region, and polluting the water used in the power plants and releasing it back to the sea.

> PST 97: Hydroelectric power plants are constructed at the stream beds. Considering that the power plants use the water and lower the flow rate, it dries out the streams. Therefore, it harms the fish populations in that stream/river. Therefore, I oppose the construction of hydroelectric power plants.

The second most coded reasoning mode was *science and technology-oriented* arguments (n=231). These arguments included statements regarding energy transformations from kinetic to electric and technological advancements to produce cleaner energy.

> PST 158: I think the hydroelectric power plants should continue to be constructed. I think there is no harm associated with using hydroelectric power. Here is how it works: Water from the high mountains speeds up to the point that they store the water. Then from a distance they release the water that has high kinetic energy. This energy is then transformed into electric energy by turning the turbines. I can say that it is clean energy.

In the *economy-oriented* arguments, the PSTs argued about the potential increase in job opportunities for local people, producing more energy resulting in lowered electricity bills, and increasing the economic well-being of the region. This reasoning mode was the third-highest reasoning mode explicitly mentioned in the written arguments (n=158). The following quote illustrates the PSTs' economy-oriented reasoning about hydroelectric power plant construction:

> PST 179: Rapid construction of this type of power plants can be seen helpful for the local people because a lot of people would be employed in the process of construction and running of power plants. As a local, I can say that residents need such opportunities. A couple of families from our village were employed in such processes of the power plant, now they are in good shape economically.

The *political-oriented* arguments focused on Turkey's political power in the region. The participants indicated that if Turkey decreased their energy demand and started to export energy to other countries, it would have political power both in the Middle East and the Balkans (n=139). Furthermore, the participants indicated that hydroelectric power plants are necessary for well-developed countries, in terms of both infrastructure and economy. Ozturk and Yilmaz-Tuzun (2016) found similar political-oriented arguments regarding Turkish preservice teachers' notions about nuclear power. The following quote is an example of this type of argument:

> PST 137: I think it is beneficial because hydroelectric power plants would lower the energy dependency on other countries. Hence, constructing our own power plants would make Turkey a stronger player in the region and we can sell energy to other countries.

The *social-oriented* reasoning mode category included the PSTs' arguments about the effect of hydroelectric power plant construction on the place of people in society (n=136). The participants argued that the region would be more prosperous as these people will be more equipped with several skills that they can contribute to the socio-economic structure of the region thanks to the hydroelectric power plant construction. For example, consider the following:

> PST 128: Turkey's future depends on economic development which can be achieved through exporting energy to other countries. In this way, Turkey develops and can invest more in education. Through

> education future generations would be more equipped with 21st-century skills and in turn will contribute to the country's socio-economic structure.

Lastly, the *health-oriented* arguments were the least used reasoning mode among all arguments (n=65). In the health-oriented arguments, PSTs emphasized the health risks due to polluted waters returned to water sources after being used in the power plants, and the low level of oxygen due to deforestation. The following quote exemplifies the PSTs' concern related to health risks:

> PST 28: They would say that trees in a small area where the power plant regulator will be constructed will be cut down. However, it is not the case. They cut down many more trees to build roads for heavy construction equipment vehicles. Hence, the number of trees declines in the area so does the oxygen levels. This can cause health problems, especially problems related to the lungs.

Table 4 and Figure 1 illustrate the total number of arguments created and reasoning modes utilized in the written arguments. Argumentation aspects refer to the five argumentation components, which were identified by analyzing each question on the questionnaire, including initial supportive arguments (ARG1), supportive arguments (ARG 2), initial counterarguments (ARG3), counterarguments (ARG4), and rebuttals (ARG 5).

Table 4. Number of Reasoning Modes Identified across Different Argument Components

Reasoning Modes and Their Explanations	Argument Components					
	ARG 1	ARG 2	ARG 3	ARG 4	ARG 5	TOTAL f (%)
ECOLOGY: Emphasizes low water levels in rivers, animal population changes in the rivers, deforestation, and polluted water returning to the sea	51	187	97	106	91	532 (42%)
ECONOMY: Emphasizes hydroelectric power plants' potential to increase local job opportunities, produce more energy (resulting in lowered electricity bills), and increase the economic well-being of the region	50	11	38	33	26	158 (13%)
HEALTH: Emphasizes health risks due to polluted waters returning to water sources after being used in the power plants, and lower levels of oxygen due to deforestation	1	33	7	12	12	65 (5%)
POLITICAL: Emphasizes Turkey's political power in the region due to the construction of hydroelectric power plants. The participants indicated that if Turkey decreased its energy demand and started to export energy to other countries, it would have more political power in the Middle East and the Balkans.	49	7	35	26	22	139 (11%)
SCIENCE OR TECHNOLOGY: Emphasizes energy transformations from kinetic to electric and technological advancements to produce cleaner energy.	82	25	40	38	46	231 (18%)
SOCIAL: Emphasizes the effects of power plant construction on the mental well-being of people in the region. The participants argued that the region would be more prosperous and the people happier with the hydroelectric plant's construction	40	15	35	22	24	136 (11%)

Results of Preservice Science Teachers' Informal Reasoning Quality

Reasoning quality measures revealed that the participants, on average, constructed more than one initial supportive argument, supportive argument, initial counterargument, counterargument, and rebuttal. They mostly constructed supportive arguments rather than counterarguments and rebuttals (descriptive statistics provided in Table 5). On average across all students, the total number of arguments was 6.02 (SD=2.58). The total number of arguments generated by a participant ranged between 0 and 17. This indicated that some participants did not construct arguments for the questions and some provided more than one justification.

Table 5. Descriptive Statistics for Argument Indicators

	Mean	SD	Min.	Max.	Skew	Kurtosis	SE
Initial supportive argument (ARG1)	1.31	0.72	0	4	0.97	1.45	0.05
Supportive argument (ARG2)	1.34	0.95	0	6	1.69	4.69	0.07
Initial counterargument (ARG3)	1.21	0.84	0	6	1.38	4.88	0.06
Counterargument (ARG4)	1.14	0.68	0	3	0.36	0.25	0.05
Rebuttal (ARG5)	1.06	0.79	0	4	0.72	0.76	0.05

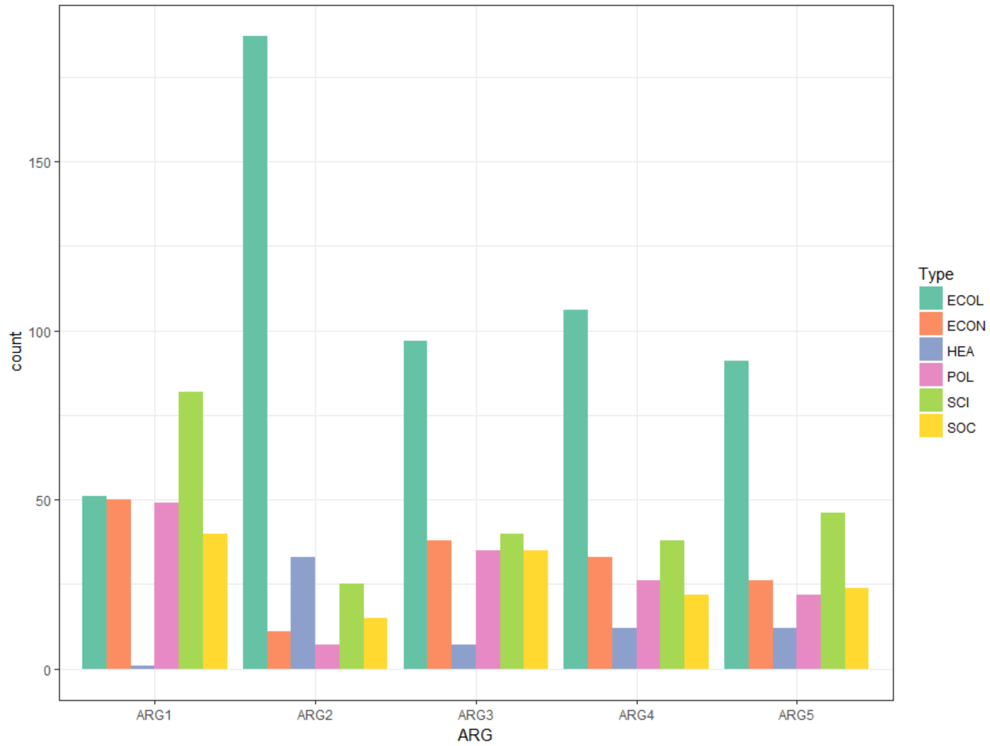

Figure 1. Patterns of Reasoning Modes Identified Across Different Argumentation Aspects

Results of Relationship between Informal Reasoning, Attitudes, and Media Literacy

Prior to conducting analyses, we investigated the variables individually and reported means, standard deviations, medians, minimum, maximum, sample skewness, and sample kurtosis values for the independent variables in Table 6. The preservice teachers’ informal reasoning mode on the average was 2.83 (SD= 1.18), meaning that they were able to informally reason using more than two aspects of the issue. The reasoning quality was also low with 1.21 (SD= 0.52) mean.

Table 6. Descriptive Statistics for Regression Inputs

	Mean	SD	Median	Min.	Max.	Skew	Kurtosis	SE
ReasMode	2.83	1.18	3	0	6	0.03	-0.13	0.08
ReasQual	1.21	0.52	1.2	0	3.4	0.71	1.79	0.04
ML	11.32	1.64	11.22	6	15	-0.23	0.48	0.11
ATSIS	10.01	1.26	10.15	5.28	12.48	-0.58	0.52	0.09

Results of the Linear Association between Informal Reasoning, Media Literacy, and Attitudes towards SSI

We investigated the strength of linear relationships between reasoning modes, reasoning qualities, media literacy levels, ATSIS and ATSIS subscales. Table 7 reports the Pearson correlation coefficient matrix. The correlation between reasoning modes, ATSIS total score, liking SSI (L-SSI) and anxiety towards SSI (Anxiety) were insignificant, linear relation between reasoning modes and ML (r=0.14), reasoning modes and Int & Use (r=0.14), reasoning qualities and media literacy (r=0.21), and ATSIS total score (r=0.15), and interest and usefulness of SSI (Int & Use, r=0.16), and L-SSI (r=0.14) were statistically significant but weak. A relatively stronger linear relationship was found between ML and ATSIS total score (r=0.35), Int & Use (r=0.35), L-SSI (r=0.34), and between reasoning modes and reasoning qualities (r=0.56). As expected ATSIS total scores and subscale scores are correlated with each other except the weak correlation between the Anxiety subscale and Int & Use subscale (r=0.12).

Table 7. Correlation between ReasMode, ReasQual, ATSIS and ML

	ReasMode	ReasQual	ML	ATSIS-total	Int&Use	L-SSI
ReasQual	0.56*					
ML	0.14*	0.21*				
ATSIS-total	0.09	0.15*	0.35*			
Int & Use	0.14*	0.16*	0.35*	0.86*		
L-SSI	0.09	0.14*	0.34*	0.92*	0.74*	
Anxiety	-0.04	0.01	0.07	0.48*	0.12	0.22*

Results of Attitudes towards SSI and Media Literacy Scores Predicting Informal Reasoning

Regression model findings are presented in Table 8; statistical significance is based on two-tailed p-values. The effect of the perceived level of ML on reasoning qualities was significant ($\hat{\beta}_1$=0.06, p=.016)—a 1-point increase in the perceived level of ML is predicted to correspond to an increase of .06 in reasoning qualities when the remaining predictors are held constant. The effect of ML on reasoning mode was marginally significant ($\hat{\beta}_1$=.09, p=.086). The effect of ATSIS was not statistically significant on both dependent variables. We investigated the distribution of studentized residuals and did not detect any substantial departure from a normal distribution. We further investigated the difference in coefficients when a case was removed (dfbetas)—Cook's distance, leverage values, variance inflation factor—and did not detect any influential data point or multicollinearity.

Table 8. Estimates and Standard Errors for Regression Models

	Reasoning Quality			Reasoning Mode		
Predictor	Coef.	SE	*p*	Coef.	SE	*p*
Intercept	1.21	.04	<.001	2.83	.08	<.001
ML[a]	.06	.02	.016	.09	.05	.086
ATSIS[a]	.04	.03	.254	.05	.07	.518

Note: [a]= Grand mean centered

In summary, results indicated that the PSTs' informal reasoning was mostly ecology-oriented. The least used informal reasoning mode was health-oriented. The PSTs' informal reasoning included more supportive arguments than counterarguments or rebuttals. Results showed that the perceived level of ML predicts informal reasoning. Furthermore, ATSIS does not explain informal reasoning about hydroelectric power plants issue. It was found that informal reasoning modes are positively correlated with informal reasoning quality and that attitudes towards SSI are moderately correlated with the perceived level of ML.

Discussion

The Validity of the Scales

CFA of ATSIS revealed reliability and validity issues similar to previous studies (Cebesoy & Dönmez Şahin, 2013; Topcu, 2010). Item number 16 had a very low factor load; we excluded this item from our analysis. Furthermore, item 17 ("attending debates on SSI does not appeal to me") was allowed to load on anxiety towards SSI and liking SSI, item 28 ("I am not interested in SSI") was allowed to load on the anxiety towards SSI and usefulness of SSI. Concerns about environmental issues encourage learners to engage in discourse and argumentation; literature indicates that SSI concerns personal decision-making through debate and discourse

(Kolstø & Ratcliffe, 2008). Literature also suggests a relationship between environmental concern and interest in environmental issues, thus interest is tied to both anxiety and usefulness.

Preservice Science Teachers' Informal Reasoning Modes on Hydroelectric Power

In this study, findings indicated that the PSTs employed multiple reasoning modes in their informal reasoning about hydroelectric power plants. Multiple reasoning modes indicate that the participants used more than one reasoning mode in their written responses in different combinations. Turkish and Taiwanese learners in previous studies used similar reasoning modes in constructing written arguments on nuclear power issues. Our study differed from these studies in an aspect. We categorized health-oriented arguments separately from social-oriented arguments because all those arguments included personally relevant statements towards individuals' own physical and mental well-being (Wu & Tsai, 2007). This may be because our study was conducted in a suburban area where hydroelectric power plant construction is a highly debated local issue. Therefore, the participants might have seen the issue as more personally relevant and potentially harmful to their health. The reasoning mode used in the arguments might be affected by the issue context and relevance, as supported by previous research (Topcu, Sadler, & Yilmaz-Tuzun, 2010).

Preservice Science Teachers' Informal Reasoning Qualities on Hydroelectric Power

Informal reasoning quality analysis revealed that supportive argument construction was more common than counterargument and rebuttal construction. This result matches Ozturk and Yilmaz-Tuzun (2017)'s findings. Literature suggests that counterargument and rebuttal often occur in oral arguments where the arguers are explicitly prompted to rebut (Erduran, Simon, & Osborne, 2004). Therefore, written arguments often reflect lower level informal reasoning qualities (Evagorou & Osborne, 2013). Although the preservice teachers in the study were explicitly asked to construct counterarguments and rebuttals, these arguments were less common than supportive arguments. Furthermore, the preservice teachers' argument quality indicators had lower mean values. Generating counterarguments and rebuttals requires high-level argumentation skills and rarely occurs in writing (Knudson, 1992; Leitão, 2003), which might be due to high cognitive load (Coirier, Andriessen, & Chanquoy, 1999). The PSTs in this study might have had limited experiences with argumentation, limiting their advanced skills.

Relationship between Media Literacy, Attitudes towards SSI, Informal Reasoning

There was a significant correlation, supported by regression analysis, between informal reasoning quality and perceived level of ML. This suggests that the perceived level of ML is an important factor influencing individuals' discourse about SSI (Klosterman et al., 2012). However, the media may present incomplete information regarding environmental problems, causing misunderstandings (Khalid, 2001). This could lead to misinformed decisions about complex environmental problems. Therefore, enhancing ML could be one way to engage individuals in high-quality informal reasoning, and hence well-informed socioscientific decision making.

There was a significant but weak correlation between informal reasoning quality and attitudes towards socio-scientific issues. A previous cross-case study conducted with 16 college students in the United States indicated that preservice teachers' decision-making processes are influenced by their attitudes towards SSI (Chang & Lee, 2010). Our results support this finding. However, weak correlation might be due to the constructs in the ATSIS – liking SSI, anxiety towards SSI, and interest and the usefulness of SSI – which may just not have a significant impact on informal reasoning quality. Because low-quality argumentation might be the result of proficient, but poorly externalized, informal reasoning (Sadler, 2004), it is also possible that our measurement of informal reasoning does not correlate with the ATSIS results.

Correlational analysis revealed that informal reasoning modes are positively correlated with informal reasoning quality. This finding was expected as the rubric we used identified the informal reasoning quality based on the number of arguments constructed (Wu & Tsai, 2007). When different modes of informal reasoning were presented, the number of arguments increased, leading to increased quality of arguments. However, using more fine-grained analysis rubrics such as Toulmin's (1958) model may lead to different results.

Our findings also indicated that attitudes towards SSI are moderately correlated with the perceived level of ML of the participants. This correlation might be due to the local nature of the SSI. Literature indicates that learners are more motivated to involve themselves in discussions about local socio-scientific issues (Karahan, Andzenge, & Roehrig, 2017). Emotional involvement might increase interest in media coverage of the issue. As attitudes towards SSI involve interests in SSI, it is reasonable to assume that how they perceived their own ML levels would affect arguers' attitudes.

Implications and Future Research Directions

The purpose of this study was to investigate PSTs' informal reasoning outcomes regarding a local SSI, hydroelectric power plants, and their perceived level of ML and attitudes towards SSI. Results indicated that ecological-oriented reasoning modes were highest (Ozturk & Yilmaz-Tuzun, 2017). However, some of the reasoning modes such as health-oriented were only employed by a limited number of PSTs. Based on the results, we suggest a holistic approach to cover SSI in science teacher education courses from different aspects that would enhance students' informal reasoning modes.

We also found that the PSTs mostly constructed supportive arguments, failing to construct rebuttals and counterarguments. Different tools increase learners' written rebuttal and counterargument construction skills. For instance, Weinberger, Stegmann, and Fischer (2010) found that online collaboration scripts increase the quality of argumentation sequences incorporating counterarguments. Computer-supported collaborative learning technologies should be used in teacher education courses to give preservice teachers argumentation skills they can bring to their future classrooms.

We found that PSTs' perceived level of ML predicted an increase in informal reasoning qualities. Dani et al. (2010) argue that "reading to evaluate information critically and reading to synthesize information have become critical aspects of ML" (p. 87). We believe that ML education, which is rarely offered in science teacher education programs, could be incorporated as part of mandatory courses, such as contemporary issues courses, so that PSTs learn how to critically evaluate information and engage in decision-making processes about complex SSI.

As suggested by Topcu (2010), we conducted analyses regarding the relationship between attitudes towards SSI and argumentation skills. We identified through regression analysis that argumentation skills were not explained by attitudes toward the given SSI. These findings may suggest that the ATSIS constructs do not predict argumentation skills. One possible explanation might be the differences in quality between verbal and written arguments, and that those differences affect the relationship between ATSIS and argumentation skills, and hence informal reasoning skills. We suggest that PSTs receive explicit instruction in externalizing informal reasoning processes and transferring it into written arguments.

This research suggests several variables that might affect informal reasoning about SSI. However, results may not be generalizable, as the participants were chosen through convenience sampling from a single university. Readers should also note the low regression coefficients and R^2 values; future studies should consider reaching out to broader, more representative populations. Our findings also portray reasoning about a local SSI. Future research might identify PSTs' differences in informal reasoning between local, national, and global issues. Instead of the holistic approach suggested by Wu and Tsai (2007), future studies might also employ a more fine-grained approach to assess the quality of justifications based on the structural components and informal reasoning modes (e.g. Erduran et al., 2004) and different ways to assess informal reasoning quality.

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