Education and Science

Vol 47 (2022) No 211 323-367

Original Article

Development of Argumentation Based Concept Cartoons for Socioscientific Issues: A Case of Science and Art Centers

Şengül Atasoy [1], Ahmet Tekbıyık [2], Muammer Çalık [3], Özgül Yılmaz Tüzün [4]

Abstract

In the present study, argumentation based concept cartoons for socioscientific issues (CCSSI) were designed for students enrolled in Science and Art Centers (SACs), and the results of the implementation were evaluated. The education design, which adopted the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model, was implemented in three stages. In the first stage, a framework plan was developed for the socioscientific issues (SSI) to generate concept cartoons. For each SSI in the framework plan the probable decisions (positive and negative), informal reasoning modes, and argument components (such as claim, evidence, counter argument and rebuttal) were determined. In the second stage, for argumentation based SSI teaching, the concept cartoons were generated and expert opinions were obtained. In the third phase the following issues were accomplished: teachers working at a SAC attended an inservice training program, a learning group was established, concept cartoons were exhibited on school corridors and simultaneously dialogic discussions were held in class. To collect data a questionnaire, interview forms, a rubric, and an observation form were utilized. Qualitative data were analyzed by means of descriptive analysis. Findings revealed that the framework plan was functional but the CCSSI needed some improvements. Based on the experts' recommendations, the CCSSI was revised and then implemented. Observations showed that the teachers achieved the expected criteria at various levels ranging from monologic to dialogic. Thus, it is recommended that further studies are needed to enrich in-class dialogic discussions for teachers and students. Moreover, it is suggested that the framework plan can be used in other disciplines and grades.

Keywords

Socioscientific issues
Argumentation
Concept cartoons
The ADDIE model
Science and arts centers

Article Info

Received: 10.19.2021
Accepted: 05.31.2022
Online Published: 07.29.2022

DOI: 10.15390/EB.2022.11327

[1] Recep Tayyip Erdoğan University, Faculty of Education, Department of Mathematics and Science Education, Turkey, sengul.atasoy@erdogan.edu.tr
[2] Kahramanmaraş Sütçü İmam University, Faculty of Education, Department of Mathematics and Science Education, Turkey, atekbiyik@gmail.com
[3] Trabzon University, Faculty of Education, Department of Primary Education, Turkey, muammercalik38@gmail.com
[4] Middle East Technical University, Faculty of Education, Department of Mathematics and Science Education, Turkey, ozgul@metu.edu.tr

Introduction

While some scientific and technological innovations and developments are readily accepted by the society, some lead to dilemmas and argumentations within the society. These topics that have both a scientific and a social dimension, are open-ended, do not have a precise answer, and controversial in nature are defined as socioscientific issues (SSI) (Kolsto, 2001; Sadler, 2004; Sadler & Donnelly, 2006). More specifically, SSI are based on scientific concepts, problems, and issues, discussed in public spaces, entail multiple perspectives (such as political, social, ecologic, ethical, moral, and psychological), and controversial in nature (Sadler, 2004).

SSI discussions require decision making processes and strategies (Topcu, Yilmaz-Tuzun, & Sadler, 2009). In order to perform informed decisions about SSI, societies need individuals who are equipped with these advanced decision making skills and strategies. For different SSI expressing claims supported with scientific evidences, being able to evaluate these claims and an active involvement in informed decision making processes are seen as citizenship responsibilities (Aikenhead, 1985; Barrue & Albe, 2013; Kolsto, 2001). Since educating citizens with these skills is an important goal for science literacy, using SSI to attain this goal is seen as an effective way in science education (Çalık & Wiyarsi, 2021; Topcu, Muğaloğlu, & Güven, 2014). As SSI contributes to the development of science literacy and the awareness of responsible citizenship, the development of students' decision making skills regarding SSI has become one of the objectives in the curricula of numerous countries, including Turkey (Ministry of National Education [MoNE], 2018), the United States of America (21st Century Science Project Team, 2003; American Association for the Advancement of Science [AAAS], 1989; National Research Council [NRC], 1996), Indonesia (Nida, Mustikasari, & Eilks, 2021), Taiwan (Ministry of Education [MOE], 1998), and Sweden (Lpf 94, 1994).

With the incorporation of controversial SSI into the science curricula, individuals are expected to not only develop decision making skills but also gain necessary content knowledge on these issues. Use of SSI in science education was helpful to develop students' argumentation skills (Albe, 2008; Aydeniz & Gürçay, 2013; Jimenez-Aleixandre, Rodriguez, & Duschl, 2000; Khishfe, 2014; Kortland, 1996; Lee, 2012), science literacy (Morin, Tytler, Barraza, Simonneaux, & Simonneaux, 2013) and discussion skills (Lewis & Leach, 2006; Rudsberg, Öhman, & Östman, 2013). In recent years, concept cartoons have also started to be used in science education as they are conducive to the presentation of controversial views based on scientific evidence, they support class or group dialogic discussions on controversial topics, and they enable students to question controversial views and justify their explanations (Cavagnetto & Hand, 2012; Chin & Teou, 2009). Within the scope of the present study, the aim was to develop argumentation based concept cartoons by using SSI for middle and high school students enrolled at the Science and Art Centers (SAC).

Concept Cartoons on SSI for Gifted Students

Currently, gifted students are defined as individuals having not only cognitive skills such as intelligence and creativity but also other abilities that develop over time, such as motivation (Hornstra, Bakx, Mathijssen, & Denissen, 2020; Lee, Meyer, & Crutchfield, 2021). It is important that gifted students should receive an education that considers their special abilities from their early years. To this end, gifted students in Turkey are able to gain the opportunity to develop and utilize their abilities at high levels in SAC. Researchers point out that developing gifted students' strengths and weaknesses can be achieved through rich physical conditions, materials, pedagogical approaches (Lo et al., 2019) as well as effective use of classroom management strategies and adaptive education programs offered in schools (van Gerven, 2021).

Gifted students are able to learn science concepts more effectively by means of teaching approaches that take into consideration of their cognitive, affective, physical and intuitive skills (Park & Oliver, 2009). Yoon, Kim, and Koo (2020) developed the science, technology and social learning model and found that this model increased gifted students' leadership perceptions of and positive attitude toward science and engineering. Moreover, Yoon et al. (2020) emphasize that to develop gifted students' problem solving skills, it is important to integrate learning environments into science courses that consider developing gifted students' problem solving skills and helping them to develop projects related to understanding and solving daily life problems and comprehend the relationship among science, technology and society.

Some researchers suggest that special talents of students can vary across disciplines (Park, Park, & Choe, 2005; Ülger & Çepni, 2020). Based on the literature review conducted on this area by Ülger and Çepni (2020), it has been concluded that gifted students' higher order thinking skills, creative thinking skills, spatial thinking skills, and skills in production alternative solutions can be developed. In a similar vein, decision making skills regarding SSI necessitate the use of these skills (Albe, 2008; Lewis & Leach, 2006). Furthermore, this literature review also highlighted the importance of using the knowledge acquired in formal and informal learning environments to develop critical thinking and logical reasoning skills (Kılınç, Boyes, & Stanisstreet, 2013).

Along with the competencies and skills mentioned above, SSI based science education gives importance to interdisciplinary thinking and requires students' use of their feelings, values, and ethical views in their decision making processes (Chen & Xiao, 2021; Zeidler, Herman, & Sadler, 2019). In their study on gifted high school students, Vesterinen, Tolppanen, and Aksela (2016) investigated how moral development plays a role in making and applying decisions in relation to the SSI for being world citizens. Their study revealed that successful students were more interested in moral topics. In parallel to this study, it has been assumed that SAC students can also attach importance to moral and ethical dimensions in relation to different SSI. Hence, within the scope of this present study while giving place to alternative perspectives in the CCSSI, moral and ethical processes have also been taken into consideration.

The comprehensive studies conducted in the last 20 years have also paved the way to the development of SSI based programs. To illustrate, by developing a society based SSI program, Kim, Ko, and Lee (2020) the lessons were designed to focus on in-depth discussion of SSI experienced by the students in their residential areas. The implemented program increased students' level of awareness, sensitivity and sense of belonging to their society and enabled the students to better adopt the social values and culture. This approach also enabled students to realize their suggested solutions about SSI in society. In another study, an SSI program was developed with high school teachers from different disciplines, and the teachers' positive and negative experiences during the implementation of the program were identified (Friedrichsen, Ke, Sadler, & Zangori, 2021). The studies conducted by Friedrichsen et al. (2021) and other researchers with respect to SSI, revealed that in terms of using SSI effectively in science courses, science teachers experienced limitations such as time constraints, lack of pedagogical knowledge, and insufficient materials (Chen & Xiao, 2021; Tidemand & Nielsen, 2017). It was anticipated that concept cartoons could meet the need for materials which could provide SSI integration to the argumentation in the classroom. In this way, students' ideas regarding SSI and the scientific evidences supporting their ideas can be more visible. Moreover, argumentation can be pedagogically further integrated (Dawson & Carson, 2020; Sadler, Barab, & Scott, 2007; Sadler & Donnelly, 2006).

Argumentation and Dialogic Discussion on SSI

In scientific studies, the discussions scientists engage in are referred to as argumentation. The process of scientists' attributing meaning to scientific knowledge is realized through discussion of arguments. The arguments supported with scientific evidence and put forward by scientists within the scope of discussions are critiqued by other scientists. At the end of this whole process the construction of scientific knowledge is attained. In classrooms, when students try to understand scientific information by developing arguments, they better comprehend how scientists obtain scientific knowledge (Dawson & Venville, 2010; Newton, Driver, & Osborne, 1999). For this purpose, the Toulmin Argument Model (Erduran, Simon, & Osborne, 2004) is the most widely used model to understand the components of an argument. According to this model, an argument consists of claim, data, warrant, qualifier and rebuttal. Hence, during the argumentation, it is important for students to develop and use argumentation skills which are developing an argument (put forward a claim), supporting claims with scientific evidence, sharing the arguments they develop with their peers, defending their own arguments against counter arguments. In the present study, students discussed the ill-structured problems by using these skills during argumentation (Sadler & Donnelly, 2006). Since the ill-structured problems addressed within the scope of SSI lead to dilemmas and discussions in society, it is important for students to discuss these SSI from different perspectives by using scientific data.

During the process of dialogic discussions held within the scope of SSI, students can use different reasoning modes. Reasoning modes are arguments consisting of different perspectives addressed within the scope of SSI. For example, while Yang and Anderson (2003) reported that high school students used social and scientific reasoning modes while discussing nuclear energy, Wu and Tsai (2011) revealed that the participants in their study used social, economic, ecological, scientific and technological reasoning modes to discuss the same topic. The variety in reasoning modes is associated with the culture of the participants (Ozturk & Yilmaz-Tüzün, 2017). The present study also examined the reasoning modes addressed by the participants.

For a SSI while the development of an argument by a student is considered as a monologic argument, developing different or counter arguments by a group of students f is accepted as dialogic argument (Newton et al., 1999). The use of dialogic arguments during classroom discussion was accepted as a dialogic discussion learning method. Reznitskaya (2012) states that in classes where dialogic education is implemented, teachers and students collaboratively hold discussions to gain a more detailed understanding of scientific data and arguments. A discussion held in such a class environment is considered a dialogic discussion, and everyone participating in the discussion was expected to reach the most plausible scientific explanation. During the discussion process, each student uses their critical thinking skills to evaluate both the discussion process and the discussion outcomes. The teacher ensures that students produce quality arguments and applies supportive strategies for the execution of a quality discussion. The most important strategy is for students to continuously seek responses to how and why questions while analyzing complex situations like SSI.

Concept Cartoons and SSI

Concept cartoons are teaching tools that enable students to reveal their opinions, increase their curiosity and develop their understanding (Naylor & Keogh, 2013). Concept cartoons include caricature type of drawings that depict students' daily experiences of science concepts and generally consist of three or four people stating their mutual alternative explanations of their experiences through the texts placed in dialogue boxes (Atasoy & Ergin, 2017; Atasoy, Eryılmaz Toksoy, & Çalık, 2020). One of the most important features that needs to be taken into consideration in relation to generating concept cartoons is to ensure that both the drawings and the speech texts are simple and objective. In this way, students' initial conditions would be equated and the chance factor would be decreased (Keogh & Naylor, 1999).

That people of different ages and levels of education (students, teachers, teacher candidates and the public) are interested in concept cartoons encourages researchers to apply these tools to reach different learning outcomes (Naylor & Keogh, 2013). As these teaching tools include visual elements, not only does learning science concepts becomes more enjoyable, but critical thinking skills are also developed with arguments generated to address problems that can be encountered in daily life (Naylor & Keogh, 2000).

Concept cartoons enable students to utilize and develop their argumentation skills and to engage in argumentation by presenting different claims that they can have through the speech texts. In this way, students who establish justifications for the given claims try to understand other students' justifications and convince them by providing their own justifications. Throughout this process by strengthening their decisions, which are based on their own and counter justifications, students can engage in a more meaningful and profound learning experience and come to a better realization of their weaknesses (Naylor & Keogh, 2013). Thus, the process of argumentation can be implemented more effectively in science lessons.

In the related literature it is observed that concept cartoons has been used for developing conceptual understanding, producing conceptual change, revealing and eradicating conceptual misunderstandings (Atasoy & Ergin, 2017; Atasoy, Tekbıyık, & Gülay, 2013; Balım, Deniş Çeliker, Türkoğuz, Evrekli, & İnel Ekici, 2015; Cinar & Bayraktar, 2014; Ekici, Ekici, & Aydın, 2007; Çil, 2014; Minárechová, 2016, Ozdemir, Coramik, & Urek, 2020; Serttaş & Türkoğlu, 2020; Taşlıdere, 2013; Türkoğuz & Cin, 2013), understanding students' epistemological beliefs (Atasoy, 2020), effective implementation of the constructivist learning theory (Kabapınar, 2005; Keogh & Naylor, 1999; Kinchin, 2004; Naylor & Keogh, 1999a; Sasmaz-Oren & Meric, 2014), formative evaluation (Chin & Teou, 2009, 2010; Ormancı & Şaşmaz-Ören, 2011; Uzoğlu, Yıldız, Demir, & Büyükkasap, 2013), problem based learning (Balim et al., 2014, Balım, İnel-Ekici, & Özcan, 2016; İnel & Balım, 2013; Kaçar, Ormanci, Özcan, & Balim, 2020; Oluk & Özalp, 2007), the argumentation process (Çinici et al., 2014; Naylor, Keogh, & Downing, 2007; Webb, Williams, & Meiring, 2008), learning of the nature of science (Çil & Çepni, 2016), development of the scientific process skills (Türkoğuz & Cin, 2014), raising awareness of science topics (Aydın, 2015; Naylor & Keogh, 1999b), academic success (Balım, İnel, & Evrekli, 2008; Baynazoğlu & Atasoy, 2020; Yilmaz, 2020; Yokus & Aycicek, 2020), informal learning (Atasoy et al., 2020), increasing effectiveness of science education (Kabapınar, 2009) and teachers' experience (Atasoy & Zoroğlu, 2014; Balım, Ormancı, Evrekli, Kaçar, & Türkoğuz, 2016; Morris, Merritt, Fairclough, Birrell, & Howitt, 2007).

In addition, Rule and Montgomery's (2013) study revealed that after lessons in which concepts cartoons were utilized, gifted students had a higher level of intrinsic motivation, their learning of concepts was more meaningful, and they could use these concepts in different situations and were able to make more individual and general reflections in the topic they learned in class.

Above mentioned studies revealed that concept cartoons were used to teach science concepts and skills, to evaluate students' learning outcomes and skills, and to increase the effectiveness of concept cartoons by integrating them in various teaching methods (constructivist teaching activities, problem based education, argumentation etc.). It is also observed that concept cartoons have been used in a wide range of implementations; however, limited studies were available in addressing SSI teaching by using concept cartoons (Atasoy & Yüca, 2021; Evren Yapıcıoğlu & Kaptan, 2017).

Evren Yapıcıoğlu and Kaptan's (2017) study aimed to develop scientific literacy and a concept cartoon was prepared on the topic of "Genetic Tests" as one of the SSI based teaching. However, there were no explanations regarding the process of developing the concept cartoons on the topic of "Genetic Tests". On the contrary, Atasoy and Yüca (2021) provided more detailed explanations in their study in relation to the process of constructing concept cartoons on three local SSI (run-of-the-river Hydroelectric Power Plants (HPP), organic tea, and Green Road Project Interlinking Highlands (GRP)) to develop the quality of students' argumentation. Overall, it is observed that concept cartoons are not sufficiently used in SSI based science teaching.

As concept cartoons enable the discussion of SSI from different perspectives with the use of the characters in the cartoons, even shy students can present their views through the characters in the concept cartoons (Chin & Teou, 2009). In addition, argumentation based concept cartoons for SSI (CCSSI) activate group and class discussions and provide opportunities for students to form their own opinions, question opponents' views and provide justified explanations. Some research studies' findings revealed that the students had difficulty in presenting counter arguments and doing rebuttal

(Bağ & Çalık, 2017; Topcu, Sadler, & Yilmaz-Tuzun, 2010). Thus, CCSSI can provide an alternative pedagogy to address this weakness. In other words, CCSSI can be helpful in increasing the quality of students' argumentation skills by presenting counter arguments with scientific evidence (Cavagnetto & Hand, 2012; Chin & Teou, 2009).

The argumentation based SSI implementations can, by their very nature, easily equip students with different reasoning modes in relation to SSI. For example, while Öztürk and Leblebicioğlu (2015) revealed that students developed ecological, ethical-aesthetic, scientific-technological and socio-economic reasoning modes on the 'HPP' SSI, Wu and Tsai (2007) reported that students developed social, economic, ecological and technological focused arguments on the 'nuclear energy' SSI. Within the framework of the present study, concept cartoons were produced by using SSI based argumentation to help middle and high school gifted students learn science concepts in depth. For this purpose, the conceptual framework recommended by Naylor and Keogh (2000) for the development of concept cartoons was chosen.

Socioscientific Issues Based Learning and Research Approaches

The frequently addressed SSI topics include cloning (Brooks & Lusk, 2011; Khishfe, Alshaya, Boujaoude, Mansour, & Alrudiyan, 2017; Topcu et al., 2010), genetic studies (Gottweis, 2002; Robillard, Roskams-Edris, Kuzeljevic, & Illes, 2014), biotechnology (Gürkan, 2013; Sürmeli & Şahin, 2010), nuclear energy (Eş, Işık Mercan, & Ayas, 2016; Ozturk & Yilmaz-Tuzun, 2017; Tekbıyık, 2015), genetically modified organisms (Chang & Chiu, 2008; Walker & Zeidler, 2007), alternative medical treatment (Saher & Lindeman, 2005; Quinn, Taylor, Coll, & McClune, 2016), mass vaccination (Lee & Grace, 2012; Pezaro, Wright, & Gillies, 2013), global warming (Al, 2015; Öztürk, 2017) and climate change (Byrne, Ideland, Malmberg, & Grace, 2014; Stenseth, Braten, & Stromso, 2016; Zangori, Peel, Kinslow, Friedrichsen, & Sadler, 2017). In addition, less frequently addressed SSI topics are tattooing (Stuckey & Eilks, 2014), experimental animals (Agell, Soria, & Carrió, 2015), stem cell (Concannon, Siegel, Halverson, & Frayermuth, 2009), road salting (Çalık & Cobern, 2017) and some local SSI (Atasoy, 2018; Atasoy, Tekbıyık, & Yüca, 2019). However, some controversial SSI, such as x-rays, landfill, mining and space pollution are seen to be rarely addressed in the literature.

Recent studies on SSI are focused on identifying the conceptual knowledge, decision making skills, informal, ethical and moral reasoning abilities of students in different grade levels within the scope of different SSI (e.g. Fang, Hsu, & Lin, 2019; Ladachart & Ladachart, 2021; Ozturk & Yilmaz-Tuzun, 2017; Topcu et al., 2009). In addition, there are studies which entail various methods of implementation for the development of these skills and a better understanding of science concepts, such as conceptual exchange (Leung & Cheng, 2020), situational learning (Herman, Zeidler, & Newton, 2020), practice based learning (Leung, 2022), argumentation (Dawson & Carson, 2020), and augmented reality and mobile learning (Chang, Liang, & Tsai, 2020). However, studies that make direct use of argumentation based concept cartoons for SSI are quite limited (Pekel, 2019).

In studies conducted on SSI, the participants were seen to be mostly selected from universities (Chabalengula, Mumba, & Chitiyo, 2011; Öztürk, 2017; Pezaro et al., 2013), high schools (Dawson, 2007; Dawson & Schibeci, 2003; Lundström, Ekborg, & Ideland, 2012), middle schools (Lee & Grace, 2012; Stenseth et al., 2016; Zangori et al., 2017) and primary schools (Byrne et al., 2014). There are also some studies where the public were involved as participants (Balas & Hariharan, 1998; Brooks & Lusk, 2011; Saher & Lindeman, 2005; Quinn et al., 2016). The sample groups from universities were found to be mostly teacher candidates (Al, 2015; Chabalengula et al., 2011; Çalık & Cobern, 2017; İşbilir, 2010; Öztürk, 2017; Pezaro et al., 2013; Saylan, 2014; Sürmeli & Şahin, 2012; Tekbıyık, 2015; Topçu, 2008). It is important to include the public as participants in studies related to SSI so that scientific decisions taken about social issues can include all the people of the society. Accordingly, in the implementation process of CCSSI, the idea that the decision making processes of parents, along with those of the gifted students, should also be taken into consideration has emerged. The present study has taken this into consideration.

The Aim of the Research

The aim of the present study is to design argumentation based concept cartoons for socioscientific issues (CCSSI) for middle and high schools students enrolled in SAC and evaluate the implementation results. For this purpose, the answers to the following research questions were sought:

1. How are the elements and content of the CCSSI prepared for SAC students?
2. To what extent do the prepared CCSSI reflect structural and argumentation features?
3. What are the reflections of the prepared CCSSI on SAC students' levels of dialogic discussion?

Method

In the present study, based on the Design and Development Research (DDR) method (Richey & Klein, 2005), the Analysis, Design, Development, Implementation and Evaluation (ADDIE) model (Aldoobie, 2015) has been utilized with the aim of designing instruction. Studies in which the DDR method is used entail the development of innovative designs and products within the research process, subsequent to which they are implemented and evaluated based on the data obtained (Lee, Jeon, & Hong, 2021; Yazıcı & Sözbilir, 2020).

The ADDIE model implemented within the scope of the present study includes three primary stages (Richey, Klein, & Nelson, 2004) (See Figure 1). In the first stage of the study SSI was identified for SAC students, and a framework plan was established for the construction of concept cartoons based on these SSI. In the second stage, which includes the design and development processes, concept cartoons were created for argumentation based SSI teaching, and expert opinions were received, according to which the essential changes were made. In the last stage, which comprises the implementation and the evaluation processes, the CCSSI was implemented in class and their effectiveness was evaluated. The reflections of the CCSSI developed on SAC students' levels of dialogic discussions was examined in this study.

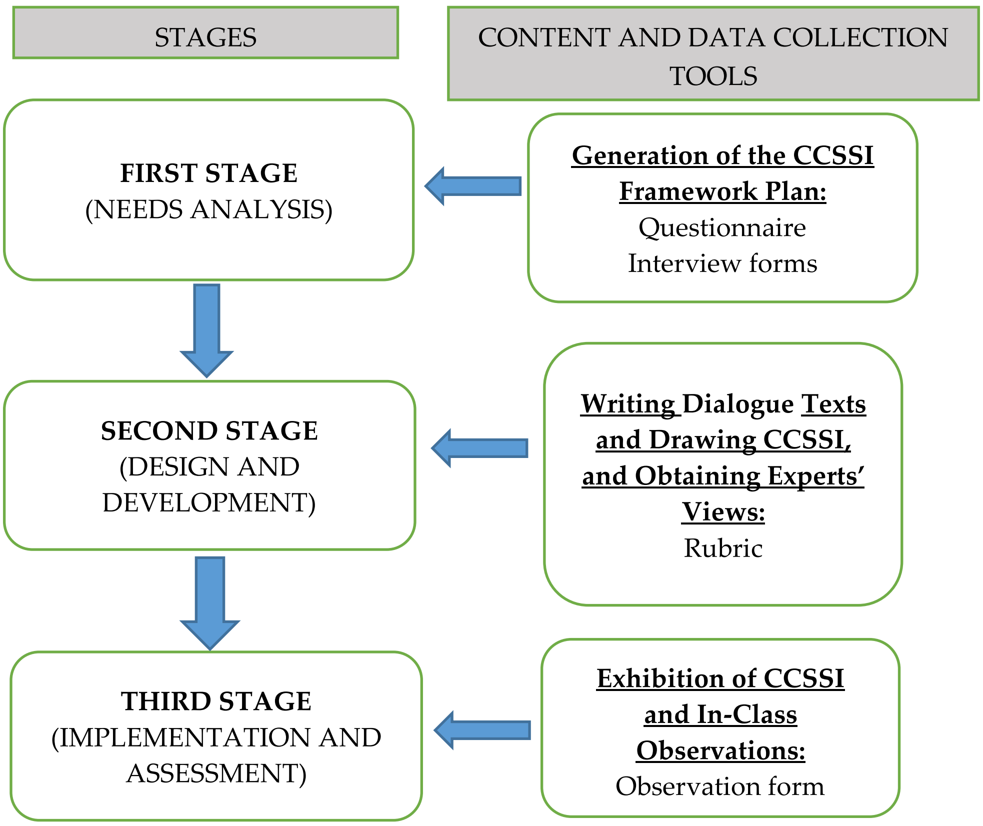


Figure 1. The stages and content of the ADDIE model, and the data collection tools

Participants

The participants of the research study were science teachers at SACs in Rize and Trabzon provinces in Turkey, the students at the same centers and the parents of these students. They participated on a voluntary basis. In addition, faculty members in science education working at the education faculty in each of the universities located in Rize and Trabzon (Table 1) participated in the study. Purposeful sampling was used to obtain rich data in line with the aims of the study and the CCSSI developed in the study could be examined effectively and in-depth (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz, & Demirel, 2019).

Table 1. The Participants' Demographic Features

Participants		**Expertise/Discipline/Graduation Level**	**Rize (N)**	**Trabzon (N)**
Teachers		Science	**1**	**1**
		Biology	**1**	**1**
		Physics	**1**	**1**
		Chemistry		**2**
Experts		Science Education	**1**	**1**
		Biology Education		**1**
		Physics Education	**2**	
		Chemistry Education	**2**	**1**
Students	**Middle School**	Science	**8**	
	High School	Physics	**4**	
		Biology	**4**	
Parents		Graduated from a University	**5**	

The Preparation and Administration of the Data Collection Tools

As data collection tools, the present study utilized a questionnaire, interview forms, a rubric, and an observation form. The questionnaire and interview form, which were developed by the researchers of the present study, were implemented during the needs analysis stage (first stage), and the rubric was utilized during the design and development processes (second stage). The observation form was used during the implementation and evaluation processes (third stage) (Figure 1). In consideration of these stages and research questions, the first research question (How are the elements and content of the CCSSI prepared for SAC students ?) was associated with the first stage, while the second research question (To what extent do the prepared CCSSI reflect structural and argumentation features?) was related to the second stage, and the third research question (What are the reflections of the prepared CCSSI on SAC students' levels of dialogic discussion?) was associated with the third stage.

First Stage (Needs Analysis)

In the first stage, scientific studies on SSI accessed through the Turkish Academic Network and Information Center, Web of Science and ERIC data bases were examined and 18 different SSI (Cloning (CL), Genetic (GN), Nuclear Energy (NE), Genetically Modified Organisms (GMO), Alternative Medical Treatment (AMT), Mass Vaccination (MV), Global Warming (GW), Tattooing (TT), Experimental Animals (EA), Stem Cell (SC), Road Salting (RS), Green Road Project Interlinking Highlands (GRP), HPP, Organic Farming (OF), X-rays (XR), Landfill (LF), Mining (MN) and Space Pollution (SP)) were initially thought of being addressed. It was found that by integrating the argumentation process, such studies in the related literature (e.g. Concannon et al., 2009; Dawson, 2007; Herman et al., 2020; Sadler & Donnelly, 2006; Topcu et al., 2009, 2010) gave place to findings obtained from the components of arguments, such as claims, evidence, counter arguments, and rebuttals. These findings were examined by the researchers, as a result of which the scientific evidence presented by the participants and the associated reasoning modes were revealed. This examination enabled the establishment of a detailed framework plan with argument components and reasoning modes in relation to the SSI addressed within the scope of the study.

Data were also obtained via a questionnaire and interviews to support the validity of the framework plan. To ensure the content validity of the argument components and reasoning modes on the framework plan, a questionnaire form consisting of three different sections was developed. The first section included one open-ended question asking the participants to evaluate the integration of SSI into science education. The second section asked the participants to identify whether each SSI obtained from the literature was appropriate for middle and high school level and add any other SSI if possible. As for the third section, it asked the participants to identify which reasoning modes each SSI in the second section could include and explain why with justifications. Apart from the participants, expert opinions were received from three experts (one science educator, one physics educator, and one chemistry educator) and three teachers (two science and one biology) to ensure the content and construct validity of the questionnaire form developed. The questions were revised and finalized based on the opinions received (Appendix 1). The questionnaire was administered to 16 participants (eight teachers and eight experts) (Table 1). The argument components and reasoning modes were reviewed based on the data obtained from the questionnaire. Moreover, in light of the same data, the decision regarding which SSI would form the context of which grade level concept cartoons was made.

Interview forms were created for each of the 18 SSI obtained from the literature. Scenarios were created for each SSI by using the scientific evidence in the related framework plan. Each scenario was followed by open-ended questions to identify the argument components. The number of open-ended questions varied based on the scientific evidence and reasoning modes present in the SSI scenarios. These open-ended questions were adapted from those in previous research studies (e.g. Atasoy et al., 2019; Öztürk & Leblebicioğlu, 2015). To ensure the content validity of the interview forms, expert opinions from three experts (one science educator, one biology educator, and one physics educator) among the participants were received. Based on these opinions, biased texts were improved and a balance between positive and negative explanations was established. The interview forms (see Appendix 2 for a sample of the form) that were revised were administered to two middle and two high school students and two parents in a SAC in Rize. The interviews were conducted face-to-face by a researcher and each lasted 10-20 minutes. The interviews were recorded with a voice recorder and subsequently transcribed.

In short, the findings that the questionnaire and interview forms yielded were evaluated by the research group, the framework plan was reviewed, and the content validity was ensured. The section on the HPP from the CCSSI framework plan is provided as a sample in Appendix 3. Thus, all the elements required to prepare the CCSSI in the first stage of the research were obtained.

Second Stage (Design and Development)

In this stage, the work carried out for the design and development of the CCSSI is presented.

Content: The framework plan was used to reflect the content of the SSI onto the concept cartoons in line with argumentation based education. The content of the cartoons was formed with the placement of each reasoning mode in the CCSSI framework plan (e.g. the benefits/advantages or hazards/disadvantages of HPP in such areas as economy, ecology, and society) and different argument components into the speech texts.

Drawing: Decisions were made on the appropriate drawing theme (drawings to reflect the condition under discussion) for each dialogue text. The drawing of the concept cartoons was done by a visual arts expert by using the flash program on the computer. The number of SSI, reasoning modes, and the views to be debated according to these modes were taken into consideration to design 41 concept cartoons.

Expert Opinion: The CCSSI Rubric (Appendix 4) was developed with the aim of examining the visual aspects and the content of the concept cartoons. This rubric enabled the CCSSI to be evaluated according to the dimensions under two main headings: structural features (the problem presentation, use of language, attractiveness, organization and visual design dimensions) and the features of the argumentations in the SSI (the relationship of the dialogues with the socioscientific issues and their reflection of the argumentation components) (Atasoy, 2017). Three different levels regarding these dimensions were identified: 'satisfactory', 'partially satisfactory', and 'unsatisfactory'. Two experts (a physics educator and a chemistry educator) in the study group secured the content validity of the rubric. It was determined that the concept cartoons possessed the criteria for the evaluation of structural and argumentation features and thus could be implemented. Subsequently, six experts (Table 1) among the participants of the study (two science educators, one physics educator, one biology educator and two chemistry educators) evaluated the CCSSI developed based on this rubric. In this process, recommendations were asked to be made for the improvement of the dimensions that were found to be 'partially satisfactory' or 'unsatisfactory' as well as detailed explanations regarding why such an evaluation was made. Thus, the deficiencies identified and the recommendations made were taken into consideration by the researchers and the necessary improvements on the CCSSI were made. With these improvements, attention was paid to ensure that all dialogues were associated with the problem condition and enable sufficient comprehension of the problem condition from the mutual dialogues in the concept cartoons (the *problem presentation* dimension), to maintain a balance between the use of daily and scientific language in the dialogues along with the comprehensibility and consistency of the dialogues (the *use of language* dimension), to ensure that the concept cartoons had sufficient content to attract students' attention (in the *attractiveness* dimension), to ensure the presence of a logical consistency between all events/phenomena, place and characters in the concept cartoons (the *organization* dimension), and the concept cartoons designs were done according to the visual design principles (such as unity, balance, size, and use of color) (the *visual design* dimension). When the concept cartoons were examined in terms of the argumentation features, attention was paid to ensuring that the concept cartoon completely reflected the SSI related to the problem condition (*SSI relatedness* dimension), that the dialogues included one or more claims and related counter arguments appropriate with the SSI, and that there was consistency between the dialogue texts reflecting the informal reasoning modes (*argumentation* dimension).

Third Stage (Implementation and Evaluation)

This stage is the pilot implementation stage of the CCSSI conducted in SAC in Rize; it entails the inservice training of the teachers, the formation of the learning groups, the exhibition of the concept cartoons on school corridors, the implementation of the in-class dialogic discussions, and the evaluation of the implementations via an observation form.

A six-hour *inservice training* was provided to the teachers one week before the in-class dialogic discussions. During the inservice training, the science, physics and biology teachers working at this school were first informed about SSI. They were also provided with information about the content of the implementation with a detailed account of the framework plan and the CCSSI. At a later stage, they were given information about the development of students' critical thinking and decision making skills in relation to the SSI and the argumentation method to be used in class. Moreover, a dialogic discussion was implemented on a sample SSI (HPP) to develop teachers' knowledge and skills in this area. Furthermore, the framework plan was turned into a booklet and given to teachers to enrich the in-class discussions and to provide teachers with ready made materials.

As common stakeholders, a *learning group* formed during the implementation stage together with experts (8 people), teachers (3 people) and volunteer parents (5 people, 2 of whom participated in the interviews) were asked to share their knowledge, ideas and opinions on the content and visuality of the SSI and the concept cartoons in the CCSSI with each other and with the researchers. The parents were included in the study on a voluntary basis by the school administration; they were provided information about the study by the researchers. The communication of the parents with the other participants was achieved through the formation of a closed group on facebook. In this group, the CCSSI and the SSI related news in social media were shared. Even though an intensive interaction did not take place on these shared posts, the communication in the group was kept active by sharing informative scientific texts for the continuity and sustainability of the process.

In the administration stage, in-class dialogic discussions were held simultaneously with the *exhibition of the concept cartoons on school corridors*. This enabled the sharing of experiences and views between all students interacting on these topics that were moved to an informal environment. With the recommendation of the school administration and teachers, the CCSSI were displayed via 70X90 size coloured posters on boards standing in appropriate sections of the school corridors where students spent most of their time out of class and where they could easily see the posters. The exhibition of the posters continued for nine weeks with two different CCSSI displayed each week. Meanwhile, the teachers led *in-class dialogic discussions* with their own groups. The researchers watched the videos related to the discussions every two weeks and the aspects that needed improvement (e.g. the monotony of the discussion environment, teacher-centered behaviors) were identified and the teachers were provided with guidance and the necessary support. Throughout all these implementations, the comprehensibility and implementability of these CCSSI were regularly evaluated by the authors of this study. The first author observed the in-class discussions of 11 CCSSI by using observation forms to evaluate the reflections of CCSSI on in-class dialogic discussion levels. The Dialogic Discussion Observation Form, developed by Reznitskaya (2012) and adapted to the Turkish language (Turhan & Kılınç, 2021), includes indicators in the dimensions of *authority, questions, feedback, meta-level reflection, explanation and collaboration* (Appendix 5). The in-class discussions were video recorded by obtaining the essential legal permissions and the participants' approvals.

Data Analysis

The Analysis of the Data Obtained from the Questionnaires

The data obtained from the questionnaires were analyzed by using descriptive analysis, and common explanations were grouped by considering the frequencies and parameters such as the contribution of the SSI to science education, the appropriacy of the SSI in terms of SAC students' grades and the reasoning modes and the related justifications. The inter-rater agreement between the two researchers was found as 86%; the discrepancies among researchers were remediated through negotiations.

The Analysis of the Data Obtained from the Interviews

A descriptive analysis was conducted for the interview data by considering the parameters of decisions about SSI (positive/negative, +/-), justification/informal reasoning modes, and participants' opinions. To ensure the reliability of the data analyses, a randomly selected data set was analyzed by two researchers. The agreement was found to be 84%. Thus, it was concluded that the researchers were in high agreement with each other. Disagreement among these two researchers was solved with the help of other two researchers.

The Analysis of the Data Obtained from the Rubric

Each dimension in the CCSSI Rubric was marked as either 'satisfactory (3 points)', 'partially satisfactory (2 points)', or 'unsatisfactory (1 point)'. Thus, the highest, the lowest and the average scores obtained from the rubric were calculated for the CCSSI and presented in a table. Furthermore, all the recommendations made were evaluated by the researchers and each one was reflected onto the concept cartoons.

The Analysis of the Data Obtained from the Observation Forms

The Dialogic Discussion Observation Form, developed by Reznitskaya (2012), was used in the study and marked with monologic level being 1-2 points, semi-dialogic level 3-4 points and dialogic level 5-6 points. However, as there were no indications for 2, 4 or 5 points in the observations made in this study, these points were not included in the scoring. For each descriptor in the observation form, the monologic level was marked as 1 point, the semi-dialogic level as 3 points and the dialogic level as 6 points. The lesson video recordings were reviewed and scored by another researcher. The inter-rater agreement was found to be 92%. When there were incompatible codings/observations, a third researcher was asked to watch the videos, and with the views of the third researcher, a consensus was arrived at. As a result of the scoring, the discussions held in three separate student groups were scaled from monologic to dialogic for the teachers, and the data were presented on a data image. Furthermore, sample statements from class discussions have also been presented.

Results

The First Stage (Needs Analysis)

In the needs analysis stage, which is the first stage in the study, the answer to the following research question was sought: "What are the components and content of the CCSSI?" The findings obtained from the interviews and questionnaires to this end are presented below. Table 2 presents the results yielded from the interviews held with the SAC students and their parents by using the interview forms.

Table 2. Findings of SAC Students' and Parents' SSI-Related Decisions and Justifications

SSI	**Students' views**				**Parents' views**			
	Health	Economic	Social	Ecological	Health	Economic	Ecological	Ethical
MV	+ + –	–			–			–
RS		+		+ –		+	–	
AMT	+				+			
SP		+	+	–			–	
GRP		+		–			–	
XR	–				–			
NE	–		–		–			
EA				–	+			–
MN	–		–	–	–		–	
GW				–			–	
HPP		+		+		+	+	
OF	+					–		
GMO	–						–	
LF				–	–	–	–	
SC				+				+
CL		+						–
GN	+		+	+	+			+
TT	–				–			

+: Positive view,-: Negative view
AMT: Alternative Medical Treatment, CL: Cloning, EA: Experimental Animals, GN: Genetic, GMO: Genetically Modified Organisms, GW: Global Warming, GRP: Green Road Project Interlinking Highlands, HPP: Hydroelectric Power Plants, LF: Landfill, MV: Mass Vaccination, MN: Mining, NE: Nuclear Energy, OF: Organic Farming, RS: Road Salting; SP: Space Pollution, SC: Stem Cell, TT: Tattooing, XR: X-ray.

A descriptive analysis was performed to identify the SSI related decisions made by the students and their parents and reasoning modes they used in their justifications while making decisions. It was revealed that while making decisions, the students preferred to use health, economic, social and ecological modes, while their parents preferred to use health, economic, ecological and ethical modes. While students justified their decisions from the health and social perspectives, they were found to be making both positive and negative decisions about the SSI. The decisions based on economic justifications were found to be mostly positive, while those rested on ecological justifications mostly negative. Similarly, parents' decisions based on ecological justifications were negative, while decisions made from the health, economic, and ethical perspectives were a mixture of both positive and negative.

While making decisions about alternative medical treatment, one student expressed their view from the health perspective:

> *"There are things that modern medicine cannot do; I mean there are things where it is ineffective; for example, modern medicine cannot do anything at progression, fatal stages of this cancer; it leaves the patient to death. In these conditions, I feel like we must try out certain things with hope by trying out various things instead of waiting helplessly for death."*

On the other hand, another student's negative decision about space pollution based on ecological justifications is as follows: *"…after it loses its function, it only stays there as trash; it has no function -- -- It just occupies a place in space. It envelopes our world as well; it will most probably in the long term cause problems for us; it may prevent the sun's rays from reaching the Earth."*

A parent's positive decision on the 'HPP' SSI based on economic justifications is as follows: *"…The HPP is more advantageous because it is not only long lasting but also has lower operational costs than production costs."*

The views of another parent, who has made an ethically positive decision on stem cell work, are as follows: *"It is not taken from a living organism in a way that distorts its wholeness anyway. It is taken from the blood in the cord. Its source is the umbilical cord and this does not give harm. If it did, I wouldn't accept it but it doesn't harm the living being in any way."*

The responses given to the questionnaire by the teachers and experts, as participants of the study, were subjected to descriptive analysis. The findings obtained for the three sections in the questionnaire (the contribution of the SSI to science education, the appropriacy of the SSI in terms of SAC students' grades and the reasoning modes and the related justifications included) are presented below.

Findings Regarding the Contributions of SSI to Science Education

The findings obtained from the descriptive analysis are presented in Table 3. The contributions of the SSI to science education were categorized into three dimensions as social, educational and scientific. In the social dimension, it was stated that SSI would increase students' levels of sensitivity and awareness and enable them to protect the benefits of the society while recommending solutions. Moreover, they stated that generating solutions to daily life problems would contribute to their learning to support their own opinions and question others' opinions.

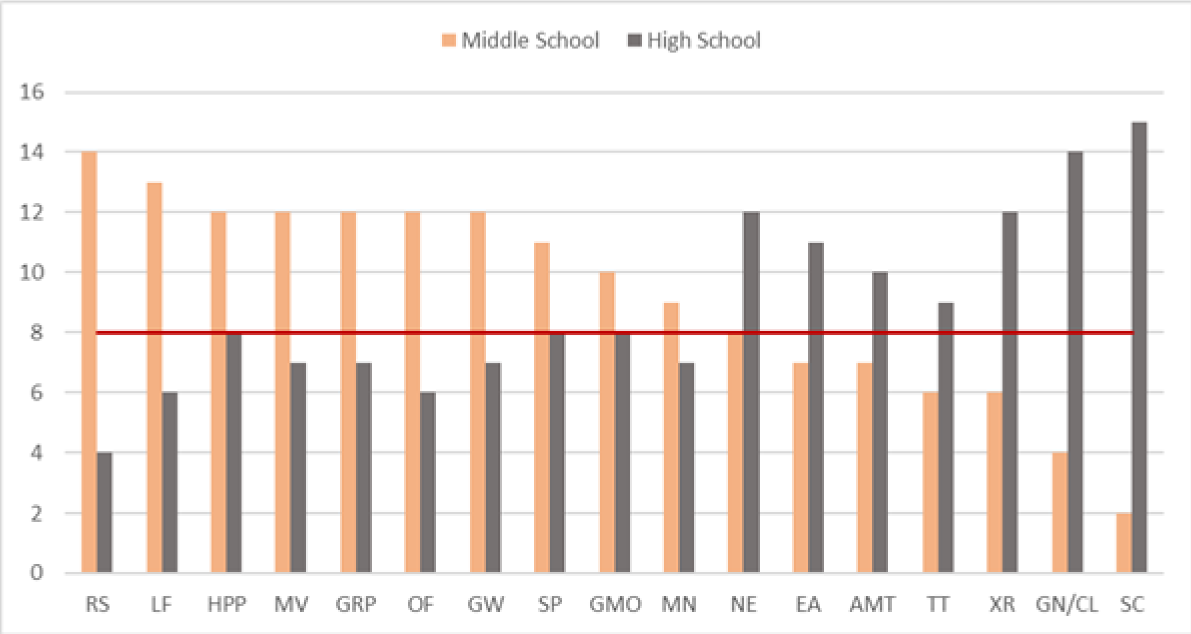
In the educational dimension, it was most frequently stated that SSI would develop decision making skills and contribute to raising science literate individuals. In addition, it was stated that by giving place to SSI in science education, students could engage in scientific discussions and develop their thinking skills. As for the scientific dimension, it was stated that SSI could equip students with scientific thinking skills.

Table 3. Findings Regarding the Contributions of SSI to Science Education

Area of contribution	**Explanations (frequency)**
Social	*As individuals gain more knowledge on SSI, they -become more sensitive, more aware, and more conscious individuals who solve problems to protect social benefits (3), -recommend solutions to events and problems in daily life (2), -learn to defend their own views and question the accuracy of others' views (2), -develop different viewpoints (2), -increase the comprehensibility of scientific topics in society (1). *As SSI include topics that are closely related to the future of human beings, -they should be integrated into science education (1), -they provide experience, practice and knowledge in relation to problems that can be encountered in daily life (1), -individuals who are led by the scientific path, far from superstitions, myths, and dogmas are raised (1). *Through SSI, students -gain understanding of how the topics learned in science lessons affect societies (1), -acquire knowledge related to social life (1), -develop the ability to make interpretations (1), -learn to associate science with daily life (1).
Educational	-SSI in science education develop students' decision making skills (4), -SSI contribute to raising science literate individuals (4), -Discussion, comprehension, attitude, behavior and skills develop based on scientific grounds (2), -SSI contribute to the development of communication, analytical and critical thinking skills (2), -Owing to the interdisciplinary approach in the use of SSI, individual differences meet on common grounds (1), and -Students' motivation toward science lessons increase and they follow the lessons with a higher level of attention (1).
Scientific	-SSI foster the habit of scientific thinking (2), -Abstract concepts in science can be examined concretely via SSI (1), -SSI support scientific and technological developments (1), -SBIs are areas of practice for fundamental science (1), -Scientific projects are regarded important thanks to SSI (1), and -Science is better understood (1).

The Appropriacy of SSI to SAC Students' Grades

The frequency distribution graph displaying the participants' markings of the appropriacy of each SSI to middle and high schools is portrayed in Figure 2. It was decided that the SSI that at least half ($f \geq 8$) of the 16 participants found appropriate for the related level of education could be implemented. Accordingly, 11 of the topics were found to be appropriate for middle school and 11 topics for high school level students (genetic and cloning were later separated). As there was no SSI which the participants found to be inappropriate for either of the levels (middle or high school), all SSI were included in the implementation.



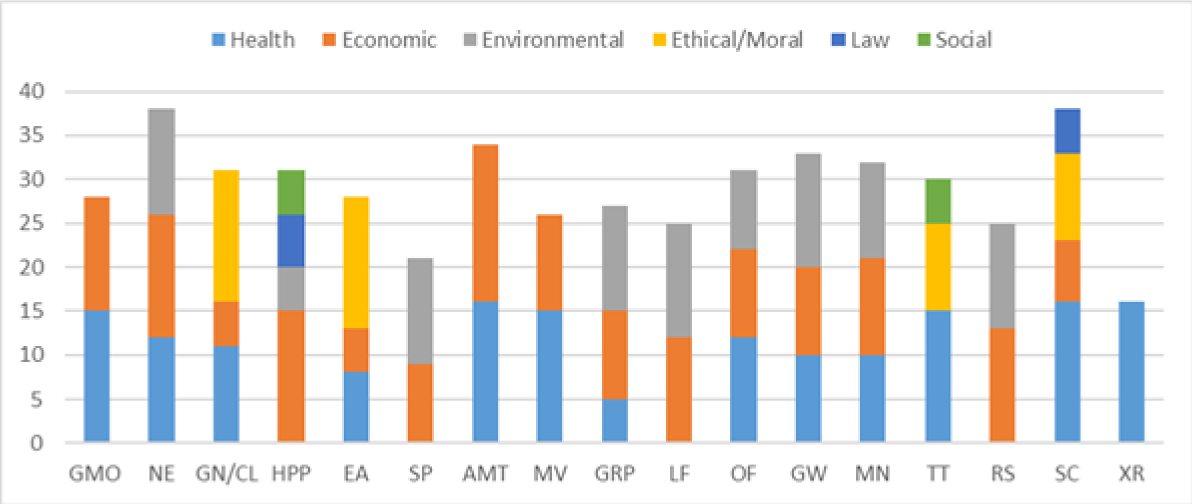
AMT: Alternative Medical Treatment, CL: Cloning, EA: Experimental Animals, GN: Genetic, GMO: Genetically Modified Organisms, GW: Global Warming, GRP: Green Road Project Interlinking Highlands, HPP: Hydroelectric Power Plants, LF: Landfill, MV: Mass Vaccination, MN: Mining, NE: Nuclear Energy, OF: Organic Farming, RS: Road Salting; SP: Space Pollution, SC: Stem Cell, TT: Tattooing, XR: X-ray.

Figure 2. Findings Regarding the Appropriacy of SSI to SAC Students' Grades

Accordingly, 'GMO, nuclear energy, HPP, space pollution, mass vaccination, GRP, landfill, organic farming, global warming, mining, and road salting' SSI were found to be appropriate for middle schools, while 'GMO, nuclear energy, genetic, cloning, HPP, experimental animals, space pollution, alternative medical treatment, tattooing, stem cell, and x-ray' were found to be appropriate for high schools.

The Reasoning Modes and Justifications that could be included in SSI

The participants were asked what reasoning modes the SSI could include and what their justifications were. Figure 3 displays the reasoning modes stated by the participants. Accordingly, they stated that, apart from the 'x-ray' SSI, all SSI included at least two and some SSI (HPP, stem cell) included four reasoning modes based on the discussions held.



AMT: Alternative Medical Treatment, CL: Cloning, EA: Experimental Animals, GN: Genetic, GMO: Genetically Modified Organisms, GW: Global Warming, GRP: Green Road Project Interlinking Highlands, HPP: Hydroelectric Power Plants, LF: Landfill, MV: Mass Vaccination, MN: Mining, NE: Nuclear Energy, OF: Organic Farming, RS: Road Salting; SP: Space Pollution, SC: Stem Cell, TT: Tattooing, XR: X-ray.

Figure 3. Findings Regarding the Reasoning Modes that SSI could include

It is important to reveal how the participants justified these reasoning modes of the dialogues of the characters in the concept cartoons during the SSCC development process. Thus, all the SSI related justifications were recorded. Table 4 presents samples from the justifications presented while they expressed their views on different informal reasoning modes.

Table 4. Samples from Justifications Presented in Informal Reasoning Modes

	Informal Reasoning Modes					
	Health	**Economic**	**Ecological**	**Ethical/Moral**	**Law**	**Social**
Sample Justifications (SSI)	The radiation emitted from power plants impacts human health. It can cause incidents of cancer. It has a large impact on living beings. (Nuclear Energy).	External dependency decreases. It creates employment in the region where mines are extracted. However, when reserves are limited, the rewards of the investments made may not be reaped (Mining).	Causes harms to the environment; impacts coastal life; changes sea levels; negatively impacts marine organisms (Landfill).	It can be disadvantageous from the religious perspective. It may not be ethical or moral to generate an embryo from a terminated pregnancy. It may not be appropriate in terms of universal ethical principles. (Stem Cell).	People may file lawsuits due to environmenta l changes. (HPP).	In terms of individual freedoms, they are spaces for self-expression (Tattooing).

The Second Stage (Design and Development)

The design and development stage, which is the second stage of the study, seeks to respond to the following research question: "To what extent do the prepared CCSSI reflect structural and argumentation features?" To this end, the average, maximum and minimum scores given by the experts with the use of the CCSSI Rubric are presented in Table 5. Subsequently, samples of the recommendations made by the experts regarding the deficiencies they identified in the CCSSI are presented. Some visuals are also portrayed for the comparison of prior and subsequent forms of some CCSSI so that the changes made based on the recommendations can be better understood.

Table 5. Scores Obtained from the Rubric

	Structural features of CCSSI					Argumentation features of CCSSI	
	Presentation of problem	**Language**	**Attractiveness**	**Organization**	**Visual Design**	**Relation of SSI**	**Argumentation**
Min.	1	2	2	1	2	2	2
Max.	3	3	3	3	3	3	3
Mean	2,4	2,6	2,8	2,6	2,8	2,4	2,6

As can be seen in Table 5, the highest points for the CCSSI were in the dimensions of *attractiveness* and *visual design*. Experts made recommendations to ensure that CCSSI were designed so that they had sufficient content and were designed in accordance with the principles of visual design (such as unity, balance, size, and use of color) to attract students' attention. Based on the average score, the dimensions of *organization* and *argumentation* were in second place. Experts made recommendations for the establishment of complete logical consistency between the events/phenomena, place, and characters in the content cartoons in the dimension of the organization dimension. In terms of the argumentation dimension, they recommended that the dialogues should include one or more claims and related counter arguments. According to Table 5, the dimension of problem presentation and the relatedness of the dialogues to the SSI received the lowest scores when compared to the other dimensions. Experts made numerous recommendations particularly on problem presentation in CCSSI, the sufficient comprehension of the problem condition from the dialogues in the concept cartoons and the relatedness of all the dialogues to the problem condition. There were very few expert opinions in relation to the complete reflection of the related SSI through the problem conditions in the concept cartoons. Samples from expert opinions for each dimension in the rubric and revisions made in the concept cartoons based on these recommendations are presented below.

One sample of a recommendation made for the first concept cartoon in the 'GMO' SSI in the

Attractiveness dimension is as follows:

> *"Since the cartoon is based specifically on the corn sample/visual, it would be better for the dialogue to be based on "GMO and local corn". In this way, I think by starting off with the sample of corn, which students mostly encounter as a GMO, they can proceed to the general concept of GMO. It can draw their attention more. At least students who have corn in their hands can express this."*

In accordance with this recommendation, the statement of the character with a corn in its hand reading "*The increase in the consumption of genetically modified food causes the disappearance of local seeds*," was revised as follows: "*The increase in the consumption of genetically modified corn causes the disappearance of local corn*." As for the second concept cartoon on the 'cloning' SSI, the necessary revision was made for the recommendation, "*I think it would be more interesting if there were a subtitle under the TV screen image, saying 'The first cloned sheep Dolly and its mother'*."

The following recommendation was done based on the 'tattooing' SSI in the dimension of visual design: "*I couldn't understand the fire and skull on the tattooer. Also, the picture of the tattooer in the image could be smaller; what it is doing is not clear; is it doing a tattoo, showing its tattoos? If it is the latter, why would it show them from the window in that way?*" For revisions in the visual design and other dimensions of the concept cartoon related to the 'tattooing' SSI, its first (Figure 4) and revised (Figure 5) versions are presented as follows.

Figure 4. The First Version of the Design and other Dimensions of the 'Tattooing' CCSSI

Figure 5. The Revised Version of the Design and other Dimensions of the 'Tattooing' CCSSI

As can be seen in Figure 5, the visuals that were not directly related to the 'tattooing' SSI were replaced with those having different tattoo designs. Thus, we tried to obtain a visual resembling a tattoo window. In addition, the concept cartoon on the 'tattooing' SSI took the form in Figure 5 after the revisions were made in relation to the recommendation, "*As it cannot be understood who is talking with whom, one needs to follow and find which person is saying what in response to which argument. Can there be a more sequenced flow?*"

One of the recommendations made by the experts in relation to the first concept cartoon on the *organization* dimension of the 'alternative medical treatment' SSI is as follows: "*A manipulation could be made to support modern medicine by having a hospital corridor in the background. For example, the statements of the speakers in a discussion program could be provided*." Based on this recommendation, the characters were placed within a discussion program. Another recommendation for the same dimension but on the 'genetic' SSI was made for the first concept cartoon: "*The green pepper held by the student is too far from the student. If we are going to form an image to examine this, I think it would be better if it held a potato or had a basket of green peppers right next to it.*" Based on this recommendation, a potato was drawn in place of the green pepper in the hand of the character. Thus, a place association was established in terms of organization.

A sample expert opinion related to the first concept cartoon on the argumentation dimension regarding the 'mass vaccination' SSI was as follows: *"It looks like the third character's statement is not in the form of a counter argument. Instead of this, a statement on why vaccinations are not produced with commercial concerns could be added. For example, the ministry seems to be using it to prevent flu pandemics."* Upon this recommendation, the character's statement that said, "*Vaccines should be subsidized through the public budget of the Ministry of Health to prevent flu pandemics without commercial and economic concerns,*" was revised as follows: "*Vaccines should be subsidized through the public budget of the Ministry of Health to prevent flu pandemics.*" With this revision, the statement was turned into a counter argument to the views of the other characters.

A recommendation made for the first concept cartoon on the 'GRP' SSI is as follows:

"I think here too many claim-justification-support constituents of the argumentation process are too provided. It seems like there aren't many justifications or supports left for the student to provide. That highlands will lose their old appeals could be given and students could be asked to provide the reasons. In the statement of the third character, that alternative solutions could be produced should be mentioned and the example for this (tour services) should not be given. It would be better if the student provided this example as a support."

Based on this recommendation in the concept cartoons, the following statements, *"I don't think there is any need for a GRP to increase plateau tourism in the region. It would be better to increase tour services rather than a GRP for people to travel the plateaus"* were replaced with *"I think there is no need for a GRP to increase plateau tourism in the region. Alternative methods can be generated to enable more people to travel the plateaus."*

With this change made in accordance with the expert opinion, students were encouraged to find the justifications and evidence made based on this new version of the claim. An expert opinion on the second concept cartoon related to the problem presentation dimension of the 'experimental animals' SSI was as follows: "*Here, the argument that animals produced in laboratories and used in a way by which they do not harm biodiversity could be used in experiments to contribute to human health could also be added*." Upon this expert opinion, with the addition of a character to the concept cartoon, the following speech text was also added: "*Animals that do not harm biodiversity should be produced in laboratories and used in experiments to contribute to human health*." With this revision, a sufficient number of arguments was provided to make the problem statement in the concept cartoon more comprehensible. An expert opinion related to the problem presentation in the second concept cartoon on the 'HPP' SSI, was as follows: *"It seems like the 3rd claim is distorting the unity of the problem presentation. The 3rd claim could replace the 2nd claim and could be presented as 'I agree with you…'. It could be presented as a counter argument to the other two."* Accordingly, revisions were made so that the statements of the first two characters expressed statements that supported each other and the third explanation functioned as a counter argument. The prior (Figure 6) and subsequent (Figure 7) forms of this concept cartoon are presented below.

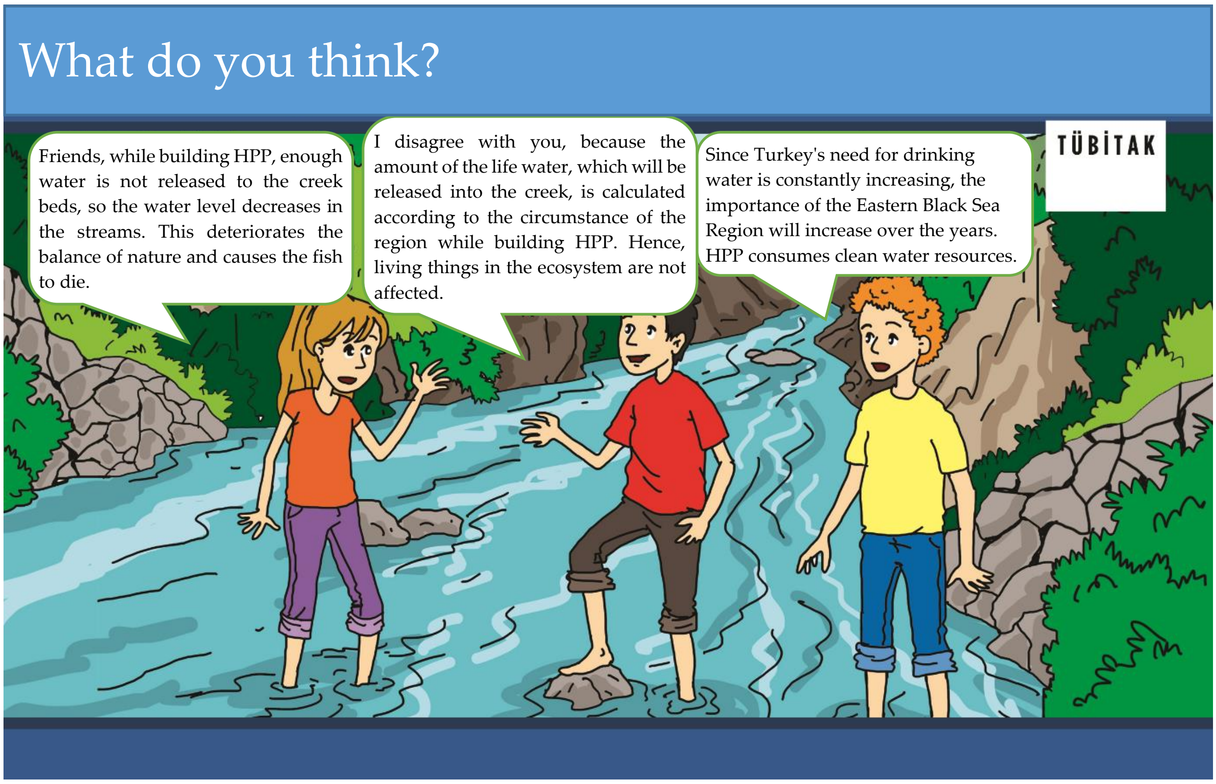


Figure 6. The First Version of the Second Concept Cartoon on the 'HPP' SSI

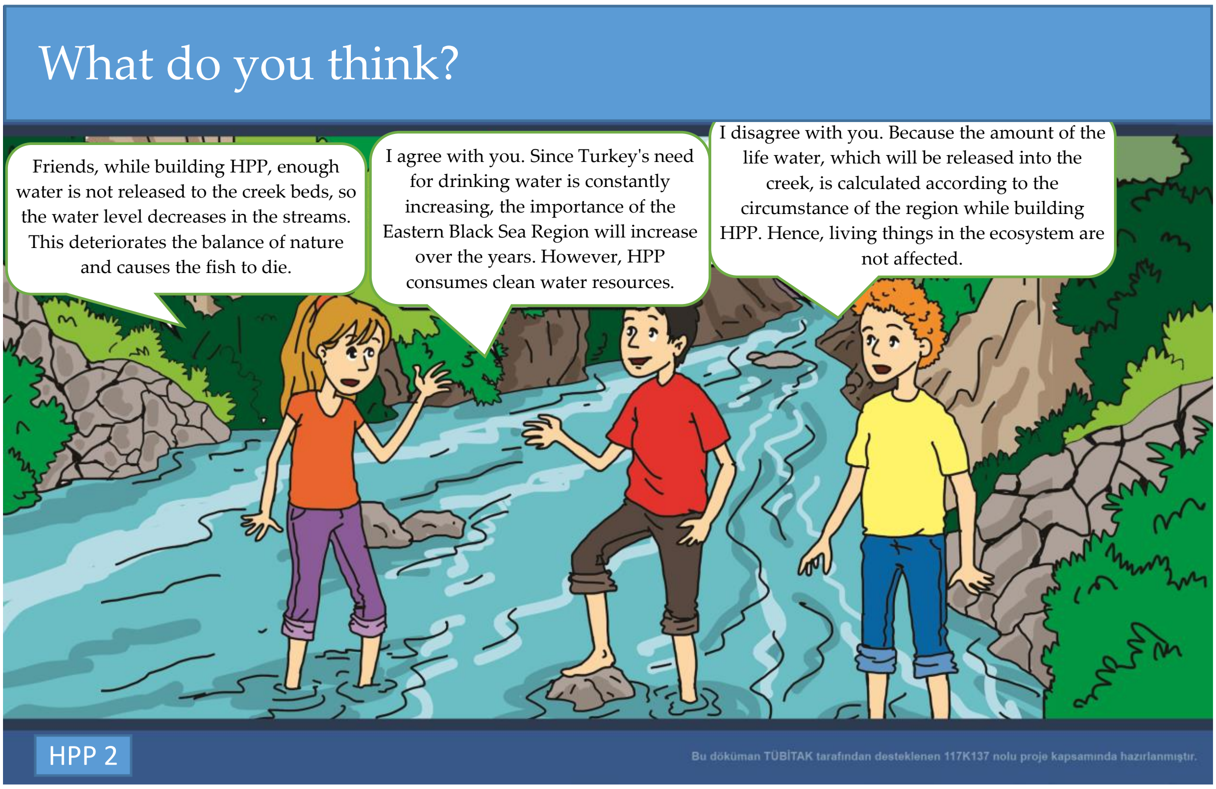


Figure 7. The Revised Version of the Problem Statement Dimension of the Second Concept Cartoon on the 'HPP' SSI

The Third Stage (Implementation and Evaluation)

In the implementation and evaluation stage, which is the third stage of the study, the response to the following research question was sought: "How do the prepared CCSSI reflect on SAC students' dialogic discussion levels?" To this end, the results obtained from the in-class CCSSI related dialogic discussions are presented in Table 6.

Table 6. Dialogic Observation Results for In-Class Implementations

	Authority	Questions	Feedback	Meta-level reflection	Explanation	Collaboration
GMO	SD	M	SD	SD	D	SD
CL	M	SD	SD	SD	SD	M
AMT	SD	D	D	D	D	SD
GRP	SD	D	SD	D	D	D
XR	SD	M	SD	SD	SD	SD
NE	SD	D	SD	SD	SD	SD
MV	SD	SD	SD	SD	SD	SD
SP	SD	D	D	D	D	SD
HPP	SD	M	SD	SD	M	SD
GW	SD	M	SD	SD	SD	SD
MN	D	M	SD	D	SD	SD

M: Monologic, SD: Semi-Dialogic, D: Dialogic
AMT: Alternative Medical Treatment, CL: Cloning, EA: Experimental Animals, GN: Genetic, GMO: Genetically Modified Organisms, GW: Global Warming, GRP: Green Road Project Interlinking Highlands, HPP: Hydroelectric Power Plants, LF: Landfill, MV: Mass Vaccination, MN: Mining, NE: Nuclear Energy, OF: Organic Farming, RS: Road Salting; SP: Space Pollution, SC: Stem Cell, TT: Tattooing, XR: X-ray.

The findings obtained from the in-class CCSSI observations in relation to the dialogic discussion levels based on the indicators are displayed in Figure 8.

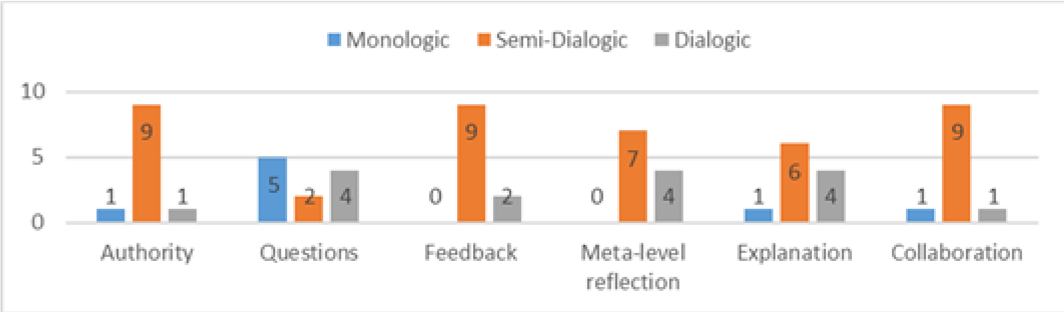


Figure 8. Teachers' Dialogic Discussion Levels Based on the Observation Form Indicators

Table 6 and Figure 8 show that in all dimensions, the arguments are performed at a maximum semi-dialogic level. In the meta-level reflection and explanation dimensions of the questions, dialogic arguments were performed to a significant degree. Discussions on the 'alternative medical treatment, GRP, nuclear energy, mass vaccination and space pollution' SSI were semi dialogic or dialogic in all dimensions.

There were differences based on the SSI type regarding the six different dimensions of the dialogic observation form: authority, questions, feedback, meta-level reflection, explanation, and collaboration. For example, in the authority dimension in the semi-dialogic discussion, the teacher asked questions in a sequence. Moreover, instead of letting students discover some conditions themselves, the teacher explained them. The teacher wrote the list of the effects of GMO foods on the board and asked students to hold a discussion on these effects. Receiving responses from students was sufficient for the teacher. The discussion was not directed by student responses.

The discussion on the 'GRP' SSI in the dimension of questions was dialogic. Here, the questions of the teacher were thought provoking for the students. These questions enabled the students to express their opinions freely and thus generate different solutions. In addition, it was observed that in some situations, students expressed their views by analyzing opinions different from those of their own.

The discussions in the feedback dimension were either semi-dialogic or dialogic. For example, in the 'x-rays' SSI, the teacher carefully listened to the students' responses, but did not intervene in any way in using student responses to help students develop their discussions or research. The teacher was more interested in the accuracy of the responses rather than the discussion process. As such, the teacher was unable to use student responses for discussions and thus led a semi-dialogic discussion.

In a dialogic discussion in the dimension of meta-level reflection related to the issue of love, based on the students' responses, the teacher helped students to develop their peers' views. Moreover, an environment where the given responses creates different views in the minds of students was established.

One of the seldom occurring monologic discussions was held in the explanations dimension of the 'HPP' SSI. Here, the students could not explain their views with sufficient arguments. Moreover, it was observed that they did not have opinions on the related topic. For this reason, they gave short answers to the questions asked by the teacher and did not provide supporting information to their responses.

Mostly semi-dialogic discussions were held in the dimension of collaboration. For example, after a student expressed a view or example on the 'space pollution' SSI, another student expressed a similar view or example. This did not produce an environment for discussion; rather, it was just opinions produced by students to support each other. The students found it difficult to develop unique arguments in relation to their peers' views. Furthermore, the students could not generate counter arguments to refute their peers' arguments.

Discussion and Conclusion

It was found that the students and parents chose the combined patterns of health, economic and ecological reasoning modes while making decisions about SSI. This may stem from the dominant modes in the related SSI. For instance, the economic and ecological modes are dominant in the 'road salting' SSI, while the health mode is at the forefront in the 'alternative medical treatment' SSI. Moreover, the fact that the students and parents preferred social and ethical reasoning modes may come from the effects of such factors as perceptual selectivity and worldview on individual differences or views (Cobern, 1996). Similarly, their positive or negative decisions related to these modes can be accepted as the indicator of the students' and parents' perspectives toward the SSI. For example, while the students and parents tended to express negative views regarding such SSI as x-rays, nuclear energy, mining, and global warming, they possessed opposing views on the 'experimental animals, organic farming and cloning' SSI. This could result from prioritizing emotional decisions instead of rational reasoning in relation to the SSI (Demir & Namdar, 2021). For instance, while the parents found the SSI 'experimental animals' positive in terms of health and negative in terms of ethics, the students handled it only from the ecological perspective and expressed negative views. The students may have emotionally developed empathy with the experimental animals. Also, the parents may have tried to holistically handle the relevant SSI through its positive and negative aspects. In other words, even if the same issue or event is addressed, the emergence of different modes on SSI can be seen as the requirement of the nature of SSI, which is open-ended, complex and multi-dimensional (Kolsto, 2001; Sadler, 2004; Sadler & Donnelly, 2006).

The teachers and experts under investigation stated that the SSI made contributions to science education in terms of three main areas (social, educational and scientific). This may result from the nature of SSI, which includes the social and scientific dimensions (Kolsto, 2001; Sadler, 2004; Sadler & Donnelly, 2006). Likewise, given the specific goal of the 2018 Science Course Curriculum, which is to "develop reasoning skills, scientific habits of mind and decision making skills by using SSI" (MoNE, 2018), their views of the educational contribution of SSI are also an expected outcome. In addition, because having an active role in decision making processes about SSI is considered as a citizenship responsibility (Aikenhead, 1985; Barrue & Albe, 2013; Kolsto, 2001), the idea "education is important in training responsible citizens" could have explicitly appeared the educational contribution. For instance, the use of SSI in science lessons as a tool to develop scientific literacy and responsible citizenship can be viewed as the indicator of the foregoing argument (Çalık & Wiyarsi, 2021; Topcu et al., 2014).

The SSI 'GMO, nuclear energy, HPP and space pollution' were found to be appropriate for both middle and high school students. This may come from the fact that the experts and teachers viewed these SSI as appropriate for the students' preparedness levels. In other words, they may have thought that middle and high school students have common competencies of reasoning or decision making about SSI. On the other hand, the differentiation of the other SSI for middle school (e.g., mass vaccination, GRP, landfill, and organic farming) and high school students (e.g. genetic/cloning, and alternative medical treatment) may stem from the idea that sufficient content knowledge is needed for the reasoning or decision making processes (Demiral & Türkmenoğlu, 2018; Jho, Yoon, & Kim, 2014). Moreover, the different topics, scope and learning outcomes of the 2018 Science Course Curriculum and the 2018 High School Physics, Chemistry and Biology curricula may have led the experts to choose different SSI for middle and high schools. The idea that lack of content knowledge or having superficial content knowledge directs students to make emotional or intuitive decisions rather than rational ones (Fang et al., 2019) may have influenced their preferences. In other words, the idea that the relevant topics and concepts need to be conceptually known for running rational reasoning and decision making processes may have influenced the experts' choices of the SSI for middle and high school students.

Regarding only the health informal reasoning mode for the 'x-ray' SSI as discussable may result from the fact that the x-ray is initially related to health and is frequently encountered in the daily health system. Hence, the dominance of the health mode in the 'x-ray' SSI may have prevented coming to the forefront of the other informal reasoning modes. The combination of several dominant informal reasoning modes for the 'HPP and stem cell' SSI can be interpreted with the nature of the SSI appearing different modes. For example, the 'HPP' SSI dominantly yielded to economic, ecological, law and social modes as discussible, whilst health, economic, ethical/moral and law modes appeared more dominant in the 'stem cell' SSI. In other words, it is thought that different content or features of the SSI differentiate the informal reasoning modes that may include or are worthy to argue (Wiyarsi & Çalik, 2019). The fact that the other SSI contained two or three discussable informal reasoning modes may result from the participants' features of perceptual selectivity. For example, even though the SSI 'x-rays, alternative medical treatment, mass vaccination, stem cell, and genetic/cloning' are directly health related-SSI, the participants depicted the different number of discussable modes. This can be seen as a clear indicator of the aforementioned argument.

In terms of the structural features of CCSSI and argumentation properties in SSI, the scores were higher than median value. Especially, in the scope of the framework plan, it is thought that aiming to develop concept cartoons different from the present materials and preferring visuals that could attract the students' attention increased the quality of the *attractiveness* and *visual design* dimensions. The scores in the *organization* and *argumentation* dimensions are believed to have stemmed from the formal consistency of the concept cartoons and the recommendations related to the argumentation components in the dialogues. The scores in the *problem presentation* and *relevance of dialogues with the SSI* dimensions reveal that the problem statement in mutual dialogues in concept cartoons should be more apparent, and rational dialogic associations should be made. The scores from the CCSSI rubric indicate that the framework plan is overall functional and concept cartoons need some improvements.

In-class dialogic discussions were highly performed in a semi-dialogic way in all dimensions. This may stem from semi-dialogic discussions, which is a transitional form between monologic and dialogic discussions. Even though dialogic discussions were expected in in-class practices, the teachers' previous habits of monologic discussion may have resulted in this issue. In other words, the fact that the teachers tried to establish a balance between their preferences of monologic and dialogic discussions may have increased the number of semi-dialogic discussions (Scott, Mortimer, & Aguiar, 2006). The fact that the dialogic dimensions particularly appeared in the 'alternative medical treatment, green road project interlinking highlands, and space pollution' SSI may come from the currentity of these SSI. That is, the students seem to have developed sufficient arguments or possessed sufficient content knowledge or conceptual understanding in depth for these SSI. Hence, it can be inferred that having proper content knowledge about the SSI shapes the dialogues in discussions. Moreover, the fact that the dialogic discussions were mostly encountered in the dimensions of *questions, meta-level reflection* and *explanation* may result from the questions encouraging the students to think, making them feel that their in-class discussions or views are important, and enabling them to establish different intellectual connections between their views. Phrased differently, supporting the students' views during in-class practices and directing the discussion by linking their views may have resulted in the appearance of dialogic discussions in these dimensions. However, a high number of monologic discussions in the *questions* dimension may stem from the teachers' in-class questions, which did not foster the students to think about the SSI, or the students' inability to express themselves freely to produce different solutions by depending on the content of the SSI. This may also come from the fact that asking higher order questions is an indicator of the depth of content knowledge (Newton & Newton, 2001). Therefore, using or asking dialogical questions, which will enable students to think, necessitates a specific kind of pedagogical content knowledge. Hence, the teachers' deficiencies of pedagogical content knowledge might be the reason for the monologic discussions in the *questions* dimension (Chen & Xiao, 2021; Tidemand & Nielsen, 2017). Similarly, the students' limited understanding of the underlying concepts concerning the 'HPP' SSI or their limited experiences with the HPP may have restricted them to develop sufficient arguments in the *explanation* dimension and explain what they thought (Table 6). Moreover, the fact that the *collaboration* dimension included mostly semi-dialogic discussions may result from the students' difficulties in developing original arguments associated with their peers' views or their inability to produce counter arguments. This may stem from the students' preferences that support their own peers' arguments rather than refuting them. Further, this may come from the fact that generating counter arguments necessitates multi-dimensional thinking and knowing about alternative viewpoints.

Suggestions

The present study took into consideration the informal reasoning of SSI of the middle and high school students enrolled in SAC and their parents for the framework plan, which was followed to develop the CCSSI. Because the similarities and differences between their reasoning about the SSI are integrated into the framework plan, it is suggested that the CCSSI, which were developed on the basis of this framework plan, can be implemented to individuals with different ages and talents/abilities. Hence, given the foregoing discussion and conclusions, the current study recommends that the framework plan be utilized in other disciplines and other grades.

Since the present study developed the concept cartoons based on the experts' and teachers' ideas and in accordance with the framework plan, future studies should ask students to generate their own concept cartoons within the scope of the same framework plan. Moreover, students-generated CCSSI can be exhibited at the end of schooling term at their schools by organizing science festivals. Also, they can be evaluated via rubrics and rewarded. It is recommended to devise CCSSI for particularly such current societal issues as the Covid-19 pandemic and the Covid-19 vaccination, which are important to stimulate students' awareness of SSI.

The number of best practices enriching and improving dialogic discussions through in-class implementations ought to be increased. Because dialogic environments are effective in enabling students to explain their own concepts, become aware of what they know, become informed about others' ideas and thus make their own decisions, argumentation-based implementations should be conducted for different science topics.

Considering the result that teachers' content knowledge and pedagogical content knowledge are important for in-class practices, future studies should unveil teachers' knowledge of SSI. Moreover, further research can be carried out to examine the effects of in-class dialogic implementations of the present CCSSI on teachers' content knowledge, professional development, and pedagogical content knowledge.

Acknowledgement

This study was funded by The Scientific and Technological Research Council of Turkey (Grant Number: 117K137). The authors would like to thank the entire project team.

References

21st Century Science Project Team. (2003). 21st century science—A new flexible model for GCSE science. *School Science Review, 85*(310), 27-34.

American Association for the Advancement of Science. (1989). Project 2061-Science for all Americans. Washington, DC: AAAS.

Agell, L., Soria, V., & Carrió, M. (2015). Using role-play to debate animal testing. *Journal of Biological Education, 49*(3), 309-321.

Aikenhead, G. S. (1985). Collective decision making in the social context of science. *Science Education, 69*(4), 453-475. doi:10.1002/sce.3730690403

Akpınar, E. (2005). Nehir tipi santrallerin Türkiye'nin hidroelektrik üretimindeki yeri. *Erzincan Eğitim Fakültesi Dergisi, 7*(2), 1-25.

Aksungur, M., Ak, O., & Özdemir, A. (2011). Nehir tipi hidroelektrik santrallerinin sucul ekosisteme etkisi: Trabzon örneği. *Journal of Fisheries Sciences, 5*(1), 79-92.

Al, S. (2015). *Pre-servıice science teachers' perceptions of socioscientific issues: Global warming as a case* (Unpublished master's thesis). Middle East Technical University, Ankara.

Albe, V. (2008). When scientific knowledge, daily life experience, epistemological and social considerations intersect: Students' argumentation in group discussion on a socio-scientific issue. *Research in Science Education, 38*, 67-90.

Aldoobie, N. (2015). ADDIE model. *American International Journal of Contemporary Research, 5*(6), 68-72.

Atasoy, Ş. (2017). Kavram karikatürü. In Z. Tatlı (Ed.), *Kavram öğretiminde Web 2.0* (pp. 95-118). Ankara: Pegem A Yayıncılık.

Atasoy, Ş. (2018). Öğretmen adaylarının yaşam alanlarına göre yerel sosyobilimsel konularla ilgili informal muhakemeleri. *Fen Bilimleri Öğretimi Dergisi, 6*(1), 60-72.

Atasoy, Ş. (2020). Using concept cartoons to identify the epistemological beliefs of middle school students. *Journal of Science Learning, 3*(3), 165-173.

Atasoy, Ş., & Ergin, S. (2017). The effect of concept cartoon-embedded worksheets on grade 9 students' conceptual understanding of Newton's Laws of Motion. *Research in Science & Technological Education*, *35*(1), 58-73. doi:10.1080/02635143.2016.1248926

Atasoy, Ş., & Yüca, O. Ş. (2021). Yerel sosyobilimsel konularda kavram karikatürleri aracılığıyla sekizinci sınıf öğrencilerinin argüman kalitelerinin geliştirilmesi. *Fen Bilimleri Öğretimi Dergisi, 9*(2), 361-388.

Atasoy, Ş., & Zoroğlu, M. A. (2014). Okul öncesi dönemdeki çocuklara yönelik kavram karikatürlerinin geliştirilmesi ve uygulanması. *e-Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi, 8*(2), 38-70. doi:10.17522/nefefmed.42580

Atasoy, Ş., Eryılmaz Toksoy, S., & Çalık, M. (2020). Identifying pre-service teachers' initial impressions of theconcept cartoons in the school corridors and informal physics learning. *Journal of Baltic Science Education, 19*(1), 25-35. doi:10.33225/jbse/20.19.25

Atasoy, Ş., Tekbıyık, A., & Gülay, A. (2013). Beşinci sınıf öğrencilerinin ses kavramını anlamaları üzerine kavram karikatürlerinin etkisi. *Türk Fen Eğitim Dergisi, 10*(1), 176-196.

Atasoy, Ş., Tekbıyık, A., & Yüca, O. Ş. (2019). Karadeniz Bölgesi'ndeki bazı yerel sosyobilimsel konularda öğrencilerin informal muhakemelerinin belirlenmesi: HES, Organik Çay ve Yeşil Yol Projesi. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 34*(2), 524-540. doi:10.16986/HUJE.2018045573

Aydeniz, M., & Gürçay, D. (2013). Assessing quality of pre-service physics teachers' written arguments. *Research in Science & Technological Education, 31*(3), 269-287.

Aydın, G. (2015). The effects of computer-aided concept cartoons and outdoor science activities on light pollution. *International Electronic Journal of Elementary Education, 7*(2), 143-156.

Bağ, H., & Çalık, M. (2017). A thematic review of argumentation studies at the K-8 level. *Education & Science*, *42*(190), 281-303.

Balas, A., & Hariharan, J. (1998). *Cloning: What are their attitudes? A report on the general attitudes of a sample of midwestern citizens*. The Annual Meeting of the National Association for Research in Science Teaching (NARST), The Ohio State University, California.

Balım, A. G., Deniş Çeliker, H., Türkoğuz, S., Evrekli, E., & İnel Ekici, D. (2015). Kavram karikatürleri destekli probleme dayalı öğrenme yönteminin öğrencilerin kavramsal anlama düzeyleri ile problem çözme becerisi algıları üzerine etkisi. *Türk Fen Eğitimi Dergisi, 12*(4), 53-76.

Balım, A. G., İnel, D., & Evrekli, E. (2008). The effects the using of concept cartoons in science education on students' academic achievements and enquiry learning skill perceptions. *İköğretim Online, 7*(1), 188-202.

Balım, A. G., İnel-Ekici, D., & Özcan, E. (2016). Concept cartoons supported problem based learning method in middle school science classrooms. *Journal of Education and Learning, 5*(2), 272-284.

Balım, A. G., Ormancı, Ü., Evrekli, E., Kaçar, S., & Türkoğuz, S. (2016). Fen derslerinde kavram karikatürü kullanım örnekleri ve öğrenci-öğretmen görüşleri. *Abant İzzet Baysal Üniversitesi Eğitim Fakültesi Dergisi, 16*(3), 773-791.

Balim, A. G., Turkoguz, S., Ormanci, U., Kacar, S., Evrekli, E., & Ozcan, E. (2014). Teachers' views about problem-based learning through concept cartoons. *Journal of Baltic Science Education, 13*(4), 458-468.

Barrue, C., & Albe, V. (2013). Citizenship education and socioscientific issues: Implicit concept of citizenship in the curriculum, views of French middle school teachers. *Science & Education*, *22*(5), 1089-1114.

Baynazoğlu, L., & Atasoy, E. (2020). Türkiye'de kavram karikatürleriyle ilgili yapılan araştırmalara yönelik bir meta-sentez çalışması. *Cumhuriyet International Journal of Education*, *9*(2), 390-409. doi:10.30703/cije.597030

Brooks, K., & Lusk, J. (2011). U.S. consumers attitudes toward farm animal cloning. *Appetite, 57*(2), 483-492.

Büyüköztürk, Ş., Kılıç Çakmak, E., Akgün, Ö. E., Karadeniz, Ş., & Demirel, F. (2019). *Eğitimde bilimsel araştırma yöntemleri* (27th ed.). Ankara: Pegem Akademi Yayıncılık.

Byrne, J., Ideland, M., Malmberg, C., & Grace, M. (2014). Climate change and everyday life: Repertoires children use to negotiate a socio-scientific issue. *International Journal of Science Education, 36*(9), 1491-1509. doi:10.1080/09500693.2014.891159

Cavagnetto, A., & Hand, B. (2012). The importance of embedding argument within science classrooms. In M. S. Khine (Ed.), *Perspectives on scientific argumentation: Theory, practice and research* (pp. 39-53). Dordrecht: Springer. doi:10.1007/978-94-007-2470-9_3

Chabalengula, V., Mumba, F., & Chitiyo, J. (2011). Elementary education preservice teachers' understanding of biotechnology and ıts related processes. *Biochemistry and Molecular Biology Education, 39*(4), 321-325.

Chang, H. Y., Liang, J. C., & Tsai, C. C. (2020). Students' context-specific epistemic justifications, prior knowledge, engagement, and socioscientific reasoning in a mobile augmented reality learning environment. *Journal of Science and Educational Technology*, *29,* 399-408.

Chang, S. N., & Chiu, M. H. (2008). Lakatos' scientific research programmers as a framework for analysing informal argumentation about socio-scientific issues. *International Journal of Science Education, 30*(13), 1753-1773.

Chen, L., & Xiao, S. (2021). Perceptions, challenges and coping strategies of science teachers in teaching socioscientific issues: A systematic review. *Educational Research Review, 32*, 100377 doi:10.1016/j.edurev.2020.100377

Chin, C., & Teou, L.-Y. (2009). Using concept cartoons in formative assessment: Scaffolding student' argumentation. *International Journal of Science Education, 31*(10), 1307-1332.

Chin, C., & Teou, L.-Y. (2010). Formative assessment: Using concept cartoon, pupils' drawings, and group discussions to tackle children's ideas about biological inheritance. *Journal of Biological Education, 44*(3), 108-115.

Cinar, D., & Bayraktar, S. (2014). Evaluation of the effects of argumentation based science teaching on 5 th grade students' conceptual understanding of the subjects related to "matter and change". *International Journal of Education in Mathematics, Science and Technology, 2*(1), 49-77.

Cobern, W. W. (1996). Worldview theory and conceptual change in science education. *Science Education, 80*(5), 579-610.

Concannon, J., Siegel, M., Halverson, K., & Frayermuth, S. (2009). College students' conceptions of stem cells, stem cell research, and cloning. *Journal of Science Education Technology*, *19*, 177-186.

Çalık, M., & Cobern, W. M. (2017). A cross-cultural study of CKCM efficacy in an undergraduate chemistry classroom. *Chemistry Education Research and Practice, 18*(4), 691-709. doi:10.1039/c7rp00016b

Çalık, M., & Wiyarsi, A. (2021). A systematic review of the research papers on chemistry-focused socio-scientific issues. *Journal of Baltic Science Education, 20*(3), 360-372. doi:10.33225/jbse/21.20.360

Çil, E. (2014). Teaching nature of science through conceptual change approach: Conceptual change texts and concept cartoons. *Journal of Baltic Science Education, 13*(3), 339-350.

Çil, E., & Çepni, S. (2016). The effectiveness of conceptual change texts and concept clipboards in learning the nature of science. *Research in Science & Technological Education, 34*(1), 43-68. doi:10.1080/02635143.2015.1066323

Çinici, A., Özden, M., Akgün, A., Herdem, K., Karabiber, L., & Deniz, M. (2014). Investigating the effectiveness of argumentation based activities supported with concept cartoon. *Adıyaman University Journal of Social Sciences Institute, 7*(18), 571-596.

Çoşkun, H. (2010). *Nehir tipi hidroelektrik santrallerinin Artvin'deki orman ekosistemlerinde neden olduğu arazi kullanım değişiminin ve arazi tahribatının belirlenmesi* (Unpublished master's thesis). Artvin Çoruh University, Artvin.

Dawson, V. (2007). An exploration of high school (12-17 year old) students' understanding of, and attitudes towards biotechnology process. *Research in Science Education, 37*(59), 59-73.

Dawson, V., & Carson, K. (2020). Introducing argumentation about climate change socioscientific issues in a disadvantaged school. *Research in Science Education, 50*(3), 863-883. doi:10.1007/s11165-018-9715-x

Dawson, V., & Schibeci, R. (2003). Western Australian high school students' attitudes towards biotechnology processes. *Journal of Biological Education, 38*(1), 7-12.

Dawson, V. M., & Venville, G. (2010). Teaching strategies for developing students' argumentation skills about socioscientific issues in high school genetics. *Research in Science Education, 40*, 133-148.

Demir, A., & Namdar, B. (2021). The effect of modeling activities on grade 5 students' informal reasoning about a real-life issue. *Research in Science Education, 51,* 429-442. doi:10.1007/s11165-019-09896-8

Demiral, Ü., & Türkmenoğlu, H. (2018). Fen bilgisi öğretmen adaylarının sosyobilimsel bir konuda karar verme stratejilerinin alan bilgileriyle ilişkisi. *Uludağ Üniversitesi Eğitim Fakültesi Dergisi, 31*(1), 309-340.

Ekici, F., Ekici, E., & Aydın, F. (2007). Utility of concept cartoons in diagnosing and overcoming misconceptions related to photosynthesis. *International Journal of Environmental & Science Education, 2*(4), 111-124.

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's Argument Pattern for studying science discourse. *Science Education, 88*(6), 915-933.

Eş, H., Işık Mercan, S., & Ayas, C. (2016). Türkiye için yeni bir sosyobilimsel tartışma: Nükleer ile yaşam. *Turkish Journal of Education*, *5*(2), 47-59.

Evren Yapıcıoğlu, A., & Kaptan, F. (2017). A mixed method research study on the effectiveness of socioscientific issue-based instruction. *Education and Science, 42*(192), 113-137.

Fang, S. C., Hsu, Y. S., & Lin, S. S. (2019). Conceptualizing socioscientific decision making from a review of research in science education. *International Journal of Science and Mathematics Education,* 17, 427-448. doi:10.1007/s10763-018-9890-2

Friedrichsen, P. J., Ke, L., Sadler, T. D., & Zangori, L. (2021). Enacting co-designed socio-scientific issues-based curriculum units: A case of secondary science teacher learning. *Journal of Science Teacher Education, 32*(1), 85-106. doi:10.1080/1046560X.2020.1795576

Ghosh, S. (2011). Participation in the green power partnership: An analysis of higher education institutions as partners in the program. *International Journal of Sustainability in Higher Education, 12*(4), 306-321. doi:10.1108/14676371111168241

Gottweis, H. (2002). Gene therapy and the public: A matter of trust. *Gene Therapy, 9*(11), 667-669. doi:10.1038/sj.gt.3301752

Gürkan, G. (2013). *Fen bilgisi öğretmen adayları ve öğretmenlerinin biyoteknoloji ve genetik mühendisliği bilgi düzeylerinin çeşitli değişkenler açısından karşılaştırılması* (Unpublished master's thesis). İnönü University, Malatya.

Herman, B. C., Zeidler, D. L., & Newton, M. (2020). Students' emotive reasoning through place-based environmental socioscientific issues. *Research in Science Education, 50*, 2081-2109. doi:10.1007/s11165-018-9764-1

Hornstra, L., Bakx, A., Mathijssen, S., & Denissen, J. J. A. (2020). Motivating gifted and non-gifted students in regular primary schools: A self-determination perspective. *Learning and Individual Differences, 80,* 101871.

İnel, D., & Balım, A. G. (2013). Concept cartoons assisted problem based learning method in science and technology teaching and students' views. *Procedia-Social and Behavioral Sciences, 93,* 376-380.

İşbilir, M. (2010). *Investigating pre-servıce science teachers' quality of written argumentations about socio-scientific issues in relation to epistemic beliefs and argumentativeness* (Unpublished master's thesis). Middle East Technical University, Ankara.

Jho, H., Yoon, H. G., & Kim, M. (2014). The relationship of science knowledge, attitude and decision making on socio-scientific issues: The case study of students' debates on a nuclear power plant in Korea. *Science &Education*, *23*(5), 1131-1151.

Jimenez-Aleixandre, M. P., Rodriguez, A. B., & Duschl, R. A. (2000). Doing the lesson'' or ''doing science'': Argument in high school genetics. *Science Education*, *84*(6), 757-792.

Kabapınar, F. (2005). Effectiveness of teaching via concept cartoons from the point of view of constructivist approach. *Educational Sciences: Theory & Practice, 5*(1), 101-146.

Kabapınar, F. (2009). What makes concept cartoons more effective? Using research to inform practice. *Education and Science, 34*(154), 104-118.

Kaçar, S., Ormanci, Ü., Özcan, E., & Balim, A. G. (2020). Concept cartoon samples integrated into problem based learning in a science course. *Journal of Inquiry Based Activities, 10*(2), 127-145.

Karadeniz, V., Akpınar, E., & Başıbüyük, A. (2011). Nehir tipi hidroelektrik santraller ve çevresel etkileri (Reşadiye Hidroelektrik Santralleri örneği). *Doğu Coğrafya Dergisi, 16*(26), 95-114.

Keogh, B., & Naylor, S. (1999). Concept cartoons, teaching and learning in science: An evaluation. *International Journal of Science Education, 21*(4), 431-446.

Khishfe, R. (2014). Explicit nature of science and argumentation instruction in the context of socioscientific issues: An effect on student learning and transfer. *International Journal of Science Education*, *36*(6), 974-1016.

Khishfe, R., Alshaya, F. S., Boujaoude, S., Mansour, N., & Alrudiyan, K. (2017). Students' understandings of nature of science and their arguments in the context of four socio-scientific issues. *International Journal of Science Education, 39*(3), 299-334. doi:10.1080/09500693.2017.1280741

Kılınç, A., Boyes, E., & Stanisstreet, M. (2013). Exploring students' ideas about risks and benefits of nuclear power using risk perception theories. *Journal of Science Education and Technology*, *22*(3), 252-266.

Kim, G., Ko, Y., & Lee, H. (2020). The effects of community-based socioscientific issues program (SSI-COMM) on promoting students' sense of place and character as citizens. *International Journal of Science and Mathematics Education, 18,* 399-418. doi:10.1007/s10763-019-09976-1

Kinchin, I. (2004). Investigating students' beliefs about their preferred role as learners. *Educational Research, 46*(3), 301-312. doi:10.1080/001318804200277359

Kolsto, S. D. (2001). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial SSI. *Science Education, 85*(3), 291-310.

Koralay, N. (2015). *Solaklı Deresi Havzası'nda nehir tipi hidroelektrik santrallerin su kalitesine etkileri* (Unpublished master's thesis). Karadeniz Teknik University, Trabzon.

Kortland, K. (1996). An STS scenario study about students' decision-making on the waste issue. *Science Education, 80*(6), 673-689.

Ladachart, L., & Ladachart, L. (2021). Preservice biology teachers' decision-making and informal reasoning about culture-based socioscientific issues. *International Journal of Science Education*, *43*(5), 641-671. doi:10.1080/09500693.2021.1876958

Lee, G.-G., Jeon, Y.-E., & Hong, H.-G. (2021). The effects of cooperative flipped learning on science achievement and motivation in high school students. *International Journal of Science Education, 43*(9), 1381-1407. doi:10.1080/09500693.2021.1917788

Lee, L. E., Meyer, M. S., & Crutchfield, K. (2021). Gifted classroom environments and the creative process: A systematic review. *Journal for the Education of the Gifted, 44*(2), 107-148.

Lee, Y. C. (2012). Socio-scientific issues in health contexts: Treading a rugged terrain. *International Journal of Science Education, 34*(3), 459-483. doi:10.1080/09500693.2011.613417

Lee, Y. C., & Grace, M. (2012). Students' reasoning and decision making about a socioscientific issue: A cross-context comparison. *Science Education, 96*(5), 787-807.

Leung, J. S. C. (2022). A practice-based approach to learning nature of science through socioscientific issues. *Research in Science Education, 52,* 259-285. doi:10.1007/s11165-020-09942-w

Leung, J. S. C., & Cheng, M. M. W. (2020). Conceptual change in socioscientific issues: Learning about obesity. *International Journal of Science Education, 42*(18), 3134-3158. doi:10.1080/09500693.2020.1856966

Lewis, J., & Leach, J. (2006). Discussion of socio-scientific issues: The role of science knowledge. *International Journal of Science Education*, *28*(11), 1267-1287.

Li, Y., & Migliaccio, K. (2011). *Water quality concepts, sampling and analyses*. ABD: CRC Press.

Lo, C. O., Porath, M., Yu, H., Chen, C., Tsai, K., & Wu, I. (2019). Giftedness in the making: A transactional perspective. *Gifted Child Quarterly, 63*(3), 172-184.

Lpf 94. (1994). *Curriculum for the non-compulsory school system, Lpf 94*. İsveç: Skolverket.

Lundström, M., Ekborg, M., & Ideland, M. (2012). To vaccinate or not to vaccinate: How teenagers justified their decision. *Cultural Studies of Science Education*, 7, 193-221.

Marım, G., & Güler, I. (2009). *Hidroelektrik santraller; Enerji ve su hakkı*. TMMOB VII. Enerji Sempozyumu, Ankara. Retrieved from https://www.emo.org.tr/ekler/4ac36697fc51169_ek.pdf

Minárechová, M. (2016). Using a concept cartoon method to address elementary school students' ideas about natural phenomena. *European Journal of Science and Mathematics Education, 4*(2), 214-228.

Ministry of Education. (1998). *1-9 grades curriculum guidelines.* Taipei: Ministry of Education.

Ministry of National Education. (2018). *2018 fen bilimleri dersi öğretim programı (ilkokul ve ortaokul 3, 4, 5, 6, 7 ve 8. sınıflar).* Ankara: Temel Eğitim Genel Müdürlüğü.

Morin, O., Tytler, R., Barraza, L., Simonneaux, L., & Simonneaux, J. (2013). Cross cultural exchange to support reasoning about socio-scientific sustainability issues. *Teaching Science*, *59*(1), 16-22.

Morris, M., Merritt, M., Fairclough, S., Birrell, N., & Howitt, C. (2007). Trialling concept cartoons in early childhood teaching and learning of science. *Teaching Science, 53*(2), 42-45.

National Research Council. (1996). *National science education standards.* Washington, DC: National Academy Press.

Naylor, S., & Keogh, B. (1999a). Constructivism in classroom: Theory into practice. *Journal of Science Teacher Education, 10*(2), 93-106.

Naylor, S., & Keogh, B. (1999b). Science on the underground: An initial evaluation. *Public Understanding of Science, 8*(2), 105-122.

Naylor, S., & Keogh, B. (2000). *Concept Cartoons in Science Education (the ConCISE Project).* Sandbach, Cheshire: Millgate House.

Naylor, S., & Keogh, B. (2013). Concept cartoons: What have we learnt?. *Journal of Turkish Science Education, 10*(1), 3-11.

Naylor, S., Keogh, B., & Downing, B. (2007). Argumentation and primary science. *Research in Science Education*, 37, 17-39.

Newton, D. P., & Newton, L. D. (2001). Subject content knowledge and teacher talk in the primary science classroom. *European Journal of Teacher Education, 24*(3), 369-379. doi:10.1080/02619760220128914

Newton, P., Driver, R., & Osborne, J. (1999). The place of argumentation in the pedagogy of school science. *International Journal of Science Education, 2*(5), 553-576. doi:10.1080/095006999290570

Nida, S., Mustikasari, V. R., & Eilks, I. (2021). Indonesian pre-service science teachers' views on socio-scientific issues-based science learning. *EURASIA Journal of Mathematics, Science and Technology Education, 17*(1), em1932.

Oluk, S., & Özalp, I. (2007). The teaching of global environmental problems according to the constructivist approach: As a focal point of the problem and the availability of concept cartoons. *Educational Sciences: Theory and Practice, 7*(2), 881-896.

Ormancı, Ü., & Şaşmaz-Ören, F. (2011). Assessment of concept cartoons: An exemplary study on scoring. *Procedia-Social and Behavioral Sciences*, *15,* 3582-3589.

Ozdemir, E., Coramik, M., & Urek, H. (2020). Determination of conceptual understanding levels related to optics concepts: The case of opticianry. *International Journal of Education in Mathematics, Science and Technology, 8*(1), 53-64.

Ozturk, N., & Yilmaz-Tuzun, O. (2017). Preservice science teachers' epistemological beliefs and informal reasoning regarding socioscientific issues. *Research in Science Education, 47*(6), 1275-1304.

Öztürk, A. (2017). An investigation of prospective science teachers' socio-scientific argumentation processes in terms of metacognition: A causal-comparative study. *Pegem Eğitim ve Öğretim Dergisi, 7*(4), 547-582.

Öztürk, S., & Leblebicioğlu, G. (2015). Sosyobilimsel bir konu olan hidroelektrik santraller (HES) hakkında karar verilirken kullanılan irdeleme şekillerinin incelenmesi. *Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi, 9*(2), 1-33.

Park, O., & Oliver, S. (2009). The translation of teachers' understanding of gifted students into instructional strategies for teaching science. *Journal of Science Teacher Education, 20*(4), 333-351.

Park, S., Park, K., & Choe, H. (2005). The relationship between thinking styles and scientific giftedness inKorea. *The Journal of Secondary Gifted Education, 16*(2-3), 87-97.

Pekel, F. O. (2019). Effectiveness of argumentation-based concept cartoons on teaching global warming, ozone layer depletion, and acid rain. *Journal of Environmental Protection and Ecology, 20*(2), 945-953.

Pezaro, C., Wright, T., & Gillies, R. (2013). Pre-service primary teachers' argumentation in socioscientific issues. Proceedings of the frontiers. In *Mathematics and Science Education Research Conference* (pp. 58-69). North Cyprus: Famagusta.

Quinn, F., Taylor, N., Coll, R. K., & McClune, W. (2016). Investigating views of science- and humanities-tertiary educated adults on complementary and alternative medicines. *The International Journal of Science in Society, 8*(3), 31-50.

Reznitskaya, A. (2012). Dialogic teaching: Rethinking language use during literature discussions. *The Reading Teacher, 65*(7), 446-456.

Richey, R. C., & Klein, J. D. (2005). Developmental research methods: Creating knowledge from instructional design and development practice. *Journal of Computing in Higher Education, 16*(2), 23-38.

Richey, R. C., Klein, J. D., & Nelson, W. (2004). Developmental research: Studies of instructional design and development. In D. Jonassen (Ed.), *Handbook of research for educational communications and technology* (2nd ed., pp. 1099-1130). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

Robillard, J., Roskams-Edris, D., Kuzeljevic, B., & Illes, J. (2014). Prevailing public perceptions of the ethics of gene therapy. *Human Gene Therapy, 25*(8), 1-7. Retrieved from https://www.researchgate.net/publication/261953214

Rudsberg, K., Öhman, J., & Östman, L. (2013). Analyzing students' learning in classroom discussions about socioscientific issues. *Science Education, 97*(4), 594-620.

Rule, A. C., & Montgomery, S. E. (2013). Using cartoons to teach about perfectionism: Supporting gifted students' social-emotional development. *Gifted Child Today, 36*(4), 254-262.

Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. *Journal of Research in Science Teaching, 41*(5), 513-536.

Sadler, T. D., & Donnelly, L. A. (2006). Socioscientific argumentation: The effects of content knowledge and morality. *International Journal of Science Education, 28*(12), 1463-1488.

Sadler, T. D., Barab, S. A., & Scott, B. (2007). What do students gain by engaging in socioscientific inquiry?. *Research in Science Education, 37*(4), 371-391.

Saher, M., & Lindeman, M. (2005). Alternative medicine: A psychological perspective. *Personality and Individual Differences, 39*(6), 1169-1178.

Sasmaz-Oren, F., & Meric, G. (2014). Seventh grade students' perceptions of using concept cartoons in science and technology course. *International Journal of Education in Mathematics, Science and Technology, 2*(2), 116-137.

Saylan, A. (2014). *Relationships among pre-service science teachers' epistemological beliefs, knowledge level and trustworthiness on information sources: Climate change, nuclear energy, and organ donation and transplantation* (Unpublished master's thesis). Middle East Technical University, Ankara.

Scott, P. H., Mortimer, E. F., & Aguiar, O. G. (2006). The tension between authoritative and dialogic discourse: A fundamental characteristic of meaning making interactions in high school science lessons. *Science Education, 90*(4), 605-631.

Serttaş, S., & Türkoğlu, A. Y. (2020). Diagnosing students' misconceptions of astronomy through concept cartoons. *Participatory Educational Research, 7*(2), 164-182.

Stenseth, T., Braten, I., & Stromso, H. (2016). Investigating interest and knowledge as predictors of students' attitudes towards socio-scientific issues. *Learning and Individual Differences, 47,* 274-280.

Stuckey, M., & Eilks, I. (2014). Increasing student motivation and the perception of chemistry's relevance in the classroom by learning about tattooing from a chemical and societal view. *Chemistry Education, Research and Practice, 15*, 156-167. doi:10.1039/C3RP00146F

Sürmeli, H., & Şahin, F. (2010). Üniversite öğrencilerinin biyoteknoloji çalışmalarına yönelik tutumları. *Eğitim ve Bilim*, *35*(155), 145-157.

Sürmeli, H., & Şahin, F. (2012). Preservice science teachers' opinions and ethical perceptions in relation to cloning studies. *C. U. Faculty of Education Journal, 41*(2), 76-86.

Şekkeli, M., & Keçecioğlu, Ö. F. (2011). Hidroelektrik santrallerin Türkiye'deki gelişimi ve Kahramanmaraş bölgesi örnek çalışması. *KSU Mühendislik Bilimleri Dergisi, 14*(2), 19-26.

Taşlıdere, E. (2013). The effect of concept cartoon worksheet on students' conceptual understanding of geometrical optics. *Education and Science, 38*(167), 144-161.

Tekbıyık, A. (2015). The use of jigsaw collaborative learning method in teaching socioscientific issues: The case of nuclear energy. *Journal of Baltic Science Education, 14*(2), 237-253.

Tidemand, S., & Nielsen, J. A. (2017). The role of socioscientific issues in biology teaching: From the perspective of teachers. *International Journal of Science Education, 39*(1), 44-61.

Topcu, M. S., Muğaloğlu, E. Z., & Güven, D. (2014). Socioscientific issues in science education: The case of Turkey. *Educational Sciences: Theory & Practice, 14*(6), 2340-2348.

Topcu, M. S., Sadler, T. D., & Yilmaz-Tuzun, O. (2010). Preservice science teachers' informal reasoning about socioscientific issues: The influence of issue context. International Journal of Science Education, 32(18), 2475-2495.

Topcu, M. S., Yilmaz-Tuzun, O., & Sadler, T. D. (2009). *Preservice science teachers' informal reasoning regarding socioscientific issues and the factors influencing their informal reasoning*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Garden Grove, CA.

Topçu, M. S. (2008). *Preservice science teachers' informal reasoning regarding socioscientific issues and the factors influencing their informal reasoning* (Unpublished doctoral dissertation). Middle East Technical University, Ankara.

Turhan, E. B., & Kılınç, A. (2021). The comparison of one monologic and one dialogic science teacher regarding conceptual teaching. *Journal of Uludağ University Faculty of Education, 34*(2), 624-657. doi:10.19171/uefad.801941

Türkoğuz, S., & Cin, M. (2013). Effects of argumentation based concept cartoon activities on students' conceptual understanding levels. *Journal of Buca Faculty of Education*, 35, 155-173.

Türkoğuz, S., & Cin, M. (2014). Effects of argumentation based concept cartoon activities on students' scientific process skills. *Mersin University Journal of the Faculty of Education, 10*(2), 142-156.

Uzoğlu, M., Yıldız, A., Demir, Y., & Büyükkasap, E. (2013). Fen bilgisi öğretmen adaylarının ışıkla ilgili kavram yanılgılarının belirlenmesinde kavram karikatürlerinin ve açık uçlu soruların etkililiklerinin karşılaştırılması. *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi, 14*(1), 367-388.

Ülger, B. B., & Çepni, S. (2020). Gifted education and STEM: A thematic review. *Journal of Turkish Science Education, 17*(3), 443-466.

Valero, E. (2012). Characterization of the water quality status on a stretch of river Lérez around a Small hydroelectric power station. *Water, 4*(4), 815-834.

van Gerven, E. (2021). Educational paradigm shifts and the effects on educating gifted students in the netherlands and flanders. *Journal for the Education of the Gifted, 44*(2), 171-200.

Vesterinen, V., Tolppanen, S., & Aksela, M. (2016). Toward citizenship science education: What students do to make the world a better place?. *International Journal of Science Education, 38*(1), 30-50. doi:10.1080/09500693.2015.1125035

Walker, K. A., & Zeidler, D. L. (2007). Promoting discourse about socio-scientific issues through scaffolded inquiry. *International Journal of Science Education, 29*(11), 1387-1410. doi:10.1080/09500690601068095

Webb, P., Williams, Y., & Meiring, L. (2008). Concept cartoons and writing frames: Developing argumentation in South African science classrooms?. *African Journal of Research in Mathematics, Science and Technology Education, 12*(1), 5-17.

Wiyarsi, A., & Çalik, M. (2019). Revisiting the scientific habits of mind scale for socio-scientific issues in the Indonesian context. *International Journal of Science Education, 41*(17), 2430-2447. doi:10.1080/09500693.2019.1683912

Wu, Y. T., & Tsai, C. C. (2007). High school students' informal reasoning on a socioscientific issue: Qualitative and quantitative analyses. *International Journal of Science Education, 29*(9), 1163-1187.

Wu, Y. T., & Tsai, C. C. (2011). High school students' informal reasoning regarding a socioscientific issue, with relation to scientific epistemological beliefs and cognitive structures. *International Journal of Science Education, 33*(3), 371-400. doi:10.1080/09500690903505661

Yang, F. Y., & Anderson, O. R. (2003). Senior high school students' preference and reasoning modes about nuclear energy use. *Journal of Science Education, 25*(2), 221-224. doi:10.1080/09500690210126739

Yazıcı, F., & Sözbilir, M. (2020). Görme engelli altıncı sınıf öğrencilerine hücre konusunun öğretimi. *Eğitim ve Bilim, 45*(204), 227-250.

Yilmaz, M. (2020). Impact of instruction with concept cartoons on students' academic achievement in science lessons. *Educational Research and Reviews, 15*(3), 95-103.

Yokus, G., & Aycicek, B. (2020). Identifying the concept cartoons' effect on academic achievement in science course: A meta-analysis study. *Pamukkale University Journal of Education*, 49, 223-246 . doi:10.9779/pauefd.592287

Yoon, J., Kim, K. J., & Koo, K. (2020). Enrichment program for the ethnic minority of gifted and talented students in science and engineering. *International Journal of Science Education, Part B, 10*(1), 36-50. doi:10.1080/21548455.2020.1714092

Zangori, L., Peel, A., Kinslow, A., Friedrichsen, P., & Sadler, T. D. (2017). Student development of model-based reasoning about carbon cycling and climate change in a socio-scientific issues unit. *Journal of Research in Science Teaching, 54*(10), 1249-1273.

Zeidler, D. L., Herman, B. C., & Sadler, T. D. (2019). New directions in socioscientific issues research. *Disciplinary and Interdisciplinary Science Education Research, 1*(11), 1-9. doi:10.1186/s43031-019-0008-7

Appendices

Appendix 1. Questionnaire

Dear participant,

This form has been developed to collect data within the framework of the project titled 'Development of Science and Art Centers Students' and their Parents' Perceptions and Decision Making Strategies of Socioscientific Issues via Argumentation based Concept Cartoons', supported by TUBITAK 1001 SOBAG.

Some of the scientific and technological innovations are readily accepted by the society, while some of them lead to dilemmas and discussions. These topics of discussion which have both a scientific and a social dimension, affect social life, and are open-ended having no definitive answers are referred to as socioscientific issues (SSI).

We thank you in advance for sharing your valuable opinions by filling in this form.

Project Coordinator

1. How would you evaluate the integration of SSI in science education?
2. Place a tick (√) to indicate which education level (middle or high school) the SSI below is appropriate for gifted students.

SSI	Middle School	High School
Genetically Modified Organisms (GMO)		
Nuclear Energy (NE)		
Genetic (GN) / Cloning (CL)		
Hydroelectric Power Plants (HPP)		
Experimental Animals (EA)		
Space Pollution (SP)		
Alternative Medical Treatment (AMT)		
Mass Vaccination (MV)		
Green Road Project Interlinking Highlands (GRP)		
Landfill (LF)		
Organic Farming (OF)		
Global Warming (GW)		
Mining (MN)		
Tattooing (TT)		
Road Salting (RS)		
Stem Cell (SC)		
X-ray (XR)		
Other SSI if possible		
…………….		
…………….		

3. Write what social and scientific dimensions of the SSI below (health, economy, ethics, ecological, social, moral, law etc.) should be addressed, stating the reasons as well, in the space provided below.

Genetically Modified Organisms (GMO) ______

Nuclear Energy (NE) ______

Genetic (GN) / Cloning (CL) ______

Hydroelectric Power Plants (HPP) ______

Experimental Animals (EA) ______

Space Pollution (SP) ______

Alternative Medical Treatment (AMT) ______

Mass Vaccination (MV) ______

Green Road Project Interlinking Highlands (GRP) ______

Landfill (LF) ______

Organic Farming (OF) ______

Global Warming (GW) ______

Mining (MN) ______

Tattooing (TT) ______

Road Salting (RS) ______

Stem Cell (SC) ______

X-ray (XR) ______

Appendix 2. Sample Interview Form (Nuclear Energy)

Akkuyu Nuclear Power Plant (NPP), which is planned to be Turkey's first nuclear power plant, is being constructed on the Mediterranean coast 140 km from Mersin in an area called Akkuyu, which is bound to the Gülnar town. As the construction of the power plant accelerates, environmental organizations come to the area and argue that people living in areas close to the power plant are under risk and are thus forced to migrate to other regions. Government authorities, on the other hand, state that the power plant will definitely be completed and operated, claiming that it will meet the continuously increasing electric power demand.

Emir lives in village called Büyükeceli, located 4 kilometers from the Akkuyu NPP. He is a 9th grade student and his family is engaged in agriculture. Some of his relatives does fishing. The recent developments and hearsays about the power plant have made Emir and his family uneasy as well, like other people. Some people in the village have started to think of selling their lands and migrating to other cities.

One of the other energy sources that frequently finds its place in the center of discussions in the international arena is nuclear energy as an alternative solution to the increasing energy problem across the world. NPPs, where nuclear energy is produced, operate by means of fission reactions in which the nucleus of an unstable atom splits into two or more nuclei. Water which is heated via nuclear reactions turns into water vapor. Subsequently, this water vapor turns the electric turbines to produce electricity.

Environmental organizations argue that NPPs must be shut down and that new ones must not be constructed as they pose various risks and pollute the environment. They refer to examples of power plant accidents in the world to support their arguments. Finally, the sudden radiation leakage, which occured in a reactor after the earthquake in Japan in the year 2011 and the tsunami it caused, caused anxiety in the entire world. Following this event, various countries started to review their nuclear energy programs. Germany did not renew the operation licenses of some of its reactors. Switzerland made decisions to suspend its reactor orders and the U.S. announced that it would review its nuclear policy after situation was resolved. These decisions are considered not as regressions but as progressions in the area of nuclear energy. The accidents experienced pave the way to new work in the area of nuclear energy security. Similarly, the government of Japan declared that they abandoned their plans to use nuclear energy in the future. However, recent evaluations revealed that this was not possible from the ecologic, economic and social perspectives. In the risk evaluation report published by the World Health Organization in 2013, it is stated that despite widespread public anxiety, the potential nuclear leakage risks for the general public in the Fukushima area and the long term health risks could be neglected.

Because recyclable energy sources are considered far from meeting the total energy need, fossil fuels cause high levels of greenhouse gas emissions, and high costs are involved in energy imports countries are forced to resort to nuclear energy.

1. If a nuclear power plant were to be constructed near the region where you live, would you consider migrating to another city on grounds of the probable risks of the power plant? Please provide justifications/reasons.
2. What can be done to prevent these risks? Could you please explain your recommendations and the reasons?
3. Which sources produce the most electricity (electric power), and are the cleanest and most economical when compared to nuclear energy? Please explain your decisions with the justifications.

Appendix 3. CCSSI Framework Plan (HPP Sample)

MODES	CLAIM	EVIDENCE	COUNTER ARGUMENT	REBUTTAL
ECOLOGY HPP (-)	The construction and operation phases of run-of-the-river Hydroelectric Power Plant (HPP) have hazardous effects particularly on aquatic ecosystems.	**1.** During the construction phase, the greatest dangers are particularly dumping the earthwork haphazardly into the river beds, the blurriness of water due to the work carried out under the water for a long time, and wastewater released into the river bed without letting it to rest. During the operation phase, the amount of sap water that needs to be released into the river bed not being sufficient, and the fish pathways being haphazardly constructed and not functioning completely are significant threats to the sustainability of the aquatic ecosystem (Aksungur, Ak, & Özdemir, 2011). **2.** It was calculated that approximately 11 hectares of forest land within the HPP establishment in Artvin would be destroyed and/or lose its unity (Çoşkun, 2010).	**1.** An opinion such that HPP are not hazardous to nature as they get the water from rivers and return it to river beds at lower altitudes after electricity generation is widespread. However, the water collection structures of HPP (regulators) create a small dam effect each and distort the unity of the river.	**1.** The arrangement needed to provide a sufficient amount of sap water to provide the sustainability of the river ecosystem is believed to be difficult. However, if river basins in Turkey are categorized according to ecosystem quality class with the use of the Tennat method, and the sap water ratio is identified accordingly, the aquatic ecosystem will not be harmed in any way (Karadeniz, Akpınar, & Başıbüyük, 2011).
ECOLOGY HPP (+)	HPP, as one of recyclable energy sources, does not harm the ecology.	**1.** The use of energy obtained from fossil fuels, which are non-recyclable energy sources, has in recent years brought to the agenda the topics of global warming and climate change. Alternatively, people	**1.** The distortion of the physical, chemical and biological water in streams and rivers for various reasons (the removal of the present flora, various facilities constructed on rivers, the use of fertilizers and	**1.** The idea that as HPP receive the water from the rivers and release the water into the river again at lower altitudes after the production of electricity, they do

		have started to seek recyclable energy that would give less harm to the ecology. Among the leading recyclable energy sources are the sun, wind, geothermal, and water energy (Valero, 2012). **2.**It is known that HPP have fewer impacts on the ecology when compared to such fossil fuels as coal, natural gas and petrol due to such reasons as their being clean and recyclable, their operational and maintenance costs being low, and their physical spans being long (Aksungur et al., 2011). **3**. The Environment Protection Agency defines green energy as electricity generated from the sun, wind, geothermal, biogas, small hydroelectric sources with specific types of biomass with low effectiveness (Ghosh, 2011).	pesticides in agricultural areas etc.) has a negative impact on the macro and micro fauna living in this river, the flora in the ecology of the river, the habitats of any wildlife (Li & Migliaccio, 2011). **2.** The HPP in Reşadiye has numerous negative effects on flora, soil, and water sources. The most important one among these is the sufficiency of sap water to ensure the sustainability of the river's ecosystem. As three power plants are constructed in alignment one after the other, the water is received into the canal without flowing into the river bed; hence, this has a negative impact on the river's ecosystem. (Karadeniz et al., 2011).	not give harm to nature is a common view. However, the water receiving structures of HPP (regulators) create a small dam effect and distort the unity of the river. In the examinations of reports prepared on the Evaluation of the Ecological Impact (EEI) for HPP projects planned to be implemented in the East Black Sea Region, it was revealed that the projects did not have a format that were conducive to revealing the impacts on the natural and socio-economic environment effectively (Aksungur et al., 2011).
ECONOMY HPP (+)	HPP is one of the most economical energy sources to meet a country's electricity demand.	HPP have considerably low construction stage costs when compared to those of thermic and nuclear plants and they are constructed in a relatively much lower time span.	**1.**As electricity is an energy type that is difficult to store, it needs to be consumed within the time frame it is produced. Moreover, due to the high costs and losses involved in its transmission, it is much more economic for it to be consumed in areas close to the plant where it is produced (Akpınar, 2005). Hence, HPP are	**1.** It is highly controversial whether or not such an important natural area is worth harming for a contribution of approximately 5% to electricity production The eco-tourism and other potentials of the area could make significant contributions to the country's economy

	being constructed in the East Black Sea basin, which is a productive region in terms of electric energy potential, and because slopes and the flow rates of rivers are high in Turkey with a regular precipitation regime (Koralay, 2015). As such, the need for electricity is met in the East Black Sea region, while the electricity needs of the other regions is unlikely to be met by these sources.	with much lower investments (Akpınar, 2005). **2.** During the construction of the tunnels, canals, and transportation roads of HPP in Reşadiye, the natural balance of hillsides was disturbed. The earthwork that emerged haphazardly as a result of the constructions was dumped into the river beds in some way, and the flora on the hillsides was sporadically removed, which increased the erosion risk. In addition, despite the plan to have a large part of the water transmission line between the regulator and the plants through tunnels in the project, a large part was transmitted over the surface to decrease costs. **3**. HPP are renewable energy sources that are constructed and operated in numerous countries around the world. However, the fixed power of the HPP in all EU countries is limited to 10 MW, the Energy Markets Law enforced in 2002 in Turkey specified this limit

				as 20 MW, and later increased it to 50 MW with a legal change it made in 2005 (http://www.ekoiq.com/haberler). This practice aimed to enable investors to use loans with low interest rates given by the World Bank for recyclable energy, but the harm to be made to the ecosystem by the HPP with increased capacity is ignored.
SOCIAL HPP (+)	As the number of HPP increases, Turkey's dependence on foreign energy sources will decrease.	**1.** There is an important potential of hydroelectric power in particularly the basins in the Black sea and the Mediterranean regions of Turkey. These can be used for HPP. 20% of Turkey's hydroelectric potential can be fulfilled with these kinds of power plants. This is one way by which dependence on foreign sources in energy production and meeting the increasing national electricity demand can be achieved (Akpınar, 2005).	**1.**Damn based HPP can be beneficial for protection from flooding, irrigation, drinking water, transportation, fishing, tourism activities. On the other hand, HPP are not beneficial in providing protection from flooding, in transportation, fishing, nor in tourism activities. In dam based HPP, it is possible to adjust the flow speed, that is the flow rate. That is why electricity can be produced even in rainless and drought seasons. In HPP, flow rate adjustments cannot be made. The electric energy to be produced by the power plant varies by season. In times when there is intensive precipitation and river flow, production	**1.**Electric energy to be obtained with the 2000 HPP project in Turkey is considered an alternative way to electricity production based on foreign sources. Although decrease in dependence on foreign sources is claimed to be possible by using sources with electric energy in this way, Turkey meets 45.9% of the energy it consumes (Şekkeli & Keçecioğlu, 2011) with the natural gas it imports from foreign countries. According to the targets stated in the Hydroelectric Electricity Energy Market and Demand Security Strategy Document, until 2023 the hydraulic potential will be completely put to

		of electricity increases, but in times of drought, no electricity may be produced in HPP (Marım & Güler, 2009).	use. Still, the predicted amount of production can only meet 5% of Turkey's 2023 electricity demand (Karadeniz et al., 2011).

Appendix 4. The CCSSI Rubric

Dear Researchers,

The form below has been developed to conduct a preliminary evaluation of and receive feedback on the concept cartoons on two dimensions: structure and content. You can duplicate the table below by copying it as many times as the number of concept cartoons you are expected to examine. Please do not forget to write the code of the concept cartoon you are examining on top of the table. In addition, for the items you marked as "partially satisfactory" or "unsatisfactory", please write in the comments section any recommendations you have for improvement or why you made such an evaluation. These recommendations will be taken into consideration to improve the concept cartoons, which will then be subjected to a pilot study. Thank you for your contributions.

The Codes for the Examined Concept Cartoons:

A. The Structural Features of the Concept Cartoons

	Level			
Dimension	**Satisfactory (3 Points)**	**Partially satisfactory (2 Points)**	**Unsatisfactory (1 Point)**	**Comments**
Problem Presentation	The problem statement is sufficiently understood from the dialogues in the concept cartoons. All the dialogues are related to the problem statement. ( )	The problem statement is partially understood from the dialogues in the concept cartoons. However, not all the dialogues are related to the problem statement. ( )	The problem statement is not understood from the dialogues in the concept cartoons. The dialogues are not related to the problem statement. ( )	
Language Use	All the dialogues are comprehensible and explicit. There is a balance between the usage of daily and scientific language. ( )	Some of the dialogues are comprehensible and explicit. The usage of daily and scientific language is partially consistent. ( )	The dialogues are not comprehensible nor consistent. The usage of daily and scientific language is inconsistent. Students are directed toward using dialogues that predominantly include scientific language without considering the students. ( )	
Attractiveness	The concept cartoons have sufficient content to attract	The concept cartoons have partially sufficient content to	The concept cartoons do not have attractive content to attract students' attention. ( )	

	students' attention. ( )	attract students' attention. ( )		
Organization	There is no logical consistency between all the events/ phenomena, places, and characters included in the concept cartoon. ( )	There are some inconsistencies between the events/ phenomena, places, and characters included in the concept cartoon. ( )	There is no logical consistency between the events/ phenomena, places, and characters included in the concept cartoon. ( )	
Visual Design	The concept cartoon has been designed in full accordance with visual design principles (unity, balance, dimension, color usage etc.). ( )	The concept cartoon has been designed disregarding some of the visual design principles (unity, balance, dimension, color usage etc.). ( )	The concept cartoon has been designed without considering any of the visual principles (unity, balance, dimension, color usage etc.). ( )	
B. Argumentation Features of Socioscientific Issues				
Dimension	**Satisfactory: 3 Points**	**Partially satisfactory: 2 Points**	**Unsatisfactory: 1 Point**	**Comments**
Relation with SSI	The issue in the concept cartoon fully reflects the related SSI. ( )	The issue in the concept cartoon partially reflects the related SSI. ( )	The issue in the concept cartoon does not reflect any SSI. ( )	
Argumentation	The dialogues include one or more SSI related arguments and the associated counter arguments. ( )	The dialogues include one or more SSI related arguments but do not include the associated counter arguments. ( )	The dialogues do not include SSI related arguments nor any counter argument. ( )	

Appendix 5. Dialogic Discussion Observation Form

Indicator	Scoring		
	Monologic	**Semi Dialogic**	**Dialogic**
	1	**3**	**6**
Authority	The teacher has significant control over the content and argumentation processes. The teacher selects the students, asks questions, transitions between the topics, and evaluates the responses.	There are opportunities for students to freely participate in argumentations. These are rare occasions and only occur to involve only a few students. Mostly it is the teacher who controls turn taking, determines the topic to be selected, and reshapes the argumentation on the specifically selected topics.	Students share significant responsibilities in relation to the topic and process of discussion. The students organize the sequence of the talks, ask questions, interact with others' views, and recommend changes in the topic and process.
Questions	The teacher aims to use the questions to remind students of the events that take place in the concept cartoons. These are the true-false test questions that are obtained from known events or other sources.	The teacher asks complex open-ended questions of various features. Open-ended questions guide students into interpreting texts that are assumed to be accepted by the teacher from a narrow perspective.	This discussion is in reality based on cognitively challenging, clear questions. The questions aim to stimulate higher-order thinking and encourage students to engage in critical evaluation and analysis.
Feedback	The teacher gives short, commonplace or vague feedback. The feedback does not enable students to develop their responses. (e.g. Uhm, okay. Mehmet?).	The teacher follows up in various ways. The teacher frequently listens to student responses and works with their responses but sometimes misses opportunities to help the group develop and advance their research.	The teacher works with student responses for students' future discoveries. The teacher praises or questions reasoning skills, not outcomes.
Meta-level reflection: establishing connections between student views	The teacher does not establish connections between students' responses to each other.	The teacher sometimes misses opportunities to establish connections between student views.	The teacher does not miss opportunities to establish the explicit connections between student responses and to encourage students to explain the views presented by other students. The teacher frequently supports student views and asks questions to the speaker directly. (e.g. Cansu, would you like to respond to Güler's example?)

Explanations	Students do not explain what they think or why they think so. Consisting of one word or phrase, their responses are brief and factual.	Sometimes students share their opinions and present sound justifications for their opinions. Longer student responses can represent simple repetitions of the events in the story.	Students assume an individual role within the topic ("I think", "I believe", "I feel") and support these with reasons and examples. They focus on details, make extensive contributions, and explain their views to others.
Collaboration	The students' responses are short, incoherent, and incohesive. Students primarily report fictional, known facts.	Students sometimes establish new opinions upon each others' views. Collaboration requires sharing similar experiences as opposed to frequently criticizing each others' views. (e.g. I experienced this as well. I was visiting my aunt in Istanbul…)	Students collaboratively and critically reform their views. As they respond to each others' views, their responses are interrelated.