Socioscientific Issues in Science Education

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What are Socioscientific Issues?

Science, technology and society have interacted with each other from past to present. Developments in science and technology aim to meet the needs of society (Sadler and Zeidler, 2005; Topçu, 2015). Technology contributes to the development of science by putting the goals of science into practice. Therefore, it can be said that science, technology and society are in a reciprocal and dynamic relationship with each other. The reciprocal relationship mentioned here may seem harmonious at first glance. However, science is inherently open to change and subjective (AAAS, 1993; Lederman, Abd-El-Khalick, Bell, & Scwartz, 2002). Technology that emerges as a result of scientific knowledge may produce some negative or controversial results (Oliveira, 2017). The technology that emerges as a result of scientific knowledge can lead to some negative or controversial results (Oliveira, 2017). This situation can lead to scientific knowledge and technological developments not being accepted by the society or to disagreements. Although they are scientific and technologically based, controversial issues that contain contradictions such as positive/negative, necessary/unnecessary, useful/harmful have given rise to socioscientific issues. In these dilemmas experienced by individuals regarding a subject, issues that are open to discussion, include dilemmas, do not have a definitive answer, are complex, open-ended and closely related to science, are called socioscientific issues (SSI) (Sadler, 2004; Topçu, 2021). In order for a subject to be considered a socioscientific issue, its most basic characteristics must include dilemmas and be based on a scientific basis (Topçu, 2015).

Socioscientific issues are issues that have scientific and social foundations, are controversial issues due to their dichotomous nature, include moral and ethical aspects of society, and have gained national and global dimensions. The term controversial is a situation where there is no single truth in calling it a controversial issue and that creates conflict between individuals by allowing for disagreements. For example; the advantages and disadvantages of establishing nuclear power plants in a region have become a controversial issue. While some segments of society welcome it positively in terms of economic development, energy production, reducing external dependency and providing employment opportunities if the necessary safety measures and conditions are provided when establishing nuclear power plants, some segments have become a subject of discussion in terms of accidents that may occur in nuclear power plants, radioactive waste, and environmental

pollution.

Sadler and Zeidler (2005) have expressed the characteristics of socioscientific issues as follows:

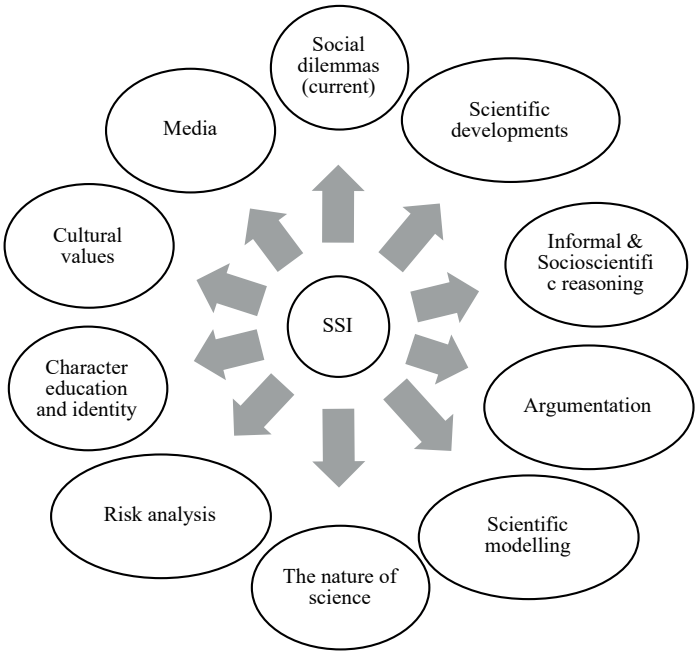
- Socioscientific issues have a scientific basis and contain discussion and contradiction in their nature,
- By their nature, they cause disagreements within society and await resolution,
- They do not have a single answer and are open to evaluation from more than one perspective,
- They are social and scientific issues that contain ethical and moral dilemmas.

Similarly, the general characteristics of socioscientific issues are listed by Ratcliffe and Grace (2003) as follows:

- They are current issues based on science and real life.
- They are based on science and are usually within the boundaries of scientific knowledge.
- They include poorly structured problem situations.
- They are usually media articles (TV, newspaper, internet, radio).
- They do not have exactly correct answers.
- They indicate local, national and global dimensions. These dimensions are also related to political and social content.
- Includes some cost-benefit analysis where risks affect values.
- Considers sustainable development.
- Includes values and ethical reasoning.
- Provides understanding of probability and risk.
- Erduran and Jimenez-Aleixandre (2007) stated the aims of discussions on socioscientific issues as follows:
- It can contribute to the increase of the level of knowledge.
- It can contribute to the social awareness of knowledge since they are issues that contain dilemmas.
- It can help students produce solutions to a complex issue they encounter in daily life.
- It can contribute to students' development of concepts related to the nature of science through socioscientific issues.
- It can contribute to students' training as good debaters and enable them to use their knowledge when making decisions on a subject.

When the definition and characteristics of socioscientific issues are taken into account, a model (Figure 1) can be created regarding socioscientific issues (Topçu, 2021).

Figure 1.: *Modeling of Socioscientific Issues*



Considering the characteristics of SSI and the age of science we are in, interest in SSI continues to increase day by day, and socio-scientific issues have been included in international reform documents and national programs based on the vision of raising scientifically literate individuals encountered in daily life, in terms of developing scientific literacy, students' scientific thinking habits, reasoning and decision-making skills (AAAS, 1993; MEB, 2013; 2018; NRC, 1996). The National Research Council (NRC) advocates that socio-scientific issues should be discussed, analyzed, and included in school curricula (NRC, 1996). When we look at the last twenty years, SSIs have been integrated into science curricula in different countries or have been attempted to be integrated. Many countries, especially the United States (US) and England, have accepted the importance of SSIs in science education and have begun to include them in their curricula (Topçu, 2019). Turkey is among the countries that have included SSIs in science curricula.

The Place of Socioscientific Issues in Science Education

Towards the end of the twentieth century, many researchers reached a common conclusion that science subjects could be better understood by considering the inclusion of social problems in science courses (Topçu, 2008; Zeidler et al. 2005). Among the main purposes of including socioscientific issues in the science curriculum; developing scientific literacy, making science interesting within society and turning it into a tool that can solve a problem situation in daily life are of great importance. In addition, in learning environments where socio-scientific issues are used, it contributes to the development of analytical thinking, scientific literacy, argumentation, questioning, analysis, inference, decision-making skills with a critical perspective, ethical and moral reasoning skills and behaviors in students (Evren & Kaptan, 2014).

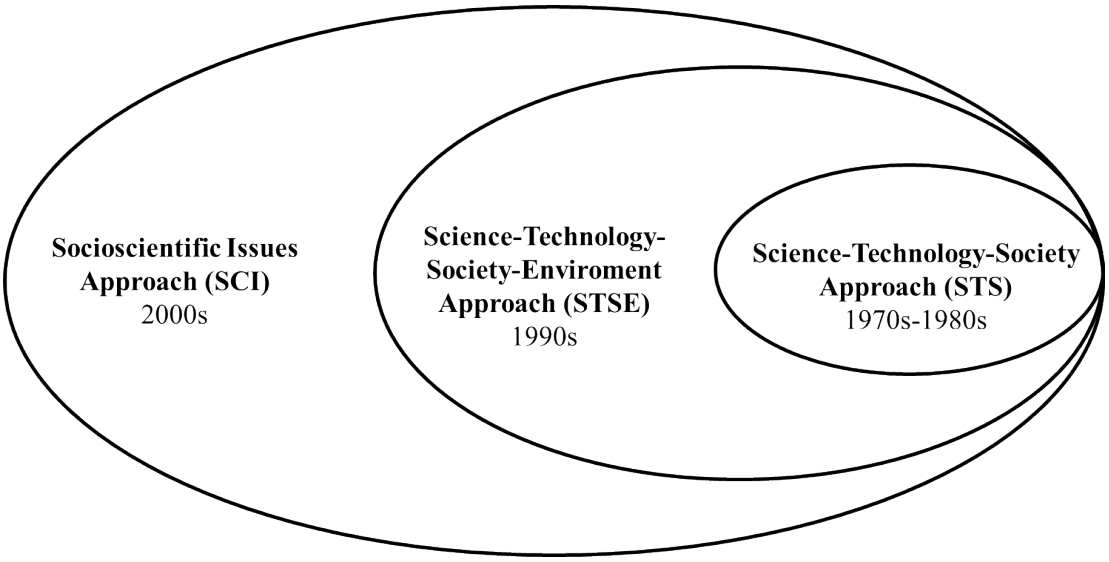
When we look at the historical development of socio-scientific issues, we can say that they have developed in a historical process that complements each other since the 1970s. In the 1970s and 1980s, the Science-Technology-Society (STS) approach was adopted and integrated into the

curriculum in many countries (Zeidler et al. 2005). The most important point in this approach was that it clearly revealed the relationship between science, technology and society. However, over time, it has been subject to some criticisms regarding not emphasizing the views and experiences of students enough and not drawing attention to ethical issues and the moral and character development of students (Zeidler et al., 2005).

In the 1990s, due to the rapidly developing and changing scientific and technological developments and the developments in science and technology, the Science-Technology-Society-Environment (STSE) approach, which is a more comprehensive approach than the Science-Technology-Society approach, was adopted. Although this approach is a more advanced version of the STS approach, the environmental dimension was added, and the issue of the environment being affected by scientific developments, which scientists frequently bring up and conduct research on, was evaluated as a popular approach and the role of the environment was questioned in more detail (Yapıcıoğlu, 2020). Although the STS approach is more comprehensive and draws attention to moral and ethical issues, it has come across studies arguing that it is inadequate because it does not emphasize argumentation, the nature of science, and the cultural and emotional development of students (Lee, 2012).

In the 2000s, SCI, which includes topics such as cloning, genetically modified organisms, stem cells, genome projects, organ and tissue transplantation, which are particularly notable in the field of genetics, has begun to become the focus of attention of many researchers. In addition, with the spread of nuclear power plants all over the world, the threat of privacy by technological tools, and the rapid development and change in many areas such as ecological degradation, a new approach called "Socioscientific Issues" has been adopted by science education researchers with the increasing criticism on STS and STSE approaches (Zeidler et al., 2005; Topçu, 2019). Although the foundation of SSCs dates back to the 1980s, in the 2000s, SSCs took on a broader conceptual framework than the STSE approach. When we look at the content of socio-scientific issues, in addition to all the components included in the STSE approach; the nature of science, scientific claims and arguments, social, emotional, personal, political and ethical dimensions, as well as individuals' decision-making based on their personal beliefs and experiences (Zeidler & Sadler, 2023). The interaction of these three approaches is shown in Figure 2 (Topçu, 2021).

Figure 2. *Science-Technology-Society Based Approaches*



SSI have reconceptualized the science-technology-society approach and added a different dimension by focusing on the personal experiences and beliefs of individuals as well as the science and technology dimension (Topçu, 2021).

The Importance of Socioscientific Issues in Science Education

In order for a society to develop and grow, it needs individuals with high reasoning skills, critical thinking and decision-making skills. Socioscientific issue-based teaching is of great importance in enabling students to reason and gain awareness about a topic that concerns society through discussions and by addressing it from a critical perspective. By addressing socioscientific issues within the scope of science education, students are enabled to learn science lessons by making better sense of them and to feel closer to the topics (Pedretti, 1999).

The development of knowledge-based decision-making skills about socio-scientific issues that we encounter in daily life and that are of close interest to society is an important part of science education, which is based on the vision of raising scientifically literate individuals (Çavuş, 2013; Topçu et al. 2014). The development of individuals' decision-making skills regarding any socio-scientific issue is of great importance in the development of scientific literacy (Driver, Newton, & Osborne, 2000). According to some studies, it has been stated that learning environments based on SSIs make learning about a scientific subject that individuals find boring or uninteresting more interesting, increase their motivation to learn information, and exhibit positive attitudes towards science education (Akşit, 2011; Topçu et al., 2014).

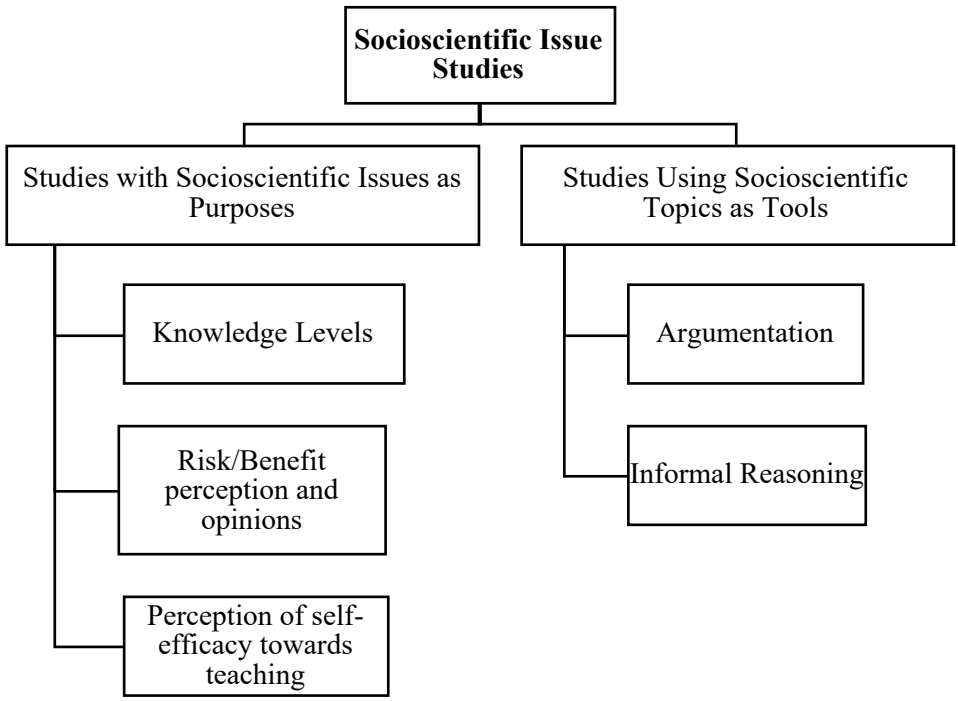
There are some reasons underlying the integration of SSI into the science curriculum. In addition to supporting the cognitive development of the individual in the teaching of SSI, it also develops the individual emotionally and morally. These subjects, by addressing a problem situation in daily life, allow students to understand such subjects better and at the same time make them interesting.

Some studies in the literature support the idea that SSI teaching increases students' motivation

for science (Zeidler and Sadler; 2005). It has been stated that SSI teaching improves students' understanding of the nature of science (Khishfe and Lederman, 2006; Walker and Zeidler, 2007). In addition, there are studies indicating that argumentation and reasoning skills also develop during the SSI education because individuals enter a process where they create claims and arguments about controversial issues using scientific data (Sadler and Zeidler, 2005; Dawson and Venville, 2009; Wu and Tsai, 2011; Öztürk and Yılmaz Tüzün, 2017; Akbaş and Çetin, 2018). Therefore, socio-scientific issues contribute to students' decision-making skills by developing their responsibility in economic, political, social, health and ethical issues related to science, their ability to look at events with a critical eye and to make conscious decisions (Gülhan, 2012). Examples of these topics that we hear frequently in daily life and that are included in the science curriculum are; some applications of genetic engineering, genetically modified foods (GMO), gene therapy and cloning, organic agriculture, global warming, nuclear energy and thermal power plants, renewable energy sources (HES, wind, solar), environmental problems, space studies, space pollution, organ donation and transplantation, and endangered species, and many other topics have been addressed as socio-scientific issues.

When studies on socio-scientific issues are examined, socio-scientific issues in the international literature focus on two themes: purpose and tool. There are studies on the use of SSIs as a tool (Topçu, Sadler & Yılmaz-Tuzun, 2010) and as a purpose (Klosterman & Sadler; Topçu, 2010). As can be seen in Figure 3, in studies where SSI are used as a purpose, the aim is to gain the gains in the curriculum within the scope of socio-scientific issues and the students' knowledge levels, perceptions and self-efficacy are emphasized. However, in studies where they are used as a tool, the students' affective development (raising awareness, creating a value system and giving conscious reactions), the development of their scientific practices, as well as their argumentation and reasoning skills are examined (Topçu, Muğaloğlu & Güven, 2014).

Figure 3. *Themes of Studies on Socioscientific Issues in Science Education*



The Place of Socioscientific Issues in Science Curriculum

According to Sadler (2004), SSIs contribute to the blending of science-related concepts that closely concern society with technological information. By associating science concepts with technology, the concepts of "science", "technology" and "society" have emerged and this concept has had an important share in shaping the curriculum of some countries. Later, "environment" was added to these three concepts and the Science, Technology, Society and Environment (STE) approach emerged (Hodson, 1994). In our country, this approach has been added to the science curriculum by the Ministry of National Education since 2004 and it has been stated that it has great importance in terms of raising students as "science literate" by understanding the relationship between these four concepts.

Socioscientific issues have been included indirectly, if not directly, in the Science and Technology Curriculum, which has been implemented in our country since the 2004-2005 academic year, among the general objectives of which are "to ensure that students realize the social, economic and ethical values related to science and technology, personal, health and environmental problems, take responsibility for them and make conscious decisions".

While socio-scientific issues were a subheading within the Science-Technology-Society-Environment outcomes in Turkey before 2013, they were included in the curriculum as a title with the program studies in 2013. In the 2013 Science Curriculum, attention was drawn to the use of SSI in terms of generating scientific thought in the form of "developing scientific thinking habits using socio-scientific issues" and it was included in the teaching objectives (MEB, 2013). In the draft program prepared in 2017, the emphasis was continued in the Science-Engineering-Technology-Society-Environment learning field. In the 2018 Science Curriculum, attention was

drawn to the fact that among the general objectives, "to develop reasoning, scientific thinking habits and decision-making skills using socio-scientific issues" (MEB, 2017; 2018). Within the scope of the changes made in the 2024 Science Curriculum, learning outcomes are; In addition to field-specific skills, conceptual skills, dispositions, social-emotional learning skills, values and literacy skills, it is aimed to effectively support the multi-faceted development of students. In this context, among the general objectives of the science curriculum, the importance of socio-scientific issues is emphasized as students are "interested in socio-scientific issues, doing research, questioning, developing innovative solutions with an interdisciplinary perspective" (MEB, 2024).

Among the main objectives of the science course curriculum is to raise scientifically literate individuals who are aware of their responsibilities in solving social problems encountered in daily life, who have creative and analytical thinking processes, and who produce alternative solutions to a problem (MEB, 2018). They are also expected to be curious about socio-scientific issues, conduct research, and develop innovative solutions with a questioning perspective (MEB, 2024).

The socio-scientific issues covered in the science curriculum are of great importance in terms of developing scientifically literate individuals, who are aware of their responsibilities regarding the social problems they encounter in daily life, and who produce alternative solutions to solve the problem, and their decision-making and reasoning skills. In addition, the inclusion of socio-scientific issues in the curriculum can contribute to students' curiosity about the subject, their research, and their development of solution suggestions with an inquisitive perspective.

Socioscientific issues have become one of the topics researched by many researchers in science education, both nationally and internationally (Driver, Newton, & Osborne, 2000; Zohar & Nemet, 2002; Ratcliffe & Grace 2003; Sadler, 2004; Sadler & Zeidler, 2005; Wu & Tsai, 2007; Topçu, 2008; Topçu, Sadler, & Tüzün, 2010; Dawson & Venville, 2010; Soysal, 2012; Kutluca, 2012; Öztürk, 2013; Evren & Kaptan, 2014; Akbaş & Çetin, 2018; Tüzüngüç, 2019, Sicimoğu, 2020; Ocak, 2022; Toktaş & Genç, 2023).

According to Simonneaux (2007), the advantages provided by socio-scientific issues used in science education;

- It improves scientific process skills and analytical thinking skills,
- It establishes a connection between scientific literacy and social life by increasing the function of scientific literacy,
- It contributes to creating social awareness,
- It enables the conceptualization of the nature of science,
- It improves argumentation skills.

In summary, addressing socio-scientific issues in science education contributes to the formation of individuals' perceptions of the nature of science, their awareness of social issues, their ability to think critically by developing reasoning and decision-making skills, the ability to look at a subject from different perspectives, and the development of higher-order thinking skills by developing

analytical thinking skills.

Teaching Framework for Teaching Socioscientific Issues

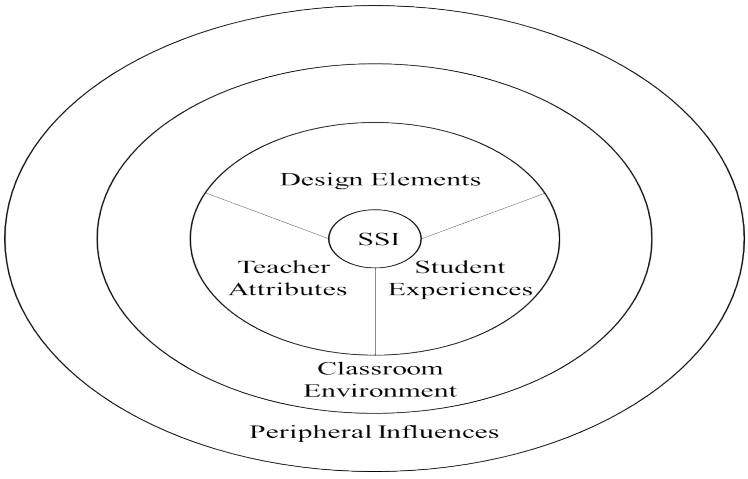
Various researchers have stated some criteria and elements to be considered regarding the use of socioscientific issues in teaching environments. Evren and Kaptan (2014) have expressed the elements to be considered in the selection of socioscientific issues planned to be used in the classroom environment as follows:

- Does the selected topic have scientific content?
- Does the selected topic contain a dilemma?
- Does it cover the interaction of science-technology-society?
- Is the selected topic open-ended and does not have a single answer?
- Does the answer vary depending on the students' value judgments (moral-ethical)?

Once a specified socio-scientific topic is selected, it is of great importance whether this topic matches the achievements in the curriculum, whether it is suitable for the pedagogical level of the students and whether it is suitable for the general objectives of the curriculum.

Sadler (2011) and Presley et al. (2013) developed an exemplary framework for teaching socioscientific issues based on theoretical and applied research on SSI in the literature. This socioscientific issue-based framework example that has been prepared is a roadmap that can be easily used by science teachers in both the SSI literature and in the teaching of SSIs in classroom environments (Topçu, 2015). When we examine this curriculum closely, we see that it consists of 3 basic components. These are design components, student experiences and teacher characteristics. The graphical representation of the framework of these components is shown in Figure 4 below.

Figure 4. *Graphical Representation of the SSI-Based Teaching Framework (Presley et al. 2013)*



As can be seen in the figure, these three basic components are framed by the classroom environment and the largest circle surrounding all these components from the outside is called Peripheral (External) effects.

Design Elements

The design component, which is one of the basic components of the SSI teaching framework, has four basic features.

- When SSI is included in the teaching process, it should first be structured around a controversial topic
- The selected controversial topic should be presented at the beginning of the lesson
- It should direct students to higher-order thinking skills such as argumentation, reasoning and decision-making
- The process should be concluded by associating the new topic that the students have learned with the scientific topic they have learned before.

Apart from these features, the teaching environment can be enriched by using media to relate the activities carried out in the classroom to real life and technology to increase learning experiences (Sadler et al., 2017).

Student Experiences

One of the important components for effective SSI-based teaching is the student experiences-learning experiences component. It basically has four features.

- Students should be given the opportunity to gain high-level thinking skills such as argumentation, reasoning and decision making
- Scientific ideas and theories related to the SSI being studied should be addressed
- Students should collect and analyze data to support their claims during the process
- Discuss or evaluate the economic and political dimensions of SSIs by creating awareness.

In addition, although it is not mandatory to associate a socio-scientific issue with the nature of science and evaluate it with ethical dimensions, it is suggested that opportunities can be given if the content of the subject is appropriate. For example; While it is not possible not to discuss the ethical dimension of genetic engineering, which is a socio-scientific issue, it is not mandatory to associate or discuss the nature of science and ethical dimension of another SSI (Sadler, 2011; Topçu, 2015).

Within the scope of the SSI-based curriculum, it will contribute to the development of students' discussion skills and awareness of the issues they encounter in daily life. In addition, it contributes to the development of communication and empathy skills in the classroom environment, as well as the development of higher-order thinking skills such as critical thinking, reasoning, and argumentation (Hacıoğlu and Kartal, 2022; Topçu, 2021).

In teaching socio-scientific issues, students can form cooperative groups to serve a common purpose, interact with each other, and support their mutual learning, as well as contributing to the development of communication skills. According to Ratliffe & Grace (2003), there are certain skills and competencies that are expected to be gained by students at the end of the process by including

socio-scientific issues in teaching. These are:

- Understand the concept of science and how to share the scientific process,
- Understand the nature of decision making at a societal and personal level,
- Know the scope of socio-scientific issues from a local, global and national perspective,
- Understand and demonstrate the nature, strengths and limitations of socio-scientific news in the media,
- Be able to make benefit and harm analysis regarding possible situations,
- Be able to make ethical and moral judgments regarding socio-scientific issues,
- Recognize the current and changing nature of socio-scientific issues,
- Understand the nature of environmental sustainability,
- Be able to make probability and risk analysis,
- Understand and evaluate the deficiencies in evidence,

In order for students to gain the specified competencies in the classroom environment, it is of great importance to create a classroom environment where students and teachers feel safe and respectful, by allowing students to work collaboratively. In order to effectively implement design components and student experiences in SSI-based teaching, a supportive classroom environment and an effective teacher role are first necessary (Sadler, 2011).

Teacher Attributes

It consists of the basic features that SSI regional education must have in order to successfully achieve its purpose;

- Whether the necessary technical features and social dimensions related to the quoted SSI are known,
- The teacher should be able to honestly state this situation, which does not have enough climate regarding the subjects he/she deals with,
- The teacher should be in the role of the person who provides authority in the classroom environment, should direct everyone in the right direction as a guide and should be able to do this,
- He/she should be prepared and ready for the performances that are the amount of storage in the classroom regarding the SSI dealt with

In the classroom environment, teachers are expected to guide students to reach the correct information and also lead the discussions in the classroom environment rather than being the ones who provide authority. Since the nature of the SSI is open to discussion, it is more difficult to manage the discussion environment in the classroom compared to the traditional teaching classroom environment. In this regard, the teacher should make good classroom plans accordingly and start the discussions after providing environments where students can freely express their supportive or opposing views (Atabey, 2016).

Bell & Lederman (2003) grouped the skills and knowledge that teachers should have about socioscientific issues under three questions:

- Does the teacher have comprehensive knowledge about the science in the content of the socioscientific issue?
- Does the teacher have comprehensive knowledge about how the socioscientific issue can enhance students' ethical and moral development?
- Does the teacher have comprehensive knowledge about argumentation and how to evaluate the quality of arguments?

There are a number of difficulties that teachers face in teaching SSI. Some of these difficulties are; students are not patient with their friends due to their age and interrupt them and talk all at once, teachers do not want to allocate enough time to these topics, especially in classes where end-of-year exam anxiety is high, and teachers have problems with impartiality due to the contradictions and discussions inherent in SSI (Chen & Xiao, 2021; Öztürk & Yılmaz-Tuzun, 2017; Seçgin, 2009). Ratcliffe & Grace (2003) also emphasized that teachers' lack of sufficient knowledge of socioscientific issues and adequate teaching strategies on controversial issues, some teachers' failure to accept that social issues are a part of the science curriculum, and insufficient time allocated to the ethical and moral dimensions of socioscientific issues due to the programs' intensive conceptual knowledge, cause socioscientific issues to be rarely included in the classroom environment.

It is of great importance for teachers to have sufficient in-depth knowledge in order to implement socio-scientific issues in the classroom in accordance with the general objectives of the science curriculum. Therefore, teachers should be equipped with this competence in teacher training programs and these competences should be developed and imparted to teachers through necessary in-service training.

Classroom Environment

Socioscientific issues have great importance among the objectives of the science curriculum. Important school environments that contribute to the achievement of the desired objectives of the curriculum are classrooms. Each classroom has its own equipment, a classroom climate created with its teachers and students. This classroom environment plays an important role in which students share their ideas with their friends, develop their ideas and sometimes change their ideas in the light of scientific information. Therefore, in order for the curriculum to achieve the desired objectives, it is important to create a classroom environment where students can easily express their ideas, support their interaction with each other and feel safe while expressing their ideas. A classroom environment that includes opposing ideas by nature and requires each student to respect each other's ideas on the subject and offers an interactive learning environment should be created (Topçu, 2019).

The second layer of the SSI-based teaching framework is the classroom environment. The classroom environment affects the basic components of SSI-based teaching, which are design,

learning experiences, and teacher characteristics. The classroom environment;

- To have high expectations for student participation and where students feel comfortable
- An interactive collaborative learning environment between teachers and students throughout the process
- When different opinions on the subject are put forward, both students and teachers should respect each other
- A learning environment should be created where teachers or students feel safe (Topçu, 2017).

It is important that the physical conditions of the classroom are equipped to respond to the learning activities of the students. In a classroom that is suitable for creating discussion environments due to the nature of socio-scientific issues and is sufficient in terms of class size, an environment will be provided for students to think better and express their ideas comfortably, allowing socio-scientific issues to be discussed as necessary (Yapıcıoğlu &Kaptan, 2018). In addition, it is important to minimize the negative situations that may be caused by the physical environment that prevents students from hearing each other in discussions that take place in the classroom.

Peripheral (External) Influences

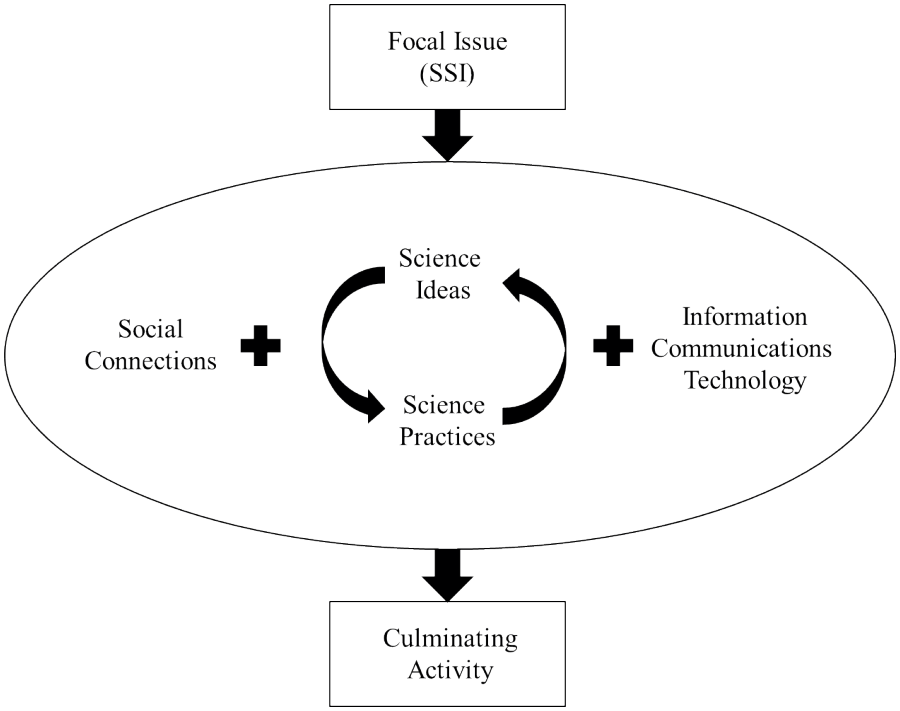
The peripheral effects located in the outermost layer of the SSI-based teaching framework scheme cover and affect both the three basic layers (design, teacher characteristics and student experiences) and the classroom environment components.

In order for SSI-based teaching to be implemented;

- Teachers should be supported and encouraged,
- Easy access to materials should be provided,
- The implemented teaching program should have the necessary flexibility
- Local SSI should exist and awareness should be created on this issue
- Effective communication and cooperation should be provided with the relevant administrators
- Necessary relationships should be established between the implemented teaching program and SSI-based teaching

Various studies have been conducted on the development of a socio-scientific issue-based teaching model and current SSI-based teaching models. Another research team that provides detailed information and research on how to do SSI-based teaching, Friedrichsen, Sadler, Graham, and Brown (2016), designed a SSI-based teaching model (Figure 5).

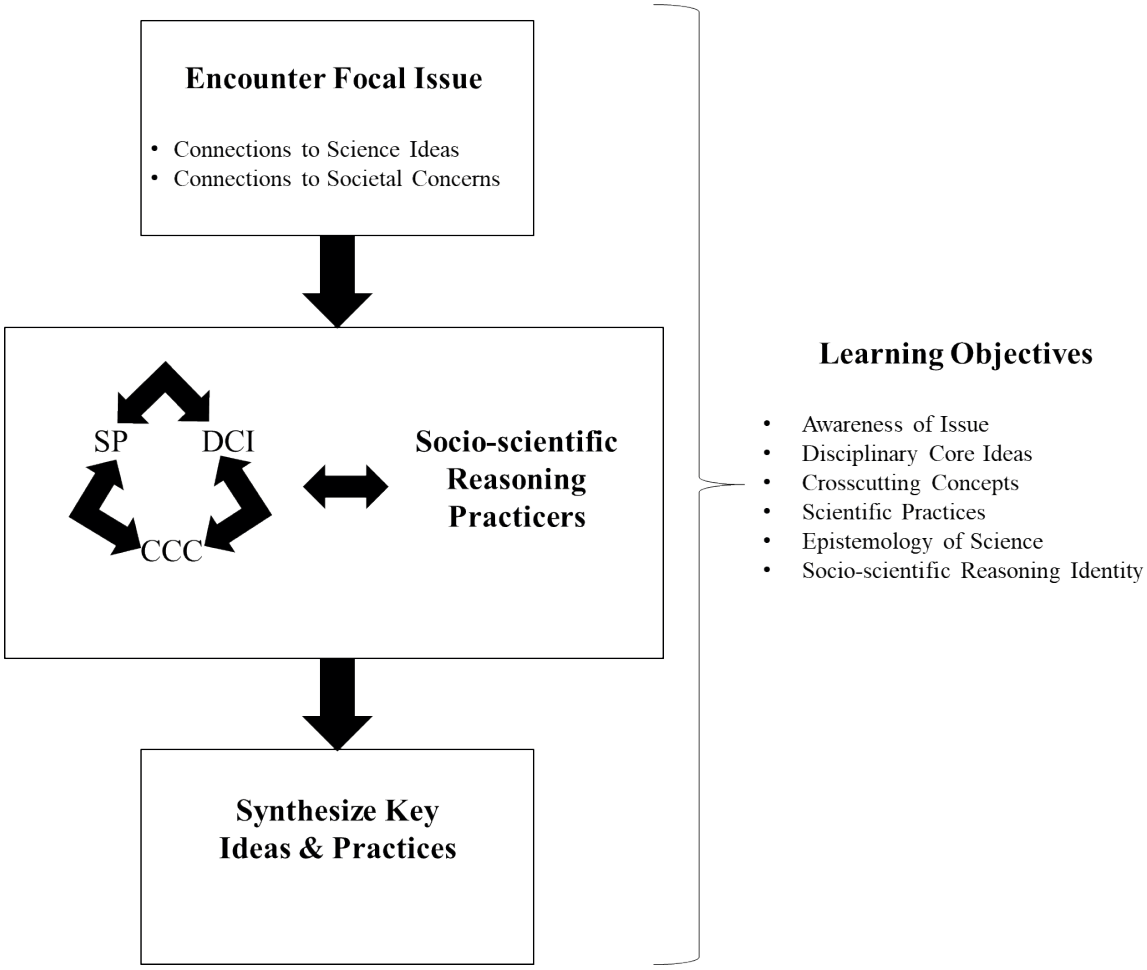
Figure 5. *Model for Teaching Socioscientific Issues (Friefrichsen et al., 2016)*



According to this model, it is recommended to start the lesson with the SSI, which is called the focus topic, at the beginning of the lesson or unit and to allow for a detailed analysis of the SSI. In the next stage, it is a model that advocates that there should be active interaction between the student and the teacher during the process where students are included in applications such as discussion, argumentation and scientific modeling regarding scientific ideas in the lessons. Again, it is recommended that students be given the opportunity to actively use information and communication technologies during the process. In the last stage, students are asked to develop a policy regarding the relevant SSI as a synthesis of all they have learned and a poster is prepared about the SSI and what is learned during the lesson or unit is reflected on the poster at the synthesis level (Topçu, 2021).

Within the scope of a study conducted on developing a SCI-based teaching model, the SSI teaching and learning model was updated (Sadler, Foulk, & Friedrichsen, 2017). This model, shown in Figure 6, has the same main idea as the previous models, but it has been made more current by adding some parts. Unlike the previous models, this teaching model has been updated to include the US National Science Standards (NGSS, 2013). In addition, three-dimensional learning of science education (science subject matter knowledge, interdisciplinary concepts, and science-engineering applications) has been associated with socioscientific reasoning. Another difference is that reflections from these three dimensions are observed in the learning outcomes and the learning outcomes are specifically stated (Sadler et al., 2017).

Figure 6. *Updated Socioscientific Issues Teaching and Learning Model (Sadler et al., 2017)*



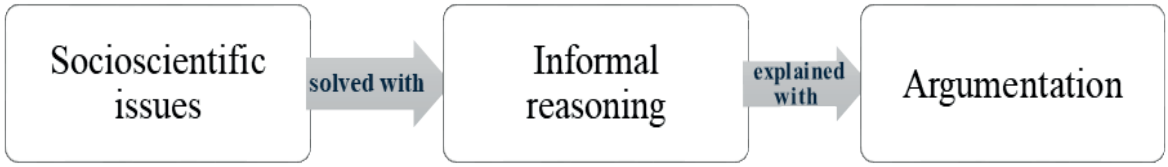
The Relationship Between Socioscientific Issues and Informal Reasoning and Argumentation

Sadler (2004) states that informal reasoning has an important effect on students' coping with problem situations involving socio-scientific issues. Informal reasoning includes reasoning about the pros and cons, advantages and disadvantages, causes and consequences of some events (Zohar and Nemet, 2002). According to Sadler (2004), informal reasoning is defined as a person's ability to evaluate and analyze a complex event rather than simple solutions to that event. Socioscientific issues are ideal topics for applying informal reasoning because they are open-ended, unstructured, and debatable problems (Kuhn, 1993). In this process, individuals consider the pros and cons, risks, and benefits of socioscientific issues from a different perspective and contribute to their evaluation. Therefore, informal reasoning can be considered as a suitable approach for socioscientific issues (Sadler, 2004; Topcu, Sadler, & Tüzün, 2010).

Individuals use informal reasoning skills to resolve any socio-scientific issue they encounter (Shaw, 1996; Sadler & Zeidler, 2005). Informal reasoning can be summarized as the process in which individuals discuss reasons and consequences and establish valid arguments in order to make logical explanations for a particular event they encounter in their daily lives (Sadler,

2004; Zohar & Nemet, 2002). Informal reasoning, individuals can use cognitive and affective processes on issues with uncertain outcomes (Topçu et al., 2010). In this process, students present a claim, a justification, a counterclaim, and evidence to refute the counterclaim (Yılmaz Tüzün, 2013). Students can use the information found in socioscientific scenarios presented to them for discussion, their personal beliefs (Wu, 2013), their experiences, or the information they obtain on any platform (Shaw, 1996) while presenting their arguments in the context of informal reasoning. Socioscientific issues are solved with informal reasoning, and informal reasoning is explained through argumentation (Sadler, 2004).

Figure 7. *Relationship of Informal Reasoning with Socioscientific Issues and Argumentation (Sadler, 2004)*

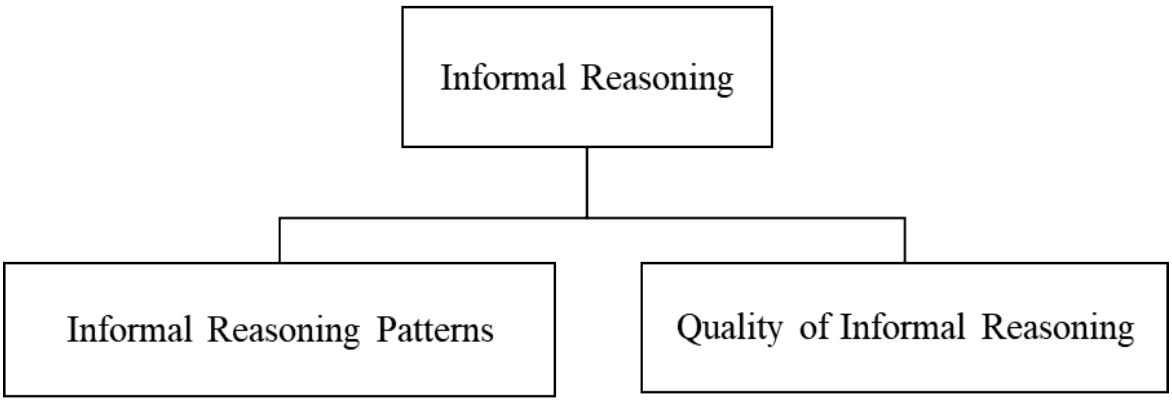


Socioscientific issues are inherently controversial, ill-structured, and complex. For this reason, informal reasoning and arguments in support of claims are important in solving socioscientific problems and making critical decisions (Means & Voss, 1996). A student who wants to make a decision or make a judgment about a socioscientific issue uses informal reasoning skills to create an argument and uses various decision-making mechanisms in this process (Urhan, 2016).

Characteristics of Informal Reasoning

Two basic features stand out in the evaluation of informal reasoning. These are; informal reasoning quality and informal reasoning patterns at Figure 8 (Topçu, 2021).

Figure 8. *Informal Reasoning and Classification*



a) Informal Reasoning Patterns/Modes

Various informal reasoning patterns/modes of students have been used in the literature about socio-scientific issues. These modes are presented in the Table 1.

Table 1. *Classification of Informal Reasoning Patterns*

Researcher(s)	**Patterns/Modes of Informal Reasoning**
Patronis, Potari & Spiliotopoulo (1999)	Ecological, Social, Economic and Practical/Realistic
Yang & Anderson (2003)	Social, Scientific and Equally Organized Reasoning (Both Scientific and Social)
Sadler & Zeidler (2005a)	Intuitive, Rational and Emotional
Wu & Tsai (2007)	Ecological, Social, Economic, Scientific and Technological Focused Arguments
Öztürk & Leblebicioğlu (2015)	Scientific-Technological, Ethical-Aesthetic, Socio-Economic and Ecological
Öztürk & Yılmaz-Tüzün (2017)	Types of Risk, Political-Social, Ecological, Economic, Scientific and Technology Oriented

b.) Quality of Informal Reasoning

According to Topçu (2021), another of the two basic features in the evaluation of informal reasoning is the quality of informal reasoning. In science education literature, the quality of informal reasoning is represented as argumentation (Driver, Newton, & Osborne, 2000). Informal reasoning generally refers to the sum of both affective and cognitive processes in the solution of complex events. It is also stated that argumentation is the form of expression of informal reasoning (Yılmaz-Tüzün, 2013; Topçu, 2021). Therefore, argumentation is an important concept.

Argumentation has an important role in understanding science-based models, applications and concepts in science education. Argumentation in science education can be defined as establishing a connection between claims and data using justifications or evaluating claims through theoretical evidence (Enderun & Jimenez- Alexindre, 2007). With the understanding of the importance of argumentation, there has been a significant increase in argumentation applications in science education from the 1980s to the present (Cavagnetto, 2010). The use of the argumentation method in science classes is considered important because it allows individuals to use their knowledge about a subject they have learned at school during discussions and to express their ideas comfortably and freely while defending them (Çapkınoğlu, 2015).

According to Sadler (2004a), the reason why socioscientific issues are used as content in the argumentation process is that the nature of socioscientific issues contributes to the creation of argumentation from multiple perspectives. It is also stated that individuals are aware of some discussions on socioscientific issues they encounter in daily life and that they contribute to the creation of more complex arguments by making scientific learning meaningful by taking an active role in producing solutions to the problem situation (Osborne et al., 2004). It has been argued that in this way, not only the application of scientific knowledge but also critical thinking is developed

by looking at scientific claims and arguments from multiple perspectives. (Puig and Jiménez-Alexandre, 2011).

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