

Informal reasoning of middle school students on a socioscientific issue

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ABSTRACT

The purpose of this study is to examine the informal reasoning processes of seventh-grade secondary school students regarding a socio-scientific issue. The study employed the case study method, a qualitative research approach. Participants consisted of 19 students who voluntarily participated in the study. In the study, students' informal reasoning about the socio-scientific issue concerning mining activities in a forest-rich region, addressed within the “Conscious Consumption” topic, was examined within the framework of a socio-scientific program developed by the researcher, based on a controversial scenario involving a dilemma. During the four-week implementation period, the researcher assumed the role of participant observer. The analysis of the data revealed that students' informal reasoning was shaped around economic, ecological, social, and political dimensions. It has been observed that the applied socio-scientific program supports students in approaching socio-scientific issues with a multifaceted and critical perspective. Small group discussions, conducted as an integral part of the socio-scientific program, have supported students in freely expressing their ideas, developing alternative perspectives, and presenting arguments aimed at persuading peers with opposing views. In contrast, whole-class discussions have enabled students to present more comprehensive evidence and justify their decisions before the community. Furthermore, it was observed that some students changed their minds during the discussion process based on economic considerations, which pushed universal evaluations based on compassion and empathy into the background.

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Introduction

Controversial issues are complex topics that are influenced by the environment in which people live and can cause disagreement among large groups of people (Oxfam, 2018). In daily life, individuals encounter many controversial issues that encompass social, economic, ecological, and political dimensions. Issues with scientific content that are controversial in nature are referred to in the literature as socio-scientific issues (SSI). SSI are dualistic scientific issues that concern society (Morris, 2014). Many issues that are newsworthy at the local, national, and global levels have socio-scientific content. This exposes children to various SSI from an early age, leading them to become knowledgeable about these issues. Addressing SSI through various reasoning skills and multiple perspectives enriches children's critical thinking skills and broadens their scientific understanding. In the classroom setting, when students are asked to prove their claims and support them with arguments on a SSI without being influenced by others, it enriches their perspective and ensures their intellectual independence (Munby, 1973). Various factors influence the development of intellectual independence in students (Geddis, 1991). Parents, mass media, teachers, friends, and politicians are among the important factors that shape students' perspectives on controversial issues. This situation demonstrates that sociocultural contexts shape students' thought processes regarding SSI.

Therefore, schools and consequently educational programs have important responsibilities. Schools should interact with daily life and social issues. Addressing SSI in schools increases students' interest in school and also equips them with the ability to apply scientific knowledge (Ideland & Malmberg, 2012). Integrating SSI into curricula enables students to think from multiple perspectives and actively participate in the decision-making process (Liu et al., 2010). Additionally, SSI enables students to articulate their ideas, promotes the sharing of diverse opinions, and fosters the development of multiple perspectives. SSI deepens students' opinion-forming processes, equipping them with critical thinking and empathy skills. As the adults of the future, it is important for children to be able to express themselves freely, respect different points of view, and support their ideas with arguments, in terms of the sustainability of democratic societies and the strengthening of social welfare (Chung et al., 2016). The decisive role of SSI in developing critical thinking, communication, and democratic participation skills in students necessitates an in-depth examination of their thinking and decision-making processes in these areas. In this regard, this study examined students' informal reasoning on a SSI.

Socioscientific issues

Thanks to the development of internet-based media technologies, people are quickly becoming aware of developments around the world and engaging with them (Klosterman et al., 2012). This situation brings societies into contact with SSI more frequently than ever before (Topçu, 2015; Wu & Tsai, 2007). These topics, shaped around the axis of science, technology, and society, involve complex social issues that often force individuals to make decisions in their daily lives (Adal & Çakıroğlu, 2022, p. 2; Dalyot et al., 2022; Kolstø, 2001; Herman et al., 2022; Sadler, 2004; Taylor et al., 2018). Therefore, SSI-based education supports individuals in making conscious decisions when faced with such complex issues and prepares students to internalize these decision-making processes (Bossér, 2018). When discussing a socio-scientific issue, individuals seek to present arguments to prove their views. This search for evidence to support their views from different perspectives develops informal reasoning (Eastwood, Schlegel, & Cook, 2011). SSI develops students' discussion and decision-making skills (Klaver et al., 2022). The reflection of SSI, which are frequently on the public agenda, in education is inevitable (Tekin et al., 2016). The frequent coverage of SSI in the press and social media influences teachers and students to bring these topics into the classroom. The student's environment may also necessitate the transfer of the SSI to the classroom. As Öztürk and Yılmaz Tüzün (2017) point out, citizens living in cities without nuclear power plants may debate nuclear power plants from an economic perspective, while citizens living in cities with nuclear power plants may debate them from an environmental perspective. The environment in which people live and the place of the socio-scientific issue on the agenda cause differences in the content of informal reasoning.

Whether or not people have knowledge about a socio-scientific issue also leads to differences in their reasoning. For example, someone who is uninformed about the damage that excessive fertilization can cause to water resources will not consider the ecological dimension of fertilization (Kortenkamp & Moore, 2001, p. 8). The systematic inclusion of SSI, which is frequently encountered in daily life, in schools develops students' reasoning skills. Education provided in schools plays an important role in the development of students' evidence-based reasoning skills (Dawson & Carson, 2020). Addressing SSI from different perspectives in different subjects can enrich students' multiple perspectives, but SSI remains more within the boundaries of science (Eastwood et al., 2012; Ratcliffe & Grace, 2003). By its very nature, SSI has the ability to enrich multiple perspectives. The examination of different scientific disciplines also enriches this perspective. Incorporating SSI into lessons confronts students with real-life problems and equips them with the skills to solve these problems (Abd-El-Khalick, 2003). SSI, which is scientifically based, socially relevant, and designed to capture students' interest, increases classroom participation (Dolan et al., 2009; Sadler & Zeidler, 2005). Approaching SSI from different perspectives creates a democratic classroom environment. A democratic classroom environment is one of the key factors that increase class participation (Ekborg et al., 2013; Ratcliffe & Grace, 2003; Sadler, 2011; Zeidler & Schafer, 1984).

During the process of discussing SSI, students strive to make their own arguments and claims strong because they see the claims, arguments, and perspectives of others (Zeidler et al., 2003). Students strive to prove their opinions and refute opposing views, and they possess the ability to develop their arguments (Lin & Mintzes, 2010; Means & Voss, 1996). The arguments produced to prove opinions and refute opposing ideas develop students' informal reasoning skills (Wu & Tsai, 2007). Even if students' informal reasoning develops similarly on a socio-scientific issues, their perspectives on the issue may differ. While one student may approach the same issue from an environmentalist perspective, another student may approach it from a human-centered perspective (Atabey & Topçu, 2020, p.92).

Today's science and technology-oriented societies are showing increasing interest in SSI. In recent years, SSI-based discussion and reasoning skills have been given greater consideration in education (Rundgren & Rundgren, 2010). Teachers' ability to manage the discussion process affects the implementation of SSI-based activities in the classroom in the same way (Reis, P. & Galvao, 2009). The teacher's experience,

attitude, and perspective toward the subject lead to socio-scientific issues (SSI) being addressed either in a superficial or in a more in-depth manner (Ratcliffe & Grace, 2003). Teachers who hold a positive attitude are more aware of how their students interpret the issue and are able to manage the discussion process more effectively (Zeidler et al., 2003). Socio-scientific issues attract students' attention because they are closely related to situations encountered in their everyday lives, and they enable students to recognize and consider others' perspectives during discussions in which they participate (Lin & Mintzes, 2010). Moreover, discussions characterized by interaction enhance the quality of students' reasoning. Addressing socio-scientific issues in an interactive manner contributes to the development of students' communication skills (Chung et al., 2016). However, in order for students to communicate effectively, a free and supportive learning environment must be established. Students should be able to express their views openly, regardless of whether those views are accepted by others (Ekborg et al., 2013). When an appropriate learning environment is provided, SSI education enables students to develop skills such as collaboration, decision-making, problem-solving, and effective communication (Zeidler et al., 2011). In order to cultivate these competencies, rich and diverse learning contexts should be offered. Through such environments, students are better able to approach issues that involve multiple perspectives from a multidimensional standpoint (Simmons & Zeidler, 2003). In this way, engagement with SSIs provides students with experiential preparation for addressing similar challenges they may encounter in the future (Sadler, 2009). Participation in SSI-based discussions further enhances students' sense of responsibility and increases their willingness to take action in response to complex societal problems (Lee et al., 2013).

Informal reasoning

Informal reasoning refers to a type of reasoning in which claims are evaluated when a problem is open-ended, complex, and ill-structured (Means & Voss, 1996; Sadler, 2004). Because issues are examined in a natural manner by weighing their advantages and disadvantages, informal reasoning is particularly suitable for SSI (Dawson & Venville, 2009; Johnson & Blair, 1991; Jones, 1991). In order to engage in informal reasoning, individuals must adopt an inquiry-oriented perspective. Those who uncritically accept the views of perceived experts as inherently correct when confronted with a problem are unable to engage in informal reasoning (Liu et al., 2010; Öztürk & Yılmaz-Tüzün, 2017). Moreover, individuals who are not permitted to consider alternative perspectives or who are not given the opportunity to support their claims with arguments cannot effectively engage in informal reasoning (Chung et al., 2016). Because informal reasoning involves an effort to persuade, students are motivated to substantiate and justify their views (Bailenson & Rips, 1996). In doing so, they generate arguments and approach issues from multiple perspectives (Voss, 1991; Wu & Tsai, 2007). By evaluating counterarguments, students gain the opportunity to reconstruct and refine their own arguments (Wu, 2013, p. 1875). In this way, informal reasoning promotes deep thinking and fosters higher-order cognitive skills (Newmann, 1991). Incorporating reasoning-based questions not only in instructional activities but also in formative assessment questions and examinations further contributes to the development of students' informal reasoning skills (Reilly & Hamilton, 1991).

In everyday life, individuals frequently engage in informal reasoning. However, the development of advanced informal reasoning skills requires deliberate and systematic planning (Gelder & Bissett, 2004). Issues such as global warming and genetically modified organisms emerge as pressing global concerns. Through social media and television programs, these topics remain consistently present in public discourse. Although they are discussed from multiple perspectives, without intentional and structured guidance, such discussions tend to remain at the level of lower-order informal reasoning skills. Even when individuals generate strong arguments to refute opposing views or defend their own positions, biases may hinder the acceptance of these well-founded arguments (Thompson & Evans, 2012). This is because informal reasoning is influenced by a variety of factors (Norris, 1991). The specific factors that shape individuals' viewpoints typically emerge during the process in which informal reasoning is examined and analyzed.

Issues derived from everyday life and societal contexts should be incorporated into school curricula (Ideland & Malmberg, 2012; Simonneaux, 2007). SSI are topics that students frequently encounter in their daily lives (Kolstø, 2001). SSI-based education involves a reasoning process centered on everyday and societal matters (Barko et al., 2011). By promoting critical thinking, awareness of stereotypes, and problem-solving skills, SSIs contribute to the development of students' informal reasoning abilities. The socio-scientific issue selected for this study—mining activities in forested areas—is frequently debated in society with respect to both its positive and negative aspects. Addressing issues that generate public awareness and remain prominent on the social agenda is therefore of considerable importance.

Aims of the current research

The present study aims to examine secondary school students' informal reasoning processes regarding a socio-scientific issue within the framework of a socio-scientific instructional program. Specifically, the study seeks to determine how students generate justifications for their views across different phases of the

program (written documents, small-group discussions, and whole-class discussions), the orientations (economic, ecological, social, and political) underlying their arguments, and how their interactions with one another lead to changes in their thinking processes.

Accordingly, the following research questions were addressed:

1. How do seventh-grade students justify their views on the socio-scientific issue across the different phases of the program (the written scenarios, the small-group discussions, and the whole-class discussions)?
2. What orientations (economic, ecological, social, and political) underlie the students' informal reasoning?
3. How do the students' interactions with one another during the program lead to changes in their reasoning and positions?

Method

In this study, a socio-scientific instructional program designed for seventh-grade students, as illustrated in Figure 1, was implemented, and students' informal reasoning processes were examined. A qualitative case study design was employed. The study was conducted with 19 seventh-grade students (10 girls and 9 boys) from two different classes at a state school, selected through convenience sampling. To ensure participants' confidentiality, real names were not used; instead, pseudonyms that would not evoke their identities were assigned. Prior to implementation, informed consent was obtained from the parents/guardians of the participating students, and assent was obtained from the students themselves; participation was voluntary, and the students were informed that they could withdraw from the study at any time. The data were accessible only to the researcher, were stored securely, and were used solely for scientific purposes. In forming the small groups, students' communication patterns and gender distribution were taken into consideration. Small groups were established after the initial completion of the scenario forms. Given that the scenarios were designed to present dilemmas, particular attention was paid to bringing together students with differing perspectives within the same groups. In this way, it was intended that students would interact with diverse modes of thinking, refine their arguments, and develop multiple perspectives understanding.

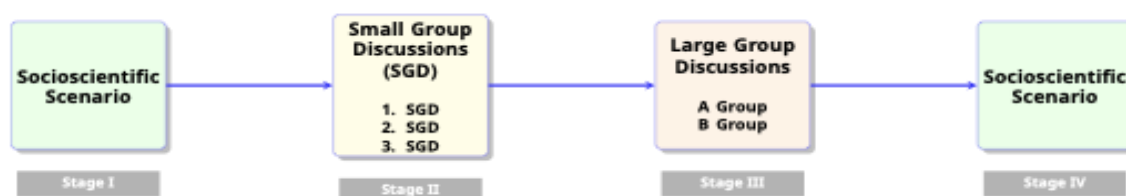


Figure 1: Data Collection Tools Used in the Research

Instruments

Data were collected through instruments developed within the scope of the socio-scientific instructional program. These instruments are listed and described in Figure 1. The scenario administered at both the beginning and the end of the program was developed by the researcher. The scenario, prepared in alignment with the "Conscious Consumption" topic in the social studies curriculum, was designed to present a dilemma. This dilemma is consistent with the "Conscious Consumption" objective, as deciding whether to extract mineral resources at the expense of a forest area requires students to weigh the use of natural resources against environmental conservation, which lies at the heart of conscious and responsible consumption. It addressed the significance of both forests and mining activities and posed the following question: *"In a region rich in forest resources, substantial mineral deposits have been identified. In your opinion, should mining activities be carried out in this region? Why?"*

Each small group consisted of three students, except for the sixth group, which included four students. In forming the groups, careful attention was paid to bringing together students with differing viewpoints. By combining the small groups, two separate whole-class groups were formed. The rationale for creating two large groups was to prevent data loss and to enhance students' individual participation. The large groups were formed randomly. The students constituting the large groups are presented with pseudonyms in Figure 2.* The program was implemented over a four-week period, during which the activities were carried

out in the following sequence: an initial written scenario, three small-group discussions, a whole-class discussion, and a final written scenario.

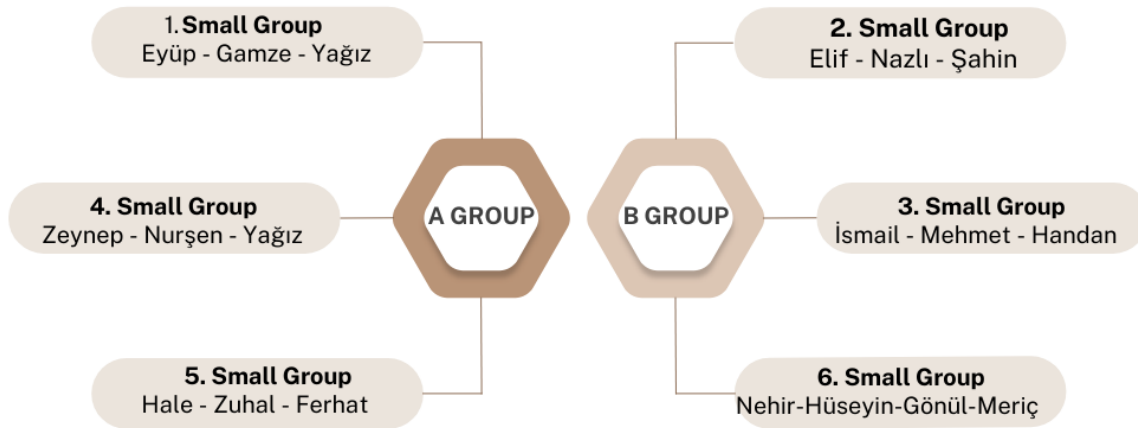


Figure 2: Smaller Groups Forming Larger Groups

Data analysis

Content analysis was employed to evaluate the data. Following data collection, the data were transcribed immediately and converted into written documents. The small-group discussions were audio-recorded, whereas the whole-class discussions were video-recorded. In the coding process, themes identified in the literature prior to data collection (Lee et al., 2012) were integrated with codes that emerged after the data were collected (Creswell, 2009). Additionally, new codes were generated during the analysis process. The analyses were conducted in accordance with the character and values analysis framework presented in Table 1 developed by Lee et al. (2012). In the coding process, two researchers first coded a certain portion of the data set both independently and collaboratively; the resulting codes were then compared, and the code definitions and theme boundaries were clarified. Following this consensus process, the first author applied the coding to the entire data set, while the second author re-examined a certain portion of the coded data to evaluate coding consistency. Discrepancies were resolved through discussion, and the final coding framework was established on the basis of researcher consensus.

Trustworthiness

Several measures were taken to ensure the trustworthiness of the study. Credibility was supported through the triangulation of multiple data sources (the written scenarios, the small-group discussions, and the whole-class discussions), the prolonged engagement provided by the four-week implementation, and member checking, in which participants were asked to confirm the researchers' interpretations of their views. In addition, the scenario and the coding framework were reviewed by field experts prior to implementation. Transferability was addressed by providing a detailed description of the research context, the participants, and the procedures, so that readers can assess the applicability of the findings to other settings. Dependability was strengthened by the coding of the data by two researchers, the consistency check, and the resolution of discrepancies through consensus, as well as by the consistent application of the character and values framework of Lee et al. (2012). Finally, confirmability was supported by grounding all interpretations in the raw data and by presenting direct quotations from the transcripts, so that the findings can be traced back to the participants' own statements.

Researcher role and reflexivity

Several steps were taken to limit the researcher's influence on the participants and on the interpretation of the data. During the discussions, the researcher adopted the role of a neutral facilitator and observer, refrained from expressing personal views or taking sides, and did not steer students toward any particular position. Students were repeatedly reminded that there were no right or wrong answers and that they were free to express their own views; participation was voluntary, and a comfortable environment was maintained so that students could express their views freely. In the analysis, the data were coded by two researchers and discrepancies were resolved through consensus, as described in the Trustworthiness section.

Table 1: Lee et al. (2012) Character and Values Analysis Table

	Defining Characteristic	Ecological Worldview	Socio-Scientific Responsibility	Social and Moral Compassion
Individual	It is grounded in personal interest, curiosity, or emotional considerations.	Its primary concern is not environmental protection, but rather personal benefits or interests	Feels a sense of responsibility regarding personal matters. Its primary concern is personal benefits or interests.	Demonstrates empathy and respect toward individuals or living beings with whom they share close relationships (e.g., family members, friends).
Societal	It is grounded in the region or country in which the individual resides.	Its primary concern is the benefits or interests of the region or country in which the individual resides. It focuses predominantly on the immediate environment. The individual may experience difficulty in comprehending the relationship between the broader global system and the local environment in which they live.	Feels a sense of responsibility regarding issues related to the region or country in which they reside. Assumes responsibility for how their personal decisions and actions affect individuals within their local context. Demonstrates willingness to take action to address problems within their region	Demonstrates empathy and respect toward individuals or living beings within the region or country in which they reside. Acknowledges and values the diversity of viewpoints present within their local context.
Global	It is grounded not in individual or societal interests or curiosities, but rather in broader value-based considerations.	Its primary concern is the protection of nature. It recognizes that human beings are an integral part of the natural system.	Feels and assumes responsibility for issues of universal significance. Exhibits a willingness to take action in order to address global problems	Demonstrates empathy and respect toward other individuals or living beings across the globe. Recognizes and values the diversity of perspectives present in different parts of the world.

Findings

Findings related to the pre-scenario

In the scenario, students demonstrated a strong ecological worldview characterized by a universal perspective. In their statements, they emphasized ecological sensitivity, ecological balance, natural disasters, environmental pollution, and the rights of future generations, thereby reflecting a predominantly ecological orientation. Within the societal dimension of the ecological worldview category, particular emphasis was placed on natural disasters. However, a personal perspective was not observed within this category. In the socio-scientific responsibility category, students' views were largely grounded in a societal perspective and articulated through multiple viewpoints. While expressing their opinions, students compared Türkiye with other countries and voiced political and economic concerns related to Türkiye. In particular, they highlighted societal welfare, employment, and economic development, thereby demonstrating an economic orientation. Students underscored the significant role of mining in the development of industrialized countries. They further stated that mineral resources contribute substantially to reducing the foreign trade deficit, attaining the welfare levels of developed countries, generating employment, and decreasing unemployment. One student, Gamze, expressed her views on this issue as follows:

"Through mining activities, we can achieve development; exports would increase and imports would decrease, which is particularly important for a developing country. Moreover, it would reduce unemployment and contribute positively to our national economy."

Within the personal dimension of the socio-scientific responsibility category, economic concerns were predominant. These concerns encompassed expectations such as improving living standards, securing stable and high income, and obtaining employment in a profession free from the risk of unemployment. For example, a student named Nurşen expressed her concerns on this issue as follows:

"If we consider our own future, if we wish to have employment and to improve our family's well-being, we must assume this responsibility."

A universal perspective was not identified within the socio-scientific responsibility category. Students approached the socio-scientific issue from multiple social and moral standpoints. At the personal and societal levels, concerns were predominantly centered on health and the right to life, whereas at the universal level, their statements emphasized respect for all living beings, as well as the significance of shelter and rest. In the social and moral compassion category of the scenario, it was observed that students' personal perspectives were limited. When empathy was involved, students tended to approach the socio-scientific issue predominantly from a universal perspective. For those who adopted a personal standpoint, their informal reasoning appeared to be shaped largely within a socially oriented framework. Within this framework, students addressed the issue from an environmentalist perspective. Their socially oriented statements emphasized the importance of a healthy and high-quality life. For instance, a student named Zeynep expressed her views on this issue as follows:

"For me, my family's health and living in a healthy environment are of utmost importance. If forests are destroyed, we may no longer be able to breathe clean air, and perhaps this could even lead to our death."

In the scenario, within the social and moral compassion category, students' societal perspectives were found to be shaped within a socially oriented framework. Students grounded their concerns about society, much like their concerns for themselves and their families, in the principles of maintaining a healthy and high-quality life. Students' evaluations suggesting that the destruction of forests would increase public health problems and lead to higher mortality rates in the long term are particularly noteworthy. In the scenario, it was observed that students most frequently expressed their views from a universal perspective within the context of social and moral compassion. When evaluating the issue within the context of conscience and empathy, students strongly emphasized that they respect not only human beings but all living creatures. Within this category, it was observed that the views of students adopting an environmentalist perspective became particularly prominent and that their informal reasoning was shaped within a socially oriented framework. In socially oriented statements, themes such as health, quality of life, the right to shelter, and belief were particularly prominent. Students grounded their concerns about health in the view that health is paramount, that environmental pollution exacerbates health problems, and that the degradation of the natural environment adversely affects human life expectancy. Furthermore, students emphasized that all living beings possess the right to life and that environmental pollution leads to the death of living organisms. Some students, drawing on their religious beliefs as justification, stated that killing living beings or interfering with their natural habitats is morally wrong and sinful. Expressing this perspective, Zeynep articulated her views as follows:

"If forests did not exist, people would not be able to breathe healthily. Moreover, I believe that intentionally killing humans or animals is a grave sin. Even cutting down living trees is sinful; if a tree has already dried out, that is a different matter."

When the findings related to the scenario are evaluated comprehensively, it is evident that within the ecological worldview category, students predominantly demonstrated a universal perspective. In their ecologically oriented statements, students emphasized themes such as ecological sensitivity, ecological balance, natural disasters, environmental pollution, and the rights of future generations. Within the societal dimension of the ecological worldview category, concerns particularly related to natural disasters appeared to be dominant. In the socio-scientific responsibility category, students were observed to make evaluations primarily from a societal perspective. In this category, they addressed the socio-scientific issue through multiple perspectives; comparisons with other countries, political inferences, and economic concerns emerged prominently. When evaluated from a personal perspective within the same category, economic concerns appeared to be more pronounced. Within the social and moral compassion category, it can be argued that students developed a multi perspectives understanding. While at the personal and societal levels they primarily expressed concerns related to health and quality of life, at the universal level their perspectives displayed notable diversity. In this context, students offered more inclusive evaluations grounded in compassion toward all living beings, religious beliefs, and the right to life.

Findings related to the first small-group discussions

In the first small-group discussions, similar to the scenario phase, no views were expressed from a personal perspective within the ecological worldview category. At the societal level, however, it was observed that students approached the issue from a more diverse range of perspectives compared to the scenario phase. After reflecting on the scenario and engaging in interaction with one another, students began to consider the issue from different viewpoints and addressed the problem from multiple angles. For instance, whereas no student addressed environmental pollution from a societal perspective in the initial scenario, during the first group discussions students referred to the societal problems associated with environmental pollution. The emergence of diverse perspectives can be attributed to the defenses students articulated in response to opposing views and the arguments they generated in support of their positions. Moreover, within the

universal dimension of the ecological worldview category, it was observed that students increasingly adopted diverse perspectives and placed greater emphasis on the issues under consideration. Students stated that environmental damage has global consequences and that the operation of mines in forested areas would lead to air pollution. They further emphasized that the destruction of forests undermines their role in preventing natural disasters such as landslides, avalanches, floods, and erosion. Whereas environmental pollution received relatively little emphasis within the universal category in the initial scenario, it emerged as the most prominently highlighted issue during the first small-group discussions. This shift can be attributed to students' exposure to differing viewpoints within the group, as well as their engagement with the defenses and arguments articulated by their peers. The consideration of issues such as water scarcity and drought for the first time within the universal category of the ecological worldview serves as a notable example of this development. Students sought to persuade peers holding opposing views by presenting arguments grounded in diverse perspectives. For instance, a student named Zeynep attempted to convince her group members who held differing opinions by drawing attention to the long-term consequences of deforestation, expressing her views as follows:

"When forests are destroyed, desertification occurs. Even if every place were filled with factories, life could not be sustained once the environment has turned into a desert. What would you do in such a situation?"

Within the personal dimension of the socio-scientific responsibility category, it was observed that the views expressed in the pre-scenario phase remained unchanged. In the first small-group discussions, students continued to address the issue primarily in terms of welfare and employment, consistent with their initial evaluations. In the societal dimension of the socio-scientific responsibility category, however, students were found to approach the issue from diverse perspectives. By presenting different viewpoints, they sought to persuade peers holding opposing positions. While no views were identified within the universal dimension of the socio-scientific responsibility category in the initial scenario, the small-group discussions revealed the articulation of perspectives reflecting greater diversity at the universal level. This shift appears to be influenced by the fact that, during the small-group discussions, students holding opposing views articulated their ideas from a universal perspective and expressed concerns related to all living beings. Students felt the need to generate arguments in order to refute counterviews. For example, although a student named Hale initially adopted an environmentalist perspective prior to the discussion, she reconsidered her position during the first small-group discussion and revised her viewpoint. In an effort to persuade her peers, Hale emphasized that extracting minerals does not preclude assuming responsibility and articulated her suggestions regarding concrete actions to be taken as follows:

"If one wishes to promote sensitivity toward nature, one could initiate an activity, disseminate information about it, and develop slogans. If the genuine aim is conservation, it is necessary to inform and raise awareness among people. In my view, it is essential to assume this responsibility for the sake of forests, animals, and human beings."

It was observed that, within the personal and societal dimensions of the social and moral compassion category, students enriched their perspectives during the small-group discussions. The frequent use of empathetic prompts during the discussions (e.g., "What if you were in their place?", "Put yourself in their position," "Imagine that it were you") played a significant role in broadening their viewpoints. In order to persuade one another, students presented diverse perspectives centered on the theme of health. The following dialogue, in which students from the first group articulated opposing views related to health, exemplifies this situation:

"What will happen if people grow up in an unhealthy environment? Polluted air will lead to diseases, and our citizens will become ill." (Eyüp)

"However, there are remedies for diseases. Even at present, treatment methods are available; as our country develops, more effective solutions can be identified." (Gamze)

Within the universal dimension of the social and moral compassion category, it was observed that students' perspectives became more diversified compared to the pre-scenario phase. Throughout the discussions, students approached all living beings with empathy, and views were expressed across all groups. In this category, students' informal reasoning was shaped within a socially oriented framework. Socially oriented statements prominently emphasized themes such as health, the right to life, shelter, belief, and psychological effects. Students who expressed opinions indicated that their sense of responsibility extended not only to themselves or the society in which they live but to all living beings. They emphasized that the destruction of forests would eliminate the natural habitats of living organisms, that forests constitute essential living spaces particularly for animals, and that harming the lives of humans, animals, or plants is morally wrong and sinful. In this regard, Handan's statements are particularly noteworthy:

“Human life is more important than your industry; are you not aware of this? This is sinful—indeed, a grave sin. One will be held accountable before God for it. The moral burden is substantial.”

Students further stated that environmental pollution would increase health problems, that a clean environment is essential for a healthy life, and that human health takes precedence above all else. When the theme of health is approached from a universal perspective, it becomes evident that students' evaluations are predominantly shaped by an environmentalist orientation. It is also noteworthy that students who did not adopt an environmentalist perspective did not articulate any statements related to health within this category. Particularly in relation to the right to life, students appear to have developed a biocentric approach. They asserted that all living beings possess an equal right to life without hierarchical superiority. As an example of this perspective, the following statement by Eyüp from the first group may be cited:

“What about other living beings? The animals... Are we to remain indifferent to their deaths?”

Findings related to the second small-group discussions

In the second small-group discussions, similar to both the scenario phase and the first small-group discussions, no views were expressed within the personal dimension of the ecological worldview category. In the societal dimension of the ecological worldview category, however, it was observed that, compared to the first small-group discussions, the diversity of views and perspectives expressed had decreased. This outcome appears to have been influenced by the fact that some students shifted from an ecocentric to an anthropocentric perspective during the first small-group discussions. While four students initially adopted an ecocentric viewpoint in the first round of discussions, they articulated their views from an anthropocentric perspective in the second small-group discussions. It is particularly noteworthy that two students from the fifth small group changed their views. This is significant because the group consisted of three students, all of whom had adopted an ecocentric perspective during the first small-group discussions. However, two students from the group entered the second small-group discussions having changed their views. Whereas none of the students in this group had adopted an anthropocentric perspective during the first small-group discussions, they stated that they revised their positions as a result of the discussions and research conducted throughout the process. Students who changed their views stated that, as a result of their research, they learned that mining has a significant impact on the national economy and contributes to increasing citizens' welfare levels by providing employment opportunities. For instance, a student named Zuhail explained the reason for her change in perspective as follows:

“As I mentioned before, I initially prioritized environmental concerns; however, after conducting further research and reflecting on the views I had defended, I reconsidered my position. Mining is highly important for our national economy and also provides employment opportunities across various sectors.” (Zuhail)

The other two students who changed their views were members of the second small group. Economic considerations played a decisive role in their shift in perspective. These students stated that they had come to recognize the significant contribution of mining to economic development and, consequently, revised their views accordingly. After students revised their views, no statements were observed within the social and moral compassion category during the second small-group discussions. Once all members of the group adopted an anthropocentric perspective toward the socio-scientific issue, a heightened emphasis on responsibility toward their country became evident, and the discourse shifted predominantly toward themes of responsibility. For example, students named Nazlı and Şahin explained the reasons for their change in perspective as follows:

“I believe that the national economy will develop further through mining activities. I now think differently and have changed my views.” (Nazlı)

“Mineral resources are not found everywhere, and our country is a developing one; therefore, I think it would be more appropriate to extract them.” (Şahin)

It is evident that the students who revised their views grounded their justifications within the societal dimension of the socio-scientific responsibility category. Their changes in perspective appear to have stemmed from the research they conducted, their engagement in reasoning about the views presented during the first small-group discussions, and their economic concerns. Compared to the initial discussions, a decrease in the diversity of perspectives was observed within the personal and societal dimensions of the social and moral compassion category. Students articulated a universal perspective grounded in compassion toward all living beings. The highest number of statements reflecting a universal perspective was identified in the fourth small group. Notably, within this category, only one student—Zeynep—expressed a view in that group. Zeynep was also the only student in her group who maintained an environmentalist perspective. In an effort to persuade her peers holding opposing views, she presented multifaceted arguments framed around conscience and compassion. The following statement exemplifies Zeynep's perspective:

“We cannot disregard the lives of wild animals. Which living being can we deem expendable? Is this not sin?”

Findings related to the third small-group discussions

In the third small-group discussions, it was observed that three of the groups articulated views across all categories except for the personal dimension of the ecological worldview category. In seeking to substantiate their positions, students presented multiple perspectives and approached the issue from diverse viewpoints. Furthermore, students' statements related to the ecological worldview demonstrated a greater degree of scientific grounding compared to previous discussions. They emphasized the need for more extensive scientific research on environmental issues, the importance of supporting such research with practical applications, and expressed the view that these efforts would contribute to increasing public awareness. In the third small-group discussions, students predominantly articulated their views from the societal dimension of the socio-scientific responsibility category, while the least emphasis was placed on the personal dimension of the social and moral compassion category. In matters related to conscience and compassion, students adopted an empathetic perspective toward all living beings, thereby demonstrating a universal stance. In political and economic matters, students expressed a sense of responsibility toward their country. For instance, a student named Gönül articulated her concern for her country as follows:

“If we do not become a developed country, I believe we will not attract anyone's attention.”

There was one student who entered the third small-group discussions having changed his view. This student, who reported experiencing confusion during the second small-group discussions, stated that prior to the third round he sought answers to the questions he had in mind, conducted research, and was influenced by the ideas of his group members, ultimately leading him to revise his perspective. The student, Mehmet, explained the reason for his change in view as follows:

“I was somewhat influenced by what you expressed during the second discussions, as my own research also indicated that environmental considerations are more important.” (Mehmet)

The group discussions, the time allocated for reflection on the arguments presented, and the research conducted to substantiate or refute viewpoints had a positive impact on the development of students' informal reasoning skills. When the findings obtained from the first group discussion are examined, they may generally be evaluated as follows:

It was observed that some students altered the views they had initially defended during the small-group discussion process and began to articulate positions supporting opposing perspectives. This shift appears to have been influenced by the contributions of other group members and the arguments presented during the discussion. For example, during the initial small-group discussions, a student named Şahin transitioned from an ecocentric perspective to an anthropocentric one. Throughout the discussion process, Şahin was observed to remain in a state of dilemma. The primary reason for this indecision was the influence of his peers, whose views differed from his own. The arguments advanced by the other two group members significantly affected Şahin during the discussion. Ultimately, Şahin expressed his indecision as follows:

“I myself became uncertain about which side to take. Whatever I say, friends, perhaps I should refrain from commenting; I remain undecided—please continue.”

This student, who initially remained undecided, changed his views during the small-group discussion process. He explained that his shift in perspective was influenced by the views expressed by other group members, stating:

“Your statements suggesting that countries which are economically underdeveloped or developing are also underdeveloped in the political sphere convinced me and played a significant role in changing my views.” (Şahin)

Another student who changed his views during the small-group discussions was Harun. Initially expressing opinions aligned with an ecocentric perspective, Harun gradually shifted toward an anthropocentric standpoint. It was observed that this change in perspective was influenced by the other members of the group. Harun explained the reason for his shift in views as follows:

“In the initial discussion, what Nurşen expressed in the previous debate influenced me significantly. I believe Nurşen is correct. Economic prosperity facilitates advancement in the field of technology, and technological development, in turn, contributes to progress in the domain of health.”

After revising his views, Harun refrained from presenting arguments during the discussions and instead adopted a more inquisitive stance. By posing questions such as “Why is that?” and “How does that occur?” he both guided the conversation and facilitated a more in-depth elaboration of the views expressed by group members.

Findings related to the whole-class discussions

In the whole-class discussions, it was observed that students concentrated their views within the societal dimension of the socio-scientific responsibility category. Students expressed a sense of responsibility regarding their country's economic and political challenges and emphasized that national interests should be prioritized in decision-making processes. Another category in which students most frequently articulated their views was the universal dimension of the social and moral compassion category. In their efforts to persuade those holding opposing views, students repeatedly emphasized the need to consider the well-being of all living beings and to approach all forms of life with empathy. Similar to the pre-scenario phase and the small-group discussions, students refrained from adopting a personal ecological perspective during the whole-class discussions. Throughout the socio-scientific program, it was observed that students distanced themselves from personal interests related to the environment and instead expressed broader concerns directed toward the world and the environment in which they live. During the whole-class discussions, it was observed that none of the students changed their views. Instead, drawing upon the positions they had previously researched and debated, students sought to persuade their peers of the validity of their existing viewpoints. Because the whole-class discussions largely consolidated and reiterated the arguments that students had already developed in the small-group phase, rather than generating new lines of reasoning, this subsection is presented more concisely and without separate illustrative quotations.

Findings regarding the final scenario

It was observed that students demonstrated fewer multiple perspectives in the final scenario. During peer interactions, however, they articulated their ideas using diverse justifications in order to persuade those holding opposing views and to substantiate their own positions. The connections between the issue and its psychological dimensions, religious beliefs, and societal problems—topics that were addressed during the small-group discussions—were not reflected in the final scenario. In the absence of direct interaction in the written format, the presence of multiple perspectives was observed to be more limited. The implemented socio-scientific program enabled students to develop diverse perspectives and enriched the content of their statements. Throughout the course of the program, it was observed that students' priorities within the universal dimension of the ecological worldview category underwent a notable shift. At the beginning of the socio-scientific program, emphasis was placed on natural disasters, ecological sensitivity, and ecological balance, whereas by the end of the program, greater emphasis was given to the natural environment, environmental pollution, and natural disasters. It was also observed that the content of students' future-oriented concerns evolved throughout the program. While initial discussions centered on the rights of future generations, the concluding phase highlighted the importance of environmental sustainability. It was observed that students who initially held an ecocentric perspective tended to frame their views predominantly within the societal dimension of the socio-scientific responsibility category after revising their positions. Similarly, students who initially adopted an anthropocentric perspective and subsequently changed their views did not articulate any statements within the societal dimension of the socio-scientific responsibility category following their shift in perspective. Whereas no statements were observed within the universal dimension of the socio-scientific responsibility category at the beginning of the program, it was evident that by the conclusion of the socio-scientific program, students articulated views within this category. By the end of the program, students' universal perspective had strengthened. Compared to the small-group discussions, a decrease in the diversity of perspectives was observed within the societal and universal dimensions of the social and moral compassion category. During interactive exchanges, students diversified their viewpoints in order to encourage those holding opposing views to engage empathetically and to approach the issue with compassion. As the final scenario was completed individually in written form, it did not produce the dialogic, face-to-face exchanges that characterised the small-group discussions; accordingly, this subsection reports the overall patterns of change across the program rather than extended verbatim excerpts.

Conclusion and discussion

Throughout the implementation of the socio-scientific program, statements were predominantly concentrated within the societal dimension of the socio-scientific responsibility category. Although students occasionally articulated a universal perspective during the program, this perspective remained secondary to the societal viewpoint. Students primarily emphasized their responsibilities toward their own country and tended to propose solutions at the national level. Societal responsibility was most frequently addressed from an economic standpoint. During the program, political statements encompassing technological and scientific developments were also observed; however, these expressions remained less prominent compared to economic orientations. Students consistently underscored that political power is

contingent upon economic strength. This finding is supported by existing literature. For instance, Albe (2008) similarly reported that statements emphasizing scientific and technological dimensions were comparatively less pronounced.

Data obtained throughout the socio-scientific program, together with findings from previous studies (Chung et al., 2016; Eastwood et al., 2011; Forbes & Davis, 2007; Sadler et al., 2004; Sadler & Donnelly, 2006; Siribunnam, Nuangchalem, & Jansawang, 2014), indicate that in process-oriented socio-scientific interventions, greater complexity and multiplicity of perspectives tend to emerge over time. Accordingly, viewpoints become more thoroughly justified, and informal reasoning increasingly incorporates multiple perspectives. The findings of the present study demonstrate that the socio-scientific program centered on a socio-scientific issue contributed to the development of students' multiperspectival thinking. When students are provided with opportunities to substantiate their arguments, refute counterarguments, and engage with the issue in depth, they tend to enrich their perspectives. Moreover, the necessity of addressing issues from multiple viewpoints arises in order to prevent discussions from becoming monotonous or routine and to facilitate the exchange of diverse ideas.

During the socio-scientific program, 13 out of 19 students did not change their initial positions. At the outset of the program, these students examined the socio-scientific issue through the lens of their existing knowledge and values and approached the topic from a single perspective. However, over the course of the program, by engaging with the issue more deeply, considering alternative viewpoints, and consulting a broader range of sources through research, they enriched their perspectives on the socio-scientific issue. Although these students did not change their views, they refined and strengthened their arguments. The majority of students participating in the socio-scientific program formed their initial perspectives at the beginning of the process and subsequently enriched those perspectives over time. According to Lee et al. (2012), the primary aim of socio-scientific issue-based interventions is not necessarily to alter individuals' positions, but rather to broaden their perspectives, enable them to present arguments supported by evidence, and foster deeper learning through the development of informal reasoning skills.

During the socio-scientific program, six students were observed to change their positions. These students frequently experienced dilemmas regarding the socio-scientific issue and sought to substantiate their views in order to resolve these conflicts. When they were unable to adequately justify their positions, they revised their stances. Therefore, for discussions on socio-scientific issues to be effective, it is essential that claims be supported with evidence. During the socio-scientific program, six students were observed to change their positions. These students frequently experienced dilemmas regarding the socio-scientific issue and sought to substantiate their views in order to resolve these conflicts. When they were unable to adequately justify their positions, they revised their stances. Therefore, for discussions on socio-scientific issues to be effective, it is essential that claims be supported with evidence. Providing an environment in which ideas could be expressed freely encouraged students who were initially reluctant to speak to participate more confidently. Moreover, this atmosphere motivated them to come prepared in order to engage actively in the discussions.

During the socio-scientific program, changes were also observed in some students' character and values. For students who initially held an ecocentric perspective and subsequently revised their views, societal responsibility appeared to play a decisive role in this shift. Similarly, for students who initially adopted an anthropocentric perspective and later changed their positions, ecological and social orientations were influential factors, consistent with the findings reported by Atasoy et al. (2019) and S. Öztürk and Leblebicioğlu (2015).

While written documents alone did not allow for detailed insight into the decision-making process, examining written documents in conjunction with discussions enabled access to more comprehensive information regarding decision-making. When students engaged in interaction, they articulated their views in greater depth. Such interaction enriched and broadened their perspectives and enhanced the quality of their arguments. The questions students posed to one another during discussions necessitated adequate preparation for participation. The combined analysis of discussions and written documents thus facilitated access to greater detail and contributed to the clarification of key points (Ratcliffe, 1997).

The findings indicate that shifts in students' positions primarily occurred during the small-group discussion phase. As students analyzed the socio-scientific issue, they actively sought supporting arguments for their claims. By sharing their knowledge and viewpoints with one another, they fostered a higher-level informal reasoning environment. No changes in position or perspective were observed during the whole-class discussions. Students attempted to persuade their peers by presenting the arguments they had developed in the small-group discussions. The group discussions implemented throughout the socio-scientific program enhanced students' interaction. Furthermore, students collaborated in their efforts to refute opposing viewpoints.

From the beginning to the end of the socio-scientific program, an observable improvement was noted in the content of the arguments presented by students. Students enhanced the quality of their arguments not only by learning from one another but also by progressively constructing their knowledge and viewpoints, conducting research before and after discussions, critically evaluating their own positions, and integrating their peers' insights into their own understanding. Consequently, it can be concluded that students developed higher-level informal reasoning skills over the course of the program.

During small group discussions, shifts in position were observed even though all students initially held the same position within some groups. These shifts were influenced by the students' internal reasoning and by the research they conducted after the initial discussions. Students also demonstrated a high level of informal reasoning. They changed their views, not to influence others or support their own or others' views, but because they were not convinced themselves. Despite initially sharing the same perspective, everyone in the small group changed their views after conducting research and engaging in self-criticism.

The findings indicate that economic considerations were influential in the position changes of two students in the second small group (specifically, a shift from an ecocentric to an anthropocentric perspective). These students explained their change in stance by recognizing the substantial contributions of mining to national economic development, overall growth, and increased employment opportunities. In other words, upon acknowledging the economic benefits of mining for the national economy, they reconsidered and revised their views. This finding supports the view that students' informal reasoning regarding socio-scientific issues is contextually variable and subject to change (Sadler & Zeidler, 2005). It is also noteworthy that, after revising their positions, students did not articulate any statements related to the social and moral compassion category. Once they adopted an economically oriented evaluation, they approached the socio-scientific issue from a more utilitarian perspective. This outcome suggests that economic factors can significantly influence decision-making processes (Levinson, 2006).

The findings of the study indicate that, throughout the socio-scientific program, students' views increasingly shifted toward a universal perspective. In other words, as discussions progressed, students began to approach the issue from a broader standpoint. Peer interaction also played a significant role in this process. As noted in the literature, peer interaction contributes substantially to the development of children's values (Benish-Weisman et al., 2022).

Implications and future research

The findings offer several implications for classroom practice. The socio-scientific program, which combined written dilemma scenarios with small-group and whole-class discussions, supported students in developing multiple perspectives and strengthening their informal reasoning. Teachers can therefore use dilemma-based socio-scientific scenarios and structured small-group discussions, together with time for reflection and opportunities to research arguments, to enrich students' reasoning. Creating a classroom environment in which students feel free to express and revise their views appears particularly important, as peer interaction played a substantial role in the changes observed in students' positions.

Future research could extend these findings by including larger and more diverse samples, different grade levels, and a range of socio-scientific issues. Longitudinal and mixed-methods designs could further illuminate how students' informal reasoning develops over time, and comparative studies could examine the relative contributions of small-group and whole-class discussions to this development.

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