International Journal of Science Education

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/tsed20

Grade 8 Lebanese students' reasoning and decision-making about scientific versus socio-scientific issues

Ihsan Ghazal, Saouma Boujaoude & Hayat Hokayem

To cite this article: Ihsan Ghazal, Saouma Boujaoude & Hayat Hokayem (22 Nov 2023): Grade 8 Lebanese students' reasoning and decision-making about scientific versus socio-scientific issues, International Journal of Science Education, DOI: 10.1080/09500693.2023.2281296

To link to this article: https://doi.org/10.1080/09500693.2023.2281296

INTERNATIONAL JOURNAL OF SCIENCE EDUCATION
https://doi.org/10.1080/09500693.2023.2281296

Grade 8 Lebanese students' reasoning and decision-making about scientific versus socio-scientific issues

Ihsan Ghazal [a], Saouma Boujaoude [b] and Hayat Hokayem [a]

[a]Andrews Institute of Mathematics and Science Education, Texas Christian University, Fort Worth, USA; [b]American University of Beirut, Beirut, Lebanon

ABSTRACT

Learners are expected to discuss and debate, using scientific evidence, the Socio-Scientific Issues (SSI) that often overlap with personal experiences and ethical dilemmas. This study investigated the reasoning of 24 Grade 8 Lebanese students when arguing about a scientific scenario as opposed to an SSI. It also examined how students make decisions and reason about SSIs. Results showed that students' reasoning is more emotional in socio-scientific contexts than in scientific ones. Also, scientific reasoning was based on macroscopic (observed) characteristics of the phenomenon in an SSI but was based on microscopic (cellular/molecular details of mechanisms) features of the phenomenon in scientific contexts. Cultural, social, and ethical considerations influenced students' decisions and reasons when constructing arguments. We discuss the results in light of the literature on reasoning about SSIs and provide instructional implications on how to teach argumentation within SSIs to enhance student reasoning.

ARTICLE HISTORY
Received 21 November 2022
Accepted 6 November 2023

KEYWORDS
Reasoning; Argumentation; Socio-scientific issues

Introduction

Society today expects learners to acquire the knowledge, skills, and attitudes that allow them to become scientifically literate citizens. Some of these skills enable learners to discuss and debate, using scientific evidence, the Socio-Scientific Issues (SSIs) that often overlap with personal experiences and ethical dilemmas (Osborne et al., 2004). The media often discuss these issues, such as genetic engineering, genetically modified organisms, and food safety. However, students often do not relate them to the science they learn in their classrooms. Research has focused on how learners make decisions in various contexts of SSIs and the factors that influence reaching those decisions. Argumentation is one tool to engage students in SSIs and help them make informed decisions about debatable scientific topics. Argumentation can also enhance students' quality of reasoning by assisting students to achieve more scientific reasoning levels. Despite adding argumentation practices to curricula in many

CONTACT Ihsan Ghazal ihsanghzl@gmail.com Andrews Institute of Mathematics and Science Education, Texas Christian University, Fort Worth, USA

This article has been corrected with minor changes. These changes do not impact the academic content of the article.
Supplemental data for this article can be accessed online at https://doi.org/10.1080/09500693.2023.2281296.

countries, students still struggle to develop their argument skills since they often lack opportunities to engage in argumentation procedures (Georgiou et al., 2020). Argumentation skills are closely tied with cognitive development (Sparks et al., 2022). Studying these skills can help understand how students develop their reasoning abilities over time. Using argumentation related to SSIs can help students better express ideas and unravel their thinking. When comparing student reasoning in SSI to scientific issues, researchers can capture real-world problems, moral and ethical developments, foster interdisciplinary thinking. In other words, SSIs help gain a more comprehensive understanding of students' abilities to understand world challenges that not only involve scientific knowledge but also ethical and social considerations. The inclusion of SSIs allows researchers to assess a broader range of decision-making skills that are more relevant in the modern world.

The literature suggests that in addition to using scientific knowledge and reasoning to debate SSIs, learners consider other factors, such as personal, social, economic, and ethical considerations (Kolstø, 2006; Liu et al., 2011; Sadler & Zeidler, 2005; Wu & Tsai, 2007; Yang & Anderson, 2003). Students' experiences and cultural interactions contribute to how they approach SSIs and attempt to resolve them (Zeidler et al., 2005). However, research on SSIs in Lebanon is scarce. As a developing country, Lebanon has faced several SSIs resulting from ethical or cultural beliefs and scientific knowledge interactions. For example, religious and ethical cultural considerations hinder learning topics such as AIDS, reproduction, and evolution (CERD, 1994). Within the context, this study investigated the kinds of reasoning Grade 8 Lebanese students engage in when involved in argumentation. Also, the study examined how these students make decisions and reason about SSIs during instruction to promote scientific literacy. Our study is context-specific, which is a key aspect contributing to the originality of our research. For example, we focused on a traditional food in the Lebanese context and aimed to shed light on the unique cultural and societal factors that influence its consumption and perception. However, it's important to acknowledge that the findings of our study are limited in their applicability beyond the Lebanese context. To make broader claims or generalise our results to a wider audience, further studies in different contexts would be necessary to extend the scope to other regions, allowing for a more comprehensive understanding of argumentation strategies and educational practices in a global context. Specifically, this study answered the following research questions:

(a) What are the different kinds of reasoning that Grade 8 Lebanese students consider when engaged in argumentation about scientific scenarios as opposed to SSI?

(b) What are the specific considerations that Grade 8 Lebanese students adopt when given a chance to make decisions concerning SSIs?

Focusing on SSIs alone, in our second research question, can yield rich and content-specific findings that contribute to a deeper understanding of how Lebanese students approach complex social problems. Also, SSIs include scientific issues as a subset and SSIs allow us to evaluate the specific contexts of the study that influence how students think of scientific issues.

Literature review

Argumentation is one of the eight scientific practices that support students' learning of science core ideas (NRC, 2012). Argumentation refers to students' ability to construct coherent, evidence-based arguments to support their claims on both scientific and SSIs. It involves the use of reasoning, evidence, and persuasive communication to convey a viewpoint, engage in discussions, and justify one's stance (Toulmin, 1958). Initial argumentation research in science education explored how science classroom environments fostered argumentation (Duschl & Osborne, 2002; Jiménez-Aleixandre et al., 2000). For example, Jiménez-Aleixandre et al. (2000) studied how students and teachers practiced argumentation during Grade 9 genetics lessons and how it contributed to science learning without teaching argumentation. They examined the nature of argumentation during genetics lessons and investigated how argumentation was used to construct scientific knowledge. After analysing group talks, students frequently used claims in their arguments, while researchers rarely reported warrants.

Argumentation studies later focused on evaluating the quality of arguments and analysing the development of students' argumentation competencies (Erduran et al., 2004; Osborne et al., 2004). Erduran et al. (2004) studied the development of argumentation patterns by tracing the quality and quantity of argumentation in middle school science classrooms. They used whole-class and small-group discussions to compare students' arguments in different lessons and examined the nature of students' rebuttals. The results indicated that the teaching method influenced argumentation, and student arguments improved over time. In addition to identifying argumentation features, Berland and McNeill (2010) explained that the more elements the students provided, the better their quality of argument was, and the higher the reasoning level the student achieved. They claimed that engaging in argumentation identifies how students build knowledge at lower, intermediate, and upper levels of reasoning. Researchers also began investigating how to support students' engagement in argumentation through the design of effective learning environments (e.g. Jiménez-Aleixandre, 2008) and the professional development of science teachers (Simon et al., 2006). Teaching argumentation depended on how the teacher introduced certain class activities. For example, open-ended questions with multiple possible answers were more complex than closed-ended questions with predetermined arguments (Berland & McNeill, 2010). The degree of teacher interference in the argumentation process affected the level of reasoning. Oral discussions revealed more complex argumentation levels than written work because students found it more difficult to communicate ideas through written work without an audience to convince them of their argument (Berland & McNeill, 2010). Other studies emphasised the importance of talk and dialogue in the classroom, providing students with increased opportunities to engage in argumentation supported by evidence (Erduran & Jiménez-Aleixandre, 2008; Kuhn, 2010; Osborne, 2010).

Recently, studies focused on interpreting argumentation as an epistemic practice that includes knowledge construction, justifying, critiquing, and evaluating claims (Brocos et al., 2022; Duschl, 2008; Duschl et al., 2021; Duschl & Ellenbogen, 2009; Guilfoyle & Erduran, 2021; Jiménez-Aleixandre & Crujeiras, 2017; Kelly & Licona, 2017; Licona & Kelly, 2019; Ong et al., 2020). This expanded perspective recognised the importance of considering social contextual factors that shape scientific discourse, going beyond the

traditional focus on argument structure. For example, Licona and Kelly (2019) investigated how students constructed scientific arguments using both English and Spanish as linguistic resources. They explored the potential benefits of translanguaging for promoting scientific argumentation and understanding in bilingual or multilingual science classrooms.

Toulmin's model was one influential framework used in studying argumentation (Toulmin, 1988). The significant elements in Toulmin's model include claims, data, warrants, and rebuttals. A claim is the fundamental element of any argument. The proposer of a claim defends it even when it consists of unjustified statements that lack supporting evidence. However, for a claim to be accepted, it should include a set of data (which constitute the evidence) that support it. A warrant is similar to the data that validate a claim (Driver et al., 2000; Osborne et al., 2004; van Eemeren et al., 1996). Warrants justify a claim and show how the supporting data are relevant to the claim and why they make it valid. More complex arguments would include rebuttals that indicate the conditions when the argument is invalid.

The use of this framework as an analytical tool in studying argumentation has gained attention in the literature due to its effectiveness in identifying the components of arguments, understanding the relationships between these components, assessing the quality of arguments, determining gaps in reasoning, and facilitating a deeper understanding of the argumentation process and reasoning (Duschl & Osborne, 2002; Erduran et al., 2004; Erduran, 2008; Jiménez-Aleixandre et al., 2000; Kelly, 2009). Furthermore, incorporating Toulmin's framework offered a valuable tool for studying argumentation in science education and socio-scientific contexts (Erduran et al., 2004). In a recent study, Brocos et al. (2022) combined elements from Toulmin's (1958) argument structures, communicative acts in argumentation discourse (van Eemeren et al., 1996), and the presence/absence of further explanations of claims. They aimed to examine how students' arguments about the acceptability of omnivorous and vegetarian diets combined epistemic and social interactions. For example, when discussing the concept of an omnivorous diet, they indicated how the argument developed, including the structure of the main arguments, the elaboration of the omnivorous diet option, and potential restrictions or clarifications that are introduced, such as a balanced omnivorous diet.

Studies using Toulmin's model and its variants, such as the TAP (Argumentation Argumentatin Patter) and CER (Claim-Evidence-Reasoning) frameworks, have allowed researchers to compare and contrast students' argumentation skills. For instance, Kelly et al. (1998) investigated students' reasoning about electricity by combining performance assessment and argumentation analysis. They aimed to understand how students construct arguments and reasoning patterns when discussing electrical concepts. By applying Toulmin's model, the researchers analysed and categorised the various warranting strategies employed by the students in their arguments. They also identified specific conditions that preceded and contributed to developing warranted arguments. Furthermore, Simon et al. (2006) emphasised the need for teachers to receive professional development and support in order to effectively teach argumentation. They suggested that by integrating the TAP framework and implementing research-based instructional strategies, teachers can enhance students' argumentation abilities. They used Toulmin's model including argument components and reasoning to understand how learners constructed their own arguments and engaged with the arguments of others.

The present study contributes to the existing literature on argumentation in science education by addressing a research gap using Toulmin's model to investigate the kinds of reasoning used to make decisions concerning specific SSIs in Lebanon. By examining the types of reasoning Grade 8 students displayed in their arguments about scientific and SSIs, this study expands our understanding of how students make decisions and reason about these complex topics. Toulmin's argument model (Toulmin, 1988), as the theoretical framework in this study, aligns with previous research that has employed Toulmin's framework to analyse and evaluate arguments in science education (Erduran et al., 2004; Jiménez-Aleixandre et al., 2000; Simon et al., 2006). Toulmin's model provides a structured approach for examining arguments, with components such as claims, evidence, and reasoning and relating them to students' decision-making processes. Moreover, by acknowledging that arguments can employ various kinds of reasoning in addition to scientific reasoning, this study aligns with previous research emphasising the importance of considering multiple perspectives and diverse forms of reasoning in argumentation (Erduran et al., 2004; Jiménez-Aleixandre et al., 2000). Furthermore, it highlights the need to bridge the gap between argumentation as a tool taught in school science settings and its authentic practice within scientific communities (Manz, 2015). This study suggests that students' reasoning about SSIs may involve complex cognitive processes influenced by social factors, extending our understanding of argumentation beyond purely scientific reasoning.

Argumentation within scientific and socio-scientific contexts

Scientific argumentation

Scientific issues as problems that can be studied using scientific methods, and that are primarily based on scientific principles and facts. Scientific issues are characterised by having clear answers that are determined through empirical evidence and logical reasoning. In essence, this means that scientific issues are problems that can be investigated scientifically and have objective, well-defined answers that can be supported by evidence and reasoning (Flick, 2018). This definition is in line with the traditional view of science as a process of discovery and explanation that relies on empirical evidence and logical reasoning to test hypotheses and develop theories (Lederman, 1992). While there may be some scientific issues that are more complex or ambiguous than others, the general idea is that scientific issues are amenable to scientific investigation and can be addressed using established scientific methods and principles.

One example of an argumentation intervention in a scientific context is a study by Sampson et al. (2011), in which middle school students were taught about energy conservation through argumentation-based inquiry. The intervention involved students engaging in small group discussions and debates about energy conservation, using evidence to support their claims and counterclaims. The results showed that the intervention improved students' knowledge and understanding of energy conservation and their ability to engage in argumentation using evidence. This study demonstrates the effectiveness of argumentation-based inquiry in teaching science topics and developing students' scientific reasoning skills.

Socio-scientific issues[1] (SSIs)

Socio-Scientific Issues (SSIs) are controversial public topics related to science that are open to different scientific, ethical, and societal perspectives and may have political implications (Sadler & Zeidler, 2005). SSIs use scientific topics and engage learners in dialogue, discussion, and debate (Zeidler & Nichols, 2009). SSIs are controversial because they often require moral and ethical considerations on the part of students to resolve those issues (Zeidler et al., 2005). Different individuals hold various views on SSIs and interpret the same data differently based on other value systems. They also struggle to logically reason and develop solutions to social problems (Oulton et al., 2004). Argumentation has become essential to the teaching and learning educational cycle (Osborne et al., 2000) because learners can use scientific evidence to justify and debate SSIs.

For example, Sadler and Zeidler (2005) focused on college students' informal reasoning patterns when presented with socio-scientific scenarios. Through two interviews, students were asked to provide arguments, counterarguments, and rebuttals to a genetics scenario, as well as identify the factors that influenced their positions in a second interview. The study found that students utilised both rational and emotive reasoning and that their familiarity and knowledge about a scenario influenced their reasoning type.

The contexts of socio-scientific issues (SSIs) have an impact on how individuals informally construct arguments. Research has shown that cultural backgrounds can influence decision-making on SSIs and students with different backgrounds tend to frame their understanding of the same SSI differently, possibly leading to diverse decisions and reasoning regarding the solutions. For instance, Indian students were more likely to argue against killing grey squirrels in the UK to preserve the indigenous red ones due to their immigrant identity projection (Evagorou et al., 2012). Thus, cultural factors are a subset of SSIs and understanding the socio-cultural contexts is crucial for effectively addressing SSIs in science education (Liu et al., 2011; Sadler et al., 2004). Moreover, social and cultural factors can also influence personal beliefs and decision-making on SSIs (Sadler & Zeidler, 2005). While some studies have focused on the impact of science on cultural beliefs and identities, more research is needed to understand the complex interactions between cultural/social ideas and scientific knowledge (Balgopal et al., 2017; Simonneaux & Simonneaux, 2009). In this paper, we used class discussion as a valuable source of data to examine the specific dynamics within that particular classroom context. By doing so, we sought to identify influencing student decision-making in SSIs within this unique setting. Decision-making is one type of argumentation and is a multi-step process in which students are given a problem, data to analyse, and they should suggest a solution (Driver et al., 2000; Sparks et al., 2022; Zeidler et al., 2011). When students make decisions, they are involved in scientific argumentation that enhances critical thinking and scientific literacy. We propose that it is important to understand the process of student engagement in decision-making about SSIs, a type of scientific argumentation. Understanding this process can be a valuable tool for educators to integrate argumentation in socio-scientific contexts.

Argumentation and reasoning

Studying argumentation alone reveals the structure of the final argument constructed by the student and does not provide insights into the reasoning processes or the quality of arguments (Osborne et al., 2004). Researchers can assess reasoning when students engage in argumentation because students would evaluate conflicting ideas or alternatives and construct knowledge in the process (Osborne et al., 2013). Thus, learning to argue to resolve a conflict is integral to creating knowledge. The relationship between argumentation and reasoning is closely intertwined. Reasoning involves the cognitive process of thinking logically and making sense of information to draw conclusions. Argumentation, on the other hand, goes a step further by structuring that reasoning into a persuasive form (Toulmin, 1958). It's the practice of effectively communicating one's reasoning to convince others of a particular viewpoint. In argumentation, individuals use reasoning to support their claims with evidence and engage in persuasive discourse. In other words, argumentation is the practice of communicating one's reasoning effectively, often in a structured and persuasive manner, to convince others of a particular viewpoint or position.

Several research studies examined the effect of argumentation on the development of students' reasoning. Several researchers claim that engaging students in argumentation has the potential to enhance their quality of reasoning (Dawson & Venville, 2013; Osborne et al., 2004; Venville & Dawson, 2010). Specifically, the researchers defined reasoning as the kind of thinking that occurs when discussing SSIs. This reasoning allows students to evaluate problems and make decisions. Many researchers selected to categorise informal reasoning as rationalistic, emotive, or intuitive (Dawson & Venville, 2009; Osborne et al., 2004; Venville & Dawson, 2010). An argument is rational when the student uses logical, scientific knowledge about a topic and evaluates the risks and benefits to make decisions. Learners construct an emotive argument based on their feelings (caring or worrying) toward another person in a particular scenario. Intuitive reasoning is the immediate feeling (negative or positive) toward an issue that precedes an emotive or rational reasoning.

Venville and Dawson (2010) showed that grade 10 students' reasoning improved when they engaged in argumentation during a unit about genetics. However, a study by the same authors in 2009 showed that high school students rarely used rational reasoning in their arguments. Another study that examined elementary students' reasoning patterns related to SSIs showed that although students used rational, emotive, and intuitive reasoning to solve socio-scientific issues, they used rational reasoning the least and intuitive reasoning the most (Ozden, 2020). Researchers claim that rational reasoning is more important than other forms of reasoning since it requires engaging in scientific thinking (Sadler & Zeidler, 2005). Another study that aimed to analyse the development patterns of students' reasoning in elementary, junior high, and senior high school, showed that students' reasoning does not develop following school grades (Widodo et al., 2017). In some cases, the topics discussed influenced students' responses and not the development of their reasoning across school levels or knowledge on the issue.

Although the reasoning categories (rationalistic, emotive, and intuitive) provide insight into the type of argument used to make decisions about an SSI, the description of the categories is confusing, especially when students blend both emotive and intuitive. For example, Venville and Dawson (2010) categorised the response 'It is interfering with

nature. You should love your child no matter' as intuitive. However, one could argue that this response is also emotional because the student believes that the child should be loved or cared for, which involves emotional reasoning. Thus, since intuitive reasoning comes right before emotive or rational reasoning, it is difficult to differentiate these categories. We suggest using emotional reasoning as a category to evaluate the quality of the argument. Removing intuitive reasoning would not impact the reasoning analysis since it later results in emotive or rational reasoning. In other words, it is an intermediate stage of thinking between emotive and rational reasoning and not the final type of reasoning the student uses to make a decision. Regarding rational reasoning, the researchers (Demir & Namdar, 2019; Osborne et al., 2004; Venville & Dawson, 2010) refer to it as a logical way of thinking that uses scientific information and weighs risks and advantages. We argue that we find logical reasoning in emotional or intuitive reasoning. As a result, we focus on scientific explanations as the main core of rational reasoning. Thus, we suggest that the first reasoning category is scientific reasoning, and the second is emotional (combining intuitive and emotive).

This study investigates the kinds of reasoning Lebanese Grade 8 students portrayed when arguing about scientific and SSIs. Given the scarcity of research on cultural and social-based scientific issues in the literature, we explore how Grade 8 make decisions on and reason about cultural and SSIs, which is even rarer. We adopt Toulmin's (1988) model of an argument as the theoretical framework that guided the design of our argumentation activities. This framework uses the claim as the response to a scenario or problem. Evidence is the scientific data supporting the claim, such as observations provided to the students. Since understanding scientific principles influences the selection and use of evidence, the reasoning explains why the evidence supports the claim and articulates the logic behind that choice. Knowing that our research questions focus on reasoning, we claim that arguments use various kinds of reasoning, so the decisions based on those

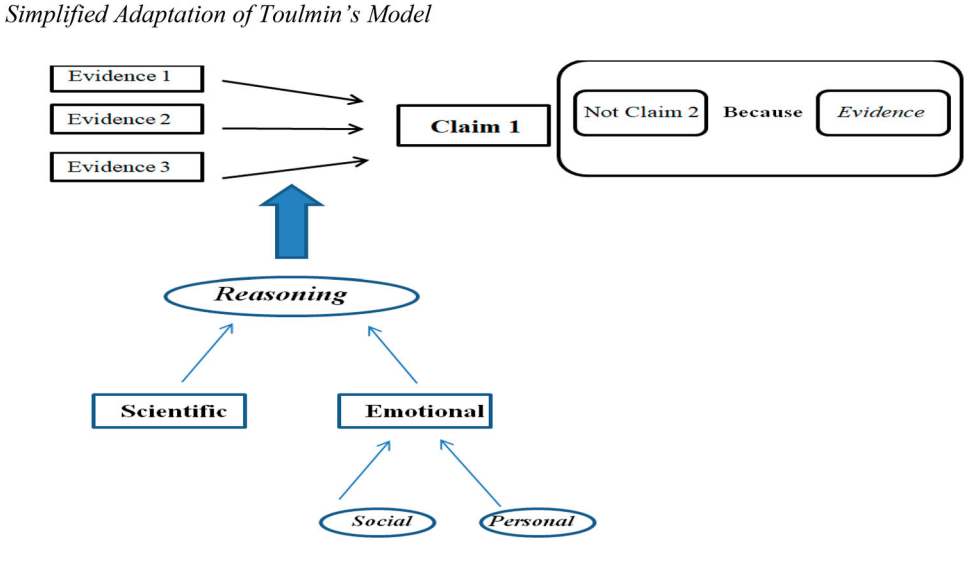

Figure 1. Simplified adaptation of Toulmin's model.

arguments do not always follow the logical scientific explanations, as shown in our framework in Figure 1. Focusing on assessing students' arguments rather than directly assessing their capacity to reason about issues stems from the idea that argumentation represents a practical application of reasoning (Toulmin, 1958). Argumentation not only assesses students' ability to think critically but also their ability to communicate their thoughts persuasively, which is a valuable skill in various real-world contexts, including scientific and socio-scientific discussions. Additionally, focusing on argumentation in the context of SSIs aligns with the study's aim to explore how students engage with and communicate about complex issues where both scientific and ethical dimensions are at play.

In the framework above, we adopt two kinds of reasoning. We define scientific reasoning as using scientific understanding to evaluate information or construct arguments. We describe emotional reasoning as the emotional response, including care for others, sympathy, empathy, and negative or positive feelings toward an issue. Emotional responses could relate to social and personal factors. Since we are analysing reasoning in scientific and SSIs, it is important to note that both reasoning involve a cognitive process by which students use scientific knowledge. In scientific scenarios, the purpose is to use scientific knowledge to make sense of scientific information while in SSIs, students integrate scientific knowledge with social and ethical considerations.

Methodology

Setting and participants

We conducted this study in a Grade 8 biology class in a private school in Beirut, Lebanon. The study duration was 12 weeks, with two periods per week (each period is 50 min). Students completed six argumentation activities during this period. The Grade 8 classroom included 24 students (14 females, ten males). One female biology teacher agreed to participate in the study. She has a degree in Biomedical engineering and did not use argumentation in her instruction before being involved in the study. Therefore, one of the researchers (first author) provided professional development for the teacher (one one-on-one session) to teach her the definition of argumentation, its elements, and how to incorporate it into science activities. This researcher encouraged the teacher to use questioning and reflection, listen thoroughly to students' responses, and challenge their views to reach effective arguments. Then, the first author developed the lesson plans and provided the teacher with them. The teacher and the first authors later discussed the lessons to clarify vague ideas and address any obstacle the teacher believed she could face. During the activities, the first author and the teacher met weekly to reflect on the flow of the lessons. Although the teacher had not taught argumentation before, the collaborative effort between the first author and the teacher exemplifies her commitment to delivering quality instruction in argumentation. The training provided by the first author and the regular weekly meetings ensured that the teacher was well-prepared and aligned with the established method. Classroom observations conducted by the first author confirmed her ability to implement argumentation. She consistently

adhered to lesson plans and activities, fostering engaging classroom discussions by posing thought-provoking questions and facilitating follow-up inquiries.

Development of argumentation activities

The intervention started in the middle of the 2016–2017 school year. The students engaged in six argumentation activities and learned argumentation skills based on Toulmin's (1988) model. The selection of the six issues related to immunity and viruses in our study was motivated by their alignment with the Lebanese eighth-grade science curriculum (CERD, 1994), their societal relevance, and our goal of assessing students' abilities to engage in discussions about real-world issues while applying their scientific knowledge. Each activity was designed based on what students had already learned, ensuring alignment with their current scientific knowledge. We considered students' prerequisite knowledge when selecting these issues to facilitate meaningful and in-depth argumentation rather than superficial discussions.

Students learned the elements of an argument after completing a worksheet about selecting to have an organ transplant which focused on self and non-self antigens. They also learned about reasoning and differentiated scientific and emotional reasoning when given examples from the first activity. This activity required students to determine which criteria (age, gender, Human Leukocyte Antigen (HLA), personal accomplishments, worth to community, intelligence) are essential or not, concerning who deserves an organ transplant. For example, a response like 'I believe that a criminal is a bad person and does not deserve an organ transplant' is not scientific. In this study, we utilised a range of activities that addressed different types of issues in science education (See Table 3 for a description of the activities). Specifically, some activities were focused on scientific concepts and principles, while others were designed to engage students in socio-scientific issues (SSIs) that require consideration of scientific, ethical, and societal perspectives. One SSI activity addressed a specific cultural aspect that shaped individuals' understandings of science. The students did not possess any prior experience and knowledge related to argumentation before taking part in this study. Any exposure to argumentation would have taken place in an informal setting. Also, the students do not learn about the immune system prior to Grade 8 (CERD, 1994). Any knowledge about this system was informal as they did not learn formal knowledge about the immune system before Grade 8. Students completed the worksheets individually first, and then discussed them in pairs. Finally, they engaged in the classroom discussion with the teacher.

Scientific argumentation activities

Are Viruses Alive? (30 min) The activity involves exploring and debating the characteristics of life and how they apply to viruses. These characteristics include the ability to grow, reproduce, respond to stimuli, and maintain homeostasis. However, viruses have properties that challenge these criteria, such as their inability to replicate without a host cell and their lack of metabolism. By engaging in the activity 'Are viruses alive?' and using argumentation to support their positions, students evaluate the evidence related to the characteristics of life and how they apply to

viruses. They are also developing their critical thinking and scientific reasoning skills using evidence-based arguments to support their positions. The purpose of the activity is to further elaborate on the characteristics of viruses and how they infect the body.

Catching a cold (Snowman Activity) (45 min). This activity touches on scientific concepts related to the transmission of viruses and the causes of colds, and the scenario is highly simplified, prompting students to think critically about the scientific concepts related to the causes and transmission of infectious diseases. For example, students evaluated two competing theories about whether a snowman with or without a jacket would catch a cold. They provided arguments to support one theory and counterarguments against the other (Retrieved from: Activity 11 – snowmen and scientific arguments.doc (live.com)). The purpose is to help students identify the factors (scientific or social factors that influence our body to get infected with microbes.

Vaccines (25 min). The activity discussed the importance of vaccines as a critical tool in preventing the spread of infectious diseases. It targeted students' understandings of how vaccines work including the components of a vaccine and the process or mechanism by which it works. For example, in the activity students argued whether someone should get a vaccine against flu. The purpose is for students to further elaborate how vaccines work and when they should be taken.

Socio-scientific issues

AIDS (30 min). AIDS is considered an SSI because it involves scientific and societal considerations. On the scientific side, AIDS is caused by the human immunodeficiency virus (HIV), which is a virus that attacks the immune system. However, AIDS is also an SSI because it has significant ethical, moral, and social implications. For example, the activity related AIDS to individuals' health as well as their way of life and manners. Students had to choose a statement about AIDS that they agree/disagree with and provide reasons for their decision (e.g. *I'm too young to get AIDS, I feel nervous using the toilet after someone with HIV has used it because I'm afraid I'll get HIV*). The statements were socio-scientific and students' responses would indicate the type of reasoning they would provide and whether it was scientific or emotional. The purpose of this activity is to elaborate on how the HIV virus is transmitted.

Allergy (Mankushe Activity) (see Appendix) (40 min). Students debated whether their school should ban a popular cultural Lebanese food (Mankushe) based on a study that showed many of the Lebanese population are allergic to one of its components. Students provided evidence to support their view. On the scientific side, the allergy to sesame is a medical issue rooted in biological factors such as the immune system's response to certain proteins found in sesame. On the socio-scientific side, the decision to ban the food from the cafeteria involves scientific considerations such as the prevalence and severity of the allergy, as well as the availability of alternative food options for students with the allergy. We also classify this activity as a cultural SSI because students this specific food (mankushe) is a staple breakfast in the Lebanese culture (something that other cultures do not consume). This requires Lebanese students to think hard about banning this food that is closely related to their

cultural habit. The purpose of this activity is to further elaborate on what causes allergies and what immune mechanisms they cause in the body. Also, in this activity, students deal with an allergen included in a traditional food, considering both scientific and social factors.

Data collection

Argumentation activity worksheets

We analysed students' responses to six argumentation activities to evaluate reasoning types in scientific and cultural/socio-scientific contexts (first research question). We provided students with activity worksheets in each lesson, and each worksheet required the performance of a specific task. The worksheets included questions that allowed students to express their opinions, explain the evidence, and provide justifications. The data also targeted the second research question and determined why students made decisions when arguing about an SSI. For example, one activity asked students to evaluate two competing theories about catching a cold: would the snowman wearing or not wearing a jacket catch a cold? Students first mention which claim they support and explain their reasons. Writing frames guided them through forming an argument: Our group supports the argument ____because we believe_____; another reason is____; we think the other claim is wrong because _____.

Videotapes of classroom discussions

We videotaped, transcribed, and coded classroom discussions to further understand students' reasoning. Data from these discussions gave insight into the argumentation process guided by the teacher and the patterns that students used to decide on and reason about cultural and SSIs.

Data analysis

Types of reasoning

To evaluate the quality of students' reasoning we grouped students' statements and responses in group discussions and worksheets as scientific, emotional, a combination, or NA (not able to classify) (Table 1). We coded a response as scientific when students provided scientific terms based on observations; '*an ingredient in food causes allergic reactions*' or microscopic explanations, '*a virus is alive because it contains DNA as genetic information.*' Also, responses that included detailed mechanisms were considered scientific, '*B cells secrete antibodies the first time, and when they see the pollen again, the sensitization cells secrete histamine, causing an allergic reaction.*'

Patterns in students' reasoning about socio scientific issues

We analysed the participants' responses to two activities involving socio-scientific issues (mankushe and AIDS) to understand further students' considerations for deciding on and reasoning about SSIs. Mankushe is a dough with sesame, thyme, and oil grilled in the oven. It is a common and traditional Lebanese breakfast that most students buy from the school cafeteria. We analysed the decisions by calculating the number of students with or against each issue. Then, we coded for the students' reasons to support

Table 1. Kinds, description, and examples of reasoning.

Category	Description	Example of student responses from Mankushe (allergy) activity	Example of student responses from AIDS Activity
Scientific	Uses scientific understanding and language to evaluate information or construct arguments.	Allergies on the mankushe are non-pathogenic, we shouldn't ban these food because some people with exaggerated immune response.	I would use the same bathroom as someone with HIV because HIV cannot be transmitted except by body fluids and not by sneezing.
Emotional	Emotional response towards others, including care, empathy, sympathy, negative or positive responses related to social and personal reasons	Mankushe shouldn't be banned because it's yummy	Parents are scared for their kids catching HIV. They will be more comfortable and less nervous if they don't use the same bathroom.
Mixed Reasoning: scientific & Emotional		Not everyone has an allergy against sesame thus the person who knows has an allergic reaction shouldn't eat it (scientific) and deprive others (emotive)	Maybe HIV is transmitted through common things like toilet or blood (scientific); even if it is not transmitted, other people would be scared of the consequences and should not be scared (emotional).
NA	Not able to classify	I don't know	

their claim to develop themes. Through an iterative process, two subcategories emerged for emotional reasoning: (1) personal and (2) social considerations. Personal considerations refer to personal benefits (e.g. enjoyment or convenience). Social considerations include the reasons such as the impacts of the activity on other people (e.g. what is the fault of people who are not allergic?) or fear that an individual could die.

Reliability

Reliability was ascertained through inter-rater agreement at the beginning of the worksheets' analysis. First, two researchers and two graduate students met to discuss and practice analysing the material. One worksheet was picked randomly, and the researchers and graduate students read the worksheet question by question together, tallying the type of reasoning based on the framework's categories, and rating the type of their reasoning (scientific or emotional).

Then, following this practice, two worksheets were selected randomly, and each rater analysed them independently. After, the two researchers and two graduate students compared their results and took note of the findings they had in common, and those that were different. The inter-rater reliability was calculated to be 90%. Since there was no considerable difference between the raters (interrater reliability was more than 85%), the researcher moved on to the second step. The first coder was the researcher and the second was a science educator and a graduate student familiar with reasoning research. Both analysed all the worksheets and discussed differences (the interrater-reliability was 90%). The representation of the reasoning categories outlined in the reasoning framework (Toulmin, 1988; Venville & Dawson, 2010) in the worksheets was checked with a mark, followed by the rating of the type of reasoning. All the worksheets were thoroughly read, starting with those related to the first argumentation activity to the sixth activity.

Results

Students' reasoning in scientific versus socio-scientific contexts

Students' reasoning was inconsistent across the activities and depended on the nature of the activity (scientific or socio/cultural) and its relation to their prior conceptions (Table 2). Moreover, cultural/social contexts influenced students' reasoning which tended to become more emotional than scientific ones.

Although students in all activities, for all contexts, dominantly showed scientific reasoning, deeper analysis revealed that the nature of these scientific reasons differed in a scientific as opposed to a socio-scientific context (Table 3). We identified two sub-categories for scientific reasoning based on students' responses: a) macroscopic scientific reasoning and b) microscopic scientific reasoning.[2] Students provided macroscopic scientific reasoning in socio-scientific contexts, whereas their reasoning was microscopic in scientific scenarios. Macroscopic scientific reasoning refers to students' scientific knowledge linked to the general observation of the phenomenon. On the other hand, microscopic scientific reasoning refers to students' using scientific knowledge of a process or a mechanism or detailed mechanisms.

Reasoning in scientific activities

In Activities 1 (are viruses alive?) and 6 (vaccination), all students showed scientific reasoning, and none had emotional reasoning. These activities were scientific and not culturally or ethically embedded. For example, Activity 1 included evidence cards to support the argument of whether viruses are alive or not. In this activity, all twenty-four students had scientific reasoning skills. Moreover, all students provided microscopic scientific reasoning for pure scientific scenarios (are viruses alive? and vaccination). In the activity, catching a cold (Table 3), although 22 students had scientific reasoning, 16 provided macroscopic scientific reasoning, while eight had a mixture of both. In this activity, students' microscopic scientific reasoning included their knowledge of natural barriers, such as nose, mouth, and mucus, that help prevent virus infections instead of simply wearing a jacket. Other students mentioned the body producing white blood cells that fight the virus. Thus, although all responses were scientific and none emotional, most of their scientific reasoning was limited to everyday observations.

Reasoning in socio-scientific contexts

In Activities 3 and 4 about AIDS, seven and six students respectively showed a combination of scientific and emotional reasonings. Also, ten students used a mix of emotional and scientific reasonings in the socio-scientific activity about allergies. Although all

Table 2. Number of responses for each kind of reasoning.

	Activity 1 Are viruses alive?	Activity 2 Catching a cold	Activities 3 & 4 AIDS: Fact/ myth	Activity 5 Allergy (Mankushe)	Activity 6 Vaccines
Scientific	**24**	**22**	**16**	**13**	**23**
Emotional	**0**	**0**	**0**	**1**	**0**
Mixed Reasoning	**0**	**0**	**6**	**10**	**0**
N/A*	**0**	**2**	**1**	**0**	**1**

*N/A not able to classify

Table 3. Example of students' scientific reasons in different contexts.

Activity	Description	Example of students' scientific reasoning	Type of Scientific Reasoning
Are Viruses Alive? (Scientific context)	Students used evidence cards to support the argument whether viruses are alive or not	I believe that viruses are alive because they damage cells and cause disease. Viruses contain DNA, and everything alive contains DNA. The immune system identifies and kills cells infected with a virus. If viruses aren't alive, the immune system will not kill the cells infected by them. They also reproduce with the help of host cells and if they aren't alive they cannot reproduce.	Microscopic *(student explained elements at the micro level and immune responses such as immune cells identifying viruses and virus reproduction in host cells)*
Catching a Cold (scientific context)	Students evaluate two competing theories: which snowman, wearing or not wearing a jacket, would catch a cold.	• I think Sami who is not wearing a jacket may be infected with the virus because if he is warm, his immune system will be strong to fight the virus. • I think that Tarek will not catch a cold because he is wearing a jacket and his body will be warm so he will not catch a cold virus. Another reason is that his immune system will stay good and warm and release power white blood cells that protect the body. However, the jacket will not protect him if the virus entered from his nose or mouth, escaping the hairs.	• Macroscopic (the student related wearing a jacket to a stronger immune system but did not provide microscopic details) • Macro and microscopic *(the student related wearing a jacket to a stronger immune system, macro, but also explained that this happens because of producing immune cells and natural barriers, micro)*
AIDS (Socio-scientific context)	Students argue with or against statements about AIDS	I disagree with the statement that I'm too young to get AIDS because some people are born with AIDS and it is not related to the age of the person.	Macroscopic *(the student did not refer to mechanisms or microelements to explain how the virus could be transmitted)*
Allergy (Mankushe) (Socio-scientific context)	Based on results of a study, students argue whether the school should or should not ban some chocolate with hazelnut and the mankushe (famous Lebanese food) from school because of a large portion of the Lebanese population is allergic to sesame (major ingredient of mankushe) and hazelnut.	• We are against banning mankushe because the people who have allergies against something should know about it and control themselves from eating them not to get allergic reactions. They also have to be aware of the ingredients in the food they eat • We are against the school decision because some kids don't have allergies on these things and people who do will not eat them because the sensitisation cells secrete histamine causing the allergic reaction. Hazelnuts and sesame are non-pathogenic and harmless.	• Macroscopic *(the student mentions allergic reactions only without referring to elements or mechanisms inside the body)* • Macroscopic and Microscopic *(student refers to mechanisms of the immune response)*
Vaccines (Scientific context)	Karen refuses to take a flu shot because she took it last year and still got sick. Students argue if Karen should take the flu vaccine.	Karen should get the vaccine because it reduces the chances of infection because memory cells remember the virus and immune system becomes stronger the 2nd time it's in contact with it. And the flu virus changes its shape each time.	Microscopic *(the student explained how a vaccine stimulates cells during the immune response)*

students provided microscopic scientific reasoning for pure scientific scenarios in the mankushe activity, which is culturally and socially embedded, only one student showed microscopic scientific reasoning (see Table 3). This student mentioned how the allergen causes sensitisation cells to release histamine, which causes allergic symptoms. All the other students used macroscopic scientific reasoning for this activity. For example, they argued that when people eat food they are allergic to, it causes an allergic reaction. Although the student used scientific knowledge that allergens cause allergic reactions in some people, they did not provide details of the process or link it to what is happening inside the body based on what these students learned. Therefore, even though students learned about allergic reactions, what happens during the first and second contacts, and the release of histamine, only one student provided these microscopic explanations in their arguments. Also, none of the students understood how the immune system works; nor did they mention how medicines can alleviate allergic reactions when taking into account an SSI.

Similarly, in the AIDS activity, students only provided macroscopic scientific reasoning and did not provide details of micro-mechanisms related to HIV transmission. Five students believed that a person who looks healthy doesn't have HIV, ignoring their knowledge of the asymptomatic phase of the disease where the individual does not have any health-related issues, which could last for years.

Decisions, reasons, and solutions regarding socio-scientific contexts

Zooming in on the mankushe scenario

Since students showed a combination of scientific and emotional reasonings in topics related to their culture and society, we decided to look deeper into the reasons for their decisions. Upon receiving an activity about a popular Lebanese food, 'Mankushe,' students debated whether their school should ban it and provided evidence to support their view. The scenario used data from a study that showed that Lebanese people have common allergies to hazelnut and sesame (Irani et al., 2011). Upon analysing the videotapes of classroom discussions, results showed that at the beginning of the debate, all the students were against the school's decision to ban mankushe (Table 4).

Table 4. Excerpt of classroom discussion at the beginning of the mankushe debate.

T: ok you are all against, but I want to see who will really support their argument. You have all the same argument, but you are with?
S1: what are we supposed to eat then?
S2: of course against because you can't mess with chocolate and mankushe
T: try to take into consideration all the facts and discuss them and decide which one convinced you more.
T: can you read your argument
S3: our argument doesn't support the decision because not everyone in the school has allergy against mankushe so, the person that shows allergic reactions shouldn't eat it and deprive others because if you had an allergic reaction other student wouldn't
T: what if this student isn't aware that he has an allergy and ate the mankushe and could've died
S4: then he dies
S5: he would learn not to eat again
T: wait, couldn't we avoid it from the beginning if hazelnut and sesame were banned from school? We could've avoided this.
T: For example, in the future, on a person who doesn't know he has an allergy and ate the mankushe and developed this allergy and almost died
S6: but he didn't

The reasons students provided to argue against the claim were primarily emotional (what are we supposed to eat? don't mess with mankushe, why should others be deprived). One student provided scientific reasoning during the discussion to defend against the claim (realising that if some students are allergic, others may not be). The students rejected the decision, and none of them considered alternative solutions.

During the debate, and as discussed with the first author before the study, the teacher tried to refute students' reasons and point out the study results from which the school's decision stemmed. The classroom discussion revealed an interesting flow of how students' reasoning changed due to the teacher's questioning and arguments against their claims.

The discussion in Table 5 shows that students remained attached to their initial claims against banning mankushe. Interestingly, students started proposing solutions to the issue (bringing their food if allergic or performing allergy tests). By the end of the session, some students had changed their arguments.

The student conversation in Table 6 shows more scientific reasoning than before, referring to the study results, and students used them to argue for banning mankushe. Also, students provided emotional reasons, such as fear of being among the small sample who could suffer an allergic reaction. Upon analysing students' written work on this activity after the discussion, 19 (70%) remained against the decision, whereas five students agreed to ban the mankushe (30%). The reasons that all five students provided were a combination of scientific and emotional reasonings. One student stated, 'what is our fault to be deprived of mankushe?'

Table 5. excerpt of classroom discussion during the debate about banning mankushe.

S1: but every person has an allergy to something, we can't ban everything
T: ok, but here start from the beginning, the study showed that many Lebanese people have allergies against hazelnut and sesame, so they only selected these two substances the school only banned these two because they are common, and there's a high probability that someone in this school develops an allergy against hazelnut or sesame than other substances, that's why they were banned
S2: if everyone has allergies, there would be no cafeteria in the school
S: they should do a test in school to know who has an allergy
T: do you think this is feasible?
S3: if someone has an allergy against food, let them not eat it
T: maybe they don't know
S4: is it possible that the students hadn't eaten Mankushe before?
T: what if he was not given enough money to afford it, and now he does?
S4: even outside school, he hadn't had Mankushe?
S5: what's our fault?
S6: so, we bring from outside school?
T: it's safer. Do you agree with me or not?
S7: No
T: basically, I'm saying we should take this decision to be safe. You are telling me that we should not why? You argue that the decision is wrong, but you are not convincing me why shouldn't we take this decision.
S7: because not everyone is allergic, why should we not eat if we're not allergic?
S8: why should we ban or be deprived of things just because of other people?
T: yes, but is this scientific evidence you are giving me? This is just emotional. I love chocolate, why should it be banned?
S8: This is not pathogenic food, why should we deprive people who do not have allergies? These non-pathogenic food won't affect people who don't have allergies
T: so it will affect people and might develop severe symptoms
S9: so what? whatever should happen will happen
T: should they ban it or not?

Table 6. Excerpt of classroom discussion showing some students' revised responses.

T: your friend changed her mind and agreed with me that we should ban these foods from schools. Construct an argument to convince others
S1: we can eat at home or bring food with us, but it's better than someone dying
T: so it's safer
S2: we always eat at school
S3: it's only 1%
S4: 1% could die
T: so this is using scientific evidence, so out of 1000 students in school, ten people have an allergy
S4: but this 1% could die
T: it's like saying it's ok for 1, 2 students to die, what do you think S4, S3 is saying, just 1% have allergies?
T: S4, what was your argument? How could you refute his argument?
S4: 1% could die. You could be that 1%
T: Is anyone else convinced?
(Students raise hands)
T: S5, how could you convince the others
S5: it's only 1%. I don't know
S4: if you were in the shoes of these not allergic people, what would you say?
S6: maybe we have this allergy but are not aware of it
S7: miss, I want to change it all. Can I use another paper
S5: But it doesn't lead to death. I am not convinced

Zooming in on the AIDS scenario

Other activities in which students showed scientific and emotional reasonings were those related to AIDS. These activities showed that ethical reasons and societal beliefs influenced students' reasoning and made them emotional. For example, to support the statement, *I've known her my whole life, she has good manners, and there's no way she has AIDS*, one student responded, '*if she has good manners and didn't do something wrong in her life, she will not catch AIDS unless she has blood transfusion or surgery.*' Thus, the student linked having good manners to AIDS, showing the influence of social factors on their decisions despite their scientific knowledge about HIV transmission.

Results also showed that ethical considerations hindered the use of scientific knowledge to support decisions. For example, 17 of the 24 (70.8%) agreed with the statement, *I feel nervous using the toilet after someone with HIV has used it because I'm afraid I'll get HIV*, whereas seven (29.2%) disagreed. Although students had six statements to choose

Table 7. Excerpt of classroom discussion about HIV transmission.

S1: do we get AIDS in the toilet?
T: what liquids are secreted that carry this disease? HIV is in semen, vaginal secretions, and blood and not in saliva
S2: so is it contagious in the toilet?
T: what do you think?
S2: yes, it is
T: if only found in semen and blood?
S2: no?
T: did we say in urine or bladder?
S2: no
T: do you know what semen and vaginal secretions are?
S2: no
T: semen is liquid ejaculated from males
S3: girls don't have secretions
S4: you don't know that
S3: so it could be contagious or not contagious. I am not convinced that it's not contagious. They say you are using the toilet after this person
S5: I disagree with you, but you can write your opinion
S6: is it transmitted through blood? How?
T: if blood has HIV and infects a needle that is used to inject another person
S7: what if someone ejaculates in the toilet? Then will it be transmitted

from and provide reasons for their decision, 13 of the 24 decided to select this particular statement, and six provided mixed reasoning (Table 1). Video transcripts during classroom discussions showed that students were confused by the science behind HIV transmission (Table 7).

The above student conversation shows that students didn't understand how HIV transmission occurs through seminal or vaginal secretions. Students falsely believed that females do not have secretions like males. Students asked specifically about the transmission of HIV in the toilet.

Discussion

Students' reasoning in scientific versus socio-scientific contexts

Our results indicated that students' reasoning skills were inconsistent across the activities and that social and cultural factors influenced students' reasoning (Ladachart & Ladachart, 2021). This result aligns with Widodo et al. (2017), who showed that the development of reasoning is non-linear across grade levels and among different issues. For example, these researchers determined that 75% of junior high school students held scientific reasoning on a Borax topic, but 20% used this reasoning on a Thalassemia-related issue. Similarly, in this study, students had scientific arguments in all the activities but still revealed a combination of scientific and emotional reasonings in activities related to AIDS and mankushe. In this study, students' scientific reasoning differed in scientific as opposed to socio-scientific contexts. In purely scientific scenarios, students linked the mechanisms they learned about immune cells to the scenario, but in socio-scientific contexts, they did not relate their scientific knowledge to the SSI. Thus, these students dominantly based their scientific reasoning on superficial macroscopic observations, even though they learned the details of the mechanisms. For example, even when students knew the effect of a particular allergen on immune cells and how the release of substances like histamine causes severe allergies, they did not use this knowledge in their reasoning when the context was culturally or socially embedded. In the socio-scientific activity of catching a cold, none of the students showed emotional reasoning like the AIDS or mankushe scenarios however, most of their scientific reasoning was macroscopic. The reason for not showing emotional reasoning in this activity could be that contrary to the AIDS or mankushe activities, the scientific knowledge about wearing a jacket did not contradict their beliefs. For example, in one argument, the snowman wearing a jacket claimed that it kept their body warm and helped the immune system fight disease. In this argument, many students believed that wearing a jacket when it's cold aligned with their scientific knowledge that keeping a constant body temperature helps the immune system operate optimally. The other theory claimed that the snowman would not catch a cold because it would need a virus to be infected. This theory did not conflict with their scientific knowledge that a virus causes infection regardless of wearing the jacket.

Decisions, reasons, and solutions during argumentation about SSI

Students did not use their knowledge about allergic reactions and the mechanisms involved to explain their choices. Even when students knew the effect of a particular

allergen, their decision to ban or keep the mankushe remained mainly emotional. This result suggests that students' engagement in an SSI tended to reflect their preferences on the issues (Ladachart & Ladachart, 2021). Sadler and Zeidler (2005) and Widodo et al. (2017) suggested that ethical, moral, and empathy strongly impact emotive reasoning. For example, most Indonesian students used emotive reasoning when presented with a scenario in which a wife cheats on her husband and has a child with her boyfriend (Widodo et al., 2017). Similarly, in the Lebanese context, students linked AIDS to bad behaviour, and this emotion could influence students' reasoning. Also, in the mankushe activity, some students sympathised with individuals who might struggle with unexpected allergic reactions and used these feelings in combination with scientific reasoning to decide on banning mankushe.

We could explain these results using the concepts of cultural or ethical border crossing and collateral learning (Ladachart & Ladachart, 2021). These results support the claim that individuals bring their social identities and cultural backgrounds into making decisions and reasoning about SSIs (Balgopal et al., 2017; Evagorou et al., 2012; Simonneaux & Simonneaux, 2009; Zeidler et al., 2005).

Implications for curriculum and instruction

This study contributes to the literature by teasing apart the various kinds of reasoning issues that are culturally and emotionally laden. It shows that knowing the scientific explanation is necessary but insufficient to make scientifically based decisions. Therefore, we believe that with such issues, there needs to be a) more space given to the teacher to lead the argumentation of SSIs and b) an interdisciplinary approach that allows individuals to highlight the value of scientific knowledge in society.

Classroom discussions showed that some students revised their decisions upon engaging in argumentation and having the teacher question their ideas. Thus, giving teachers space for argumentation and scaffolding through questions allows students to change their minds or think of alternative solutions to accommodate allergic individuals. Berland and McNeill (2010) argued that the argumentation process should include individuals stating and defending their claims, questioning and evaluating each other's claims, and revising their and others' claims. They also stressed the importance of teacher questioning and oral communication in argumentation. While our findings provide valuable insights into the Lebanese educational landscape and the specific challenges and considerations of students in this context, they should be interpreted within this local framework. Future research could extend the scope to other regions, allowing for a more comprehensive understanding of argumentation strategies and educational practices in a global context.

Ethics statement

The American University of Beirut's (AUB) Institutional Review Board reviewed and approved our research (IRB ID: EDU.SB.14). The teacher sent out the child and parental consent forms and waited a week to gather all documents. Only data from students who provided parental and child assent were used in the analysis. We removed students' original names and added pseudonyms or numbers.

Notes

1. Scientific issues are characterised by empirical, objective, narrowly focused, and less subjective questions. In contrast, SSIs are complex, involve ethical and moral considerations, require interdisciplinary perspectives, and often demand value-based decision-making. It is worth noting that SSI include scientific issues so the science is in there, but we also expand to look at the context which influences specific contexts or cultural background influences students reasoning of scientific issues.
2. While the definitions of 'macroscopic' and 'microscopic' scientific reasoning remain consistent across both scientific and socio-scientific contexts, the key difference in SSIs lies in the focus and application of these reasoning types. In SSIs, macroscopic scientific reasoning emphasises broad observations and the overarching societal and ethical implications, whereas microscopic scientific reasoning deals with the specific scientific processes related to the SSI being analysed.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Ihsan Ghazal http://orcid.org/0000-0002-7710-3855
Saouma Boujaoude http://orcid.org/0000-0001-9789-7042

References

Balgopal, M. M., Wallace, A. M., & Dahlberg, S. (2017). Writing from different cultural contexts: How college students frame an environmental SSI through written arguments. *Journal of Research in Science Teaching*, *54*(2), 195–218. https://doi.org/10.1002/tea.21342

Berland, L. K., & McNeill, K. L. (2010). A learning progression for scientific argumentation: Understanding student work and designing supportive instructional contexts. *Science Education*, *94*(5), 765–793. https://doi.org/10.1002/sce.20402

Brocos, P., Jiménez-Aleixandre, M. P., & Baker, M. J. (2022). "Be rational!" epistemic aims and socio-cognitive tension in argumentation about dietary choices. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.933062

Center for Educational Research and Development. (1994). *National educational plan*. www.crdp.org

Dawson, V., & Venville, G. (2013). Introducing high school biology students to argumentation about socioscientific issues. *Canadian Journal of Science, Mathematics and Technology Education*, *13*(4), 356–372. https://doi.org/10.1080/14926156.2013.845322

Dawson, V., & Venville, G. J. (2009). High-school students' informal reasoning and argumentation about biotechnology: An indicator of scientific literacy? *International Journal of Science Education*, *31*(11), 1421–1445. https://doi.org/10.1080/09500690801992870

Demir, A., & Namdar, B. (2019). The effect of modeling activities on grade 5 students' informal reasoning about a real-life issue. *Research in Science Education*, https://doi.org/10.1007/s11165-019-09896-8

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*, *84*(3), 287–312. https://doi.org/10.1002/(SICI)1098-237X(200005)84:3<287::AID-SCE1>3.0.CO;2-A

Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic, and social learning goals. *Review of Research in Education*, *32*(1), 268–291. https://doi.org/10.3102/0091732x07309371

Duschl, R., Avraamidou, L., & Azevedo, N. (2021). Data-Texts in the sciences. *Science & Education*, *30*, 1159–1181. https://doi.org/10.1007/s11191-021-00225-y

Duschl, R., & Ellenbogen, K. (2009). Argumentation and epistemic criteria: Investigating learners' reasons for reasons. *Educación Química*, *20*(2), 111–118. https://doi.org/10.1016/S0187-893X(18)30017-X

Duschl, R. A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. *Studies in Science Education*, *38*(1), 39–72. https://doi.org/10.1080/03057260208560187

Erduran, S., & Jiménez-Aleixandre, M. (2008). *Argumentation in science education: Perspectives from classroom-based research*. Springer.

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's argument pattern for studying science discourse. *Science Education*, *88*(6), 915–933. https://doi.org/10.1002/sce.20012

Evagorou, M., Jimenez-Aleixandre, M. P., & Osborne, J. (2012). Should we kill the grey squirrels?' A study exploring students' justifications and decision-making. *International Journal of Science Education*, *34*(3), 401–428. https://doi.org/10.1080/09500693.2011.619211

Flick, L. B. (2018). The nature of science and the scientific method. In L. B. Flick (Ed.), *Scientific methods for the social sciences* (pp. 1–28). Taylor & Francis.

Georgiou, M., Mavrikaki, E., Halkia, K., & Papassideri, I. (2020). Investigating the impact of the duration of engagement in socio-scientific issues in developing Greek students' argumentation and informal reasoning skills. *American Journal of Educational Research*, *8*, 16–23.

Guilfoyle, L., & Erduran, S. (2021). Recalibrating the evolution versus creationism debate for student learning: Towards students' evaluation of evidence in an argumentation task. *International Journal of Science Education*, *43*(18), 2974–2995. https://doi.org/10.1080/09500693.2021.2004330

Irani, C., Maalouly, G., Germanos, M., & Kazma, H. (2011). Food allergy in country: Is sesame seed the "region" peanut. *World Allergy Organization Journal*, *4*(1), 1–3. https://doi.org/10.1097/WOX.0b013e318204b745

Jiménez-Aleixandre, M. P. (2008). Argumentation in science education: An overview. In S. Erduran, & M. P. Jiménez-Aleixandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research* (pp. 3–28). Springer.

Jiménez-Aleixandre, M. P., Bugallo Rodriguez, A., & Duschl, R. A. (2000). Doing the lesson? Or doing science?: Argument in high school genetics. *Science Education*, *84*(6), 757–792. https://doi.org/10.1002/1098-237x(200011)84:6<757::aid-sce5>3.0.co;2-f

Jiménez-Aleixandre, M. P., & Crujeiras, B. (2017). Epistemic practices and scientific practices in science education. *Science Education*, 69–80. https://doi.org/10.1007/978-94-6300-749-8_5

Kelly, G. J. (2009). Inquiry, argument, and science instruction: A comparison of inductive and deductive instruction. In R. A. Duschl, & R. E. Grandy (Eds.), *Teaching scientific inquiry: Recommendations for research and implementation* (pp. 397–425). Sense Publishers.

Kelly, G. J., Druker, S., & Chen, C. (1998). Students' reasoning about electricity: Combining performance assessments with argumentation analysis. *International Journal of Science Education*, *20*(7), 849–871. https://doi.org/10.1080/0950069980200707

Kelly, G. J., & Licona, P. (2017). Epistemic practices and science education. *Science: Philosophy, History and Education*, 139–165. https://doi.org/10.1007/978-3-319-62616-1_5

Kolstø, S. D. (2006). Patterns in students' argumentation confronted with a risk-focused socio-scientific issue. *International Journal of Science Education*, *28*(14), 1689–1716. https://doi.org/10.1080/09500690600560878

Kuhn, D. (2010). Teaching and learning science as argument. *Science Education*, *94*(5), 810–824. https://doi.org/10.1002/sce.20395

Ladachart, L., & Ladachart, L. (2021). Preservice biology teachers' decision-making and informal reasoning about culture-based socioscientific issues. *International Journal of Science Education*, 1–31. https://doi.org/10.1080/09500693.2021.1876958

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching*, *29*(4), 331–359. https://doi.org/10.1002/tea.3660290404

Licona, P. R., & Kelly, G. J. (2019). Translanguaging in a middle school science classroom: Constructing scientific arguments in English and spanish. *Cultural Studies of Science Education*, *15*(2), 485–510. https://doi.org/10.1007/s11422-019-09946-7

Liu, S. Y., Lin, C. S., & Tsai, C. C. (2011). College students' scientific epistemological views and thinking patterns in socioscientific decision making. *Science Education*, *95*(3), 497–517. https://doi.org/10.1002/sce.20422

Manz, E. (2015). Representing student argumentation as functionally emergent from scientific activity. *Review of Educational Research*, *85*(4), 553–590. https://doi.org/10.3102/0034654314558490

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. The National Academies Press.

Ong, Y. S., Duschl, R. A., & Plummer, J. D. (2020). Scientific argumentation as an epistemic practice: Secondary students' critique of science research posters. *Science Education in the 21st Century*, 81–93. https://doi.org/10.1007/978-981-15-5155-0_6

Osborne, J. (2010). Arguing to learn in science: The role of collaborative, critical discourse. *Science*, *328*(5977), 463–466. https://doi.org/10.1126/science.1183944

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching*, *41*(10), 994–1020. https://doi.org/10.1002/tea.20035

Osborne, J., Erduran, S., Simon, S., & Monk, M. (2000). Enhancing the quality of argument in school science. *School Science Review*, *82*, 63–70.

Osborne, J., Simon, S., Christodoulou, A., Howell-Richardson, C., & Richardson, K. (2013). Learning to argue: A study of four schools and their attempt to develop the use of argumentation as a common instructional practice and its impact on students. *Journal of Research in Science Teaching*, *50*(3), 315–347. https://doi.org/10.1002/tea.21073

Oulton, C., Dillon, J., & Grace, M. M. (2004). Reconceptualizing the teaching of controversial issues. *International Journal of Science Education*, *26*(4), 411–423. https://doi.org/10.1080/0950069032000072746

Ozden, M. (2020). Elementary school students' informal reasoning and its' quality regarding socioscientific issues. *Eurasian Journal of Educational Research*, *20*(86), 1–24. https://doi.org/10.14689/ejer.2020.86.4

Sadler, T. D., Chamber, F. W., & Zeidler, D. L. (2004). Student conceptualizations of the nature of science in response to a socioscientific issue. *International Journal of Science Education*, *26*(4), 387–409. https://doi.org/10.1080/0950069032000119456

Sadler, T. D., & Zeidler, D. L. (2005). Patterns of informal reasoning in the context of socioscientific decision making. *Journal of Research in Science Teaching*, *42*(1), 112–138. https://doi.org/10.1002/tea.20042

Sampson, V., Enderle, P., Grooms, J., & Witte, S. (2011). Argument-driven inquiry as a way to help students learn how to participate in scientific argumentation and craft written arguments: An exploratory study. *Science Education*, *95*(2), 217–257. https://doi.org/10.1002/sce.20421

Simon, S., Erduran, S., & Osborne, J. (2006). Learning to teach argumentation: Research and development in The science classroom. *International Journal of Science Education*, *28*(2–3), 235–260. https://doi.org/10.1080/09500690500336957

Simonneaux, L., & Simonneaux, J. (2009). Students' socio-scientific reasoning on controversies from the viewpoint of education for sustainable development. *Cultural Studies of Science Education*, *4*(3), 657–687. https://doi.org/10.1007/s11422-008-9141-x

Sparks, R. A., Jimenez, P. C., Kirby, C. K., & Dauer, J. M. (2022). Using critical integrative argumentation to assess socioscientific argumentation across decision-making contexts. *Education Sciences*, *12*(10), 644. https://doi.org/10.3390/educsci12100644

Toulmin, S. (1958). *The uses of argument*. Cambridge University Press.

Toulmin, S. E. (1988). *The uses of argument*. Cambridge University Press.

van Eemeren, F. H., Grootendorst, R., Johnson, R. H., Platin, C., & Willard, C.A. (1996). *Fundamentals of argumentation theory: A handbook of historical backgrounds and contemporary developments* (1st ed.). Routledge.

Venville, G. J., & Dawson, V. M. (2010). The impact of a classroom intervention on grade 10 students' argumentation skills, informal reasoning, and conceptual understanding of science. *Journal of Research in Science Teaching*, *47*(8), 952–977. https://doi.org/10.1002/tea.20358

Widodo, A., Saptarani, D., Riandi, R., & Rochintaniawati, D. (2017). Development of students' informal reasoning across school level. *Journal of Education and Learning*, *11*, 273. https://doi.org/10.11591/edulearn.v11i3.639

Wu, Y. T., & Tsai, C. C. (2007). High school students' informal reasoning on a socio-scientific issue: Qualitative and quantitative analyses. *International Journal of Science Education*, *29*(9), 1163–1187. https://doi.org/10.1080/09500690601083375

Yang, F.-Y., & Anderson, O. R. (2003). Senior high schools' preference and reasoning modes about nuclear energy use. *International Journal of Science Education*, *25*(2), 221–244. https://doi.org/10.1080/09500690210126739

Zeidler, D. L., Applebaum, S. M., & Sadler, T. D. (2011). Enacting a socioscientific issues classroom: Transformative transformations. In T. D. Sadler, (Ed.), *Socio-Scientific issues in the classroom: Teaching, learning and research* (pp. 277–305). *Contemporary Trends and Issues in Science Education*. Springer. ISBN 978-94-007-1159-4.

Zeidler, D. L., & Nichols, B. H. (2009). Socioscientific issues: Theory and practice. *Journal of Elementary Science Education*, *21*(2), 49–58. https://doi.org/10.1007/BF03173684

Zeidler, D. L., Sadler, T. D., Simmons, M. L., & Howes, E. V. (2005). Beyond STS: A research-based framework for socioscientific issues education. *Science Education*, *89*(3), 357–377. https://doi.org/10.1002/sce.20048