Chapter 11
Metalogue: Engaging Students in Scientific and Socio-scientific Argumentation

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Evagorou: In this chapter, Shirley and Ruth raise several interesting issues related to (socio-scientific issues) SSI, argumentation, and decision-making. A major question in this study was the quality of students' arguments, and if there is a link between the nature of the evidence (e.g., scientific, environmental, financial) and the quality of the arguments. The results are not conclusive as to this point, and the authors suggest that more evidence is necessary. The issue of quality of arguments has been prominent in discussions in the science education community lately (e.g., Erduran, 2008) and reading this study made me think about the following issues:

(a) Is the quality of the arguments also connected to the quality of the evidence that is presented in the learning environments? If so, what more do we need to learn to inform the design of SSI and argumentation curriculum?
(b) Are the arguments supported by evidence collected/produced by the students bound to be of higher quality?

Another issue that arises from this chapter is the level of engagement with the learning environment and what kind of affordances different curriculum materials might have, especially when SSI are involved. The closer the connection between the issue under study and students' identities, the more students' beliefs systems are affected, making it more probable that students will ignore evidence and provide weaker justifications that are mostly based on personal values

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(Simonneaux & Simonneaux, 2009) or their personal and cultural identities (López-Facal & Jiménez-Aleixandre, 2008). This trend supports that development of learning experiences that are not authentic. On the other hand, other researchers argue that the issue is not whether students' decisions are more value-based than knowledge-based, but on what kind of knowledge is regarded as relevant by the students (Kolstoe, 2006). The Bleaksville debate presented to Jackie's class engaged her students in discussions, but I am wondering whether a more authentic learning experience (e.g., measuring and discussing air quality in London) would afford better quality arguments, and what kind of evidence the students would choose (scientific, environmental, financial) to support their arguments.

Sampson: The study described in this chapter, which examined how students made decisions and used evidence as they discussed various ways to improve air-quality in the imaginary town of Bleaksville and how the classroom teacher attempted to promote and support this process, provided many key insights into how students engage in socio-scientific argumentation when they are given an opportunity. It also, like all good research, raises new questions and opens up some potential avenues for future work.

The first question that came to my mind as I read Shirley and Ruth's study concerned the relationship between argumentation that is scientific in nature, which is the focus of my research, and socio-scientific argumentation is: How much of an overlap is there between scientific argumentation and socio-scientific argumentation? Shirley and Ruth briefly touched on this issue when they described argumentation in general and compared it to the nature of socio-scientific argumentation. It seems to me that there is some obvious overlap between the two because both processes require people to construct, justify, and refute arguments. However, there are also some major differences. For example, Shirley and Ruth describe how the students in their study were trying to determine which policy to endorse in order to improve air quality without making the citizens unhappy. This type of activity, where people need to consider different courses of action related to a complex problem from multiple viewpoints, seems to be a hallmark of socio-scientific argumentation but it is very different from the purpose of argumentation that is more scientific in nature. In scientific argumentation, people are often attempting to explain or describe a natural phenomenon or develop a valid and acceptable answer to a research question. This is a different goal and thus the types of claims that can be made in each context will be different. There are also several differences in the nature of the supports and challenges that people can use in these two contexts. In socio-scientific contexts, a wide range of reasons are viewed as an acceptable way to support or challenge the viability of a course of action. These reasons include, but not are limited to, social, economic, moral, and empirical. In scientific contexts, in contrast, the reasons that tend to be used to support or challenge a claim are often limited to those that are empirical, theoretical, methodological, or analytical in nature. There are other differences to be sure. I therefore think science educators working in the field of socio-scientific argumentation will need to help students understand the similarities and differences between argumentation that is scientific and socio-scientific in nature.

My second question, which stems from my first, concerns the issue of transfer. If there are significant differences between scientific and socio-scientific argumentation such as the ones I described earlier, can we expect students to transfer what they have learned about participating in one type of argumentation to the other? This issue has not been well investigated but I think it is important. I do not think we can assume that students will be able to participate in these two forms of argumentation in a desired manner without learning about both of them. This conjecture is based, in large part, on the difficulties that students face when they are first asked to participate in scientific forms of argumentation that are so well documented in the literature. Yet, it is important to note that the difficulties that students have when they first participate in scientific argumentation do not seem to stem from a lack of natural ability. Most students just have never had an opportunity to participate in scientific argumentation and do not understand the "rules of the game" and are therefore forced to rely on "everyday" forms of argumentation. That is one reason why short interventions often lead to substantial improvements in students argumentation skills (e.g., Venville & Dawson, 2010); students just need to be introduced to what counts as quality in a given context. Therefore, if socio-scientific argumentation and scientific argumentation are different but related to forms of argumentation, perhaps it would be better for science educators to treat the ability to participate in each type of argumentation as distinct but equally desirable outcomes of a high quality science education.

The third question that I have is: How should we, as field, define evidence in a socio-scientific context and should all types of information be considered evidence? Shirley and Ruth, for example, describe how the students were given "evidence statements" that they classified as scientific, environmental, economic, and social. Yet, as I read the samples they included in the chapter, the statements appeared to be different types of reasons rather than evidence. I tend to define evidence in science as observations, measurements, or findings from other studies that have been collected, analyzed, and interpreted by researchers (Sampson & Gerbino, 2010). I use this definition to help students understand the difference between evidence, data, and unsubstantiated inferences when I ask them to construct evidence-based argument in response to a research question. However, this definition is not the only one in the literature and it is perhaps not even the most useful definition. Other authors, for example, describe evidence in science simply as data that is used to support a claim (Berland & Reiser, 2009; McNeill, Lizotte, Krajcik, & Marx, 2006). This is a much more general definition than the one I use in my research.

I raise this question because I think it is important for students to understand what does and does not count as genuine evidence in science. Do we also need to help students understand the difference between the various types of reasons that can be used during an episode of socio-scientific argumentation? Some reasons such as intuitive and emotive ones or appeals to the greater good are often used to persuade people but these types of reasons might not be as strong or convincing as others (such as ones that are economic, political, empirical, and ethical or moral in nature). Therefore, it might be a productive strategy to help students learn how to identify the various types of reasons people use to support a viewpoint or course of

action and how to challenge these reasons in an appropriate manner if we want them to learn how to participate in better socio-scientific argumentation.

Fourth, should we, as field, expand our assessments of argumentation to include the nature or types of criteria students use to evaluate claims, answers to research questions, or alternative courses of action proposed by others? Shirley and Ruth provided an interesting analysis of the nature of the argumentation that students engaged in during the Bleaksville activity. However, this analysis was structural in nature and focused on the absence or presence of various components of an argument. I cannot help but wonder what we would have learned about the students' socio-scientific argumentation if Shirley and Ruth had also examined the nature of the criteria that students used to evaluate the different policies or the nature of the rebuttals these students privileged in this context. For example, did the students rely on economic reasons more than scientific reasons when they evaluated the different policies or to challenge an alternative idea? I think this type of analysis would tell us a great deal about the students' thinking during an episode of socio-scientific argumentation and would give us a measure of how often students tend to use scientific explanations to evaluate different perspectives.

Finally, Shirley and Ruth's description of how the teacher, Jackie, attempted to promote and support student participation in socio-scientific argumentation during the Bleaksville activity was extremely interesting. I think the field, as a whole, needs to focus more on how teachers modify and adapt curricula and structure classroom instruction in different contexts and the underlying reasons for their decisions. This study, for example, made me wonder about the underlying goals of the classroom teacher. It seems to me that Jackie's main goal was to increase the likelihood that the students would discuss the policies and not for them to learn how to engage in better socio-scientific argumentation. I think this is one reason why we tend to see teachers, such as Jackie, scaffold student engagement in this type of activity so much; teachers often want to make sure their students do it "right" the first time. However, it might be better to let students make mistakes and allow them to learn from them (along with more productive strategies and techniques) if the long-term goal is better argumentation skills, especially if the teacher plans to engage students in argumentation repeatedly over the course of the semester. I also wondered about how much the "unwritten rules of school" influenced the students' actions during this activity. The Bleaksville activity is clearly different from typical science classroom activities and it often takes students a long time to learn how to participate in unfamiliar activities. Students also need to see the value of this type of activity such that it makes sense and they have a reason to construct and evaluate arguments with their peers in the context of school science (Berland & Reiser, 2009). Is there a need for more longitudinal studies of how teachers scaffold socio-scientific argumentation inside the classroom over time and how students learn to participate in this type of complex activity? I think we could learn a great deal from this type of research.

Maria also raises some interesting questions about the quality of arguments generated by students and the nature of the activities used by science educators to promote and support students in socio-scientific argumentation. Overall, I think

there clearly is a relationship between the nature of the arguments crafted by students and the amount and type of information available to students and the nature of the topic. For example, if we want students to construct an evidence-based argument, then students need to have access to data gathered through empirical research (or findings from empirical studies) that they can analyze, interpret, and transform into evidence. In socio-scientific contexts, students also need access to information about political motives, economic realities, and other factors. Students, in other words, need to have access to a great deal of information before we can expect them to look at an issue from multiple perspectives and construct two-sided arguments.

In the context of an imaginary scenario, such as the Bleaksville activity, the responsibility for finding or creating this information lies with the developers of the activity. Yet, students do not have to engage in socio-scientific argumentation around an imaginary scenario. Students can be asked to weigh the pros and cons of a proposed tax on beverages with high sugar content or evaluate the merits of a proposed cap and trade policy as a way to control carbon emissions. In this type of activity, students could use the available literature to develop their arguments and critique the arguments of their peers. I think the more important question is how to structure an activity in the appropriate manner in light of the topic, students involved, and the student learning objectives. The number of questions educators must consider when designing an activity, curriculum, or learning environment is vast. For example, what do we want students to be able to do during an episode of socio-scientific explanation? Should students be supplied with information or should we expect them to find their own? If we supply students with information should it all be relevant or should we expect students to determine what is and what is not important? Is it better to start simple for students and get more complex or is better to start with a complex issue and let students learn from their mistakes? There is a great deal of research that needs to be done before we can begin to develop tentative answers to these types of questions. I think we also need to learn more about student thinking in these various situations before we can begin to take advantage of the potential benefits of engaging students in socio-scientific argumentation. Last, but certainly not least, we also need to determine if the answers to these various questions are context specific or broadly applicable.

Simon and Amos: Maria raises two questions in her response to the chapter. First she asks whether the quality of arguments is connected to the quality of evidence provided to the students in the learning environment and second, whether quality of argument would be higher when evidence is sourced by the students themselves. The answer to the first question is clearly yes; in a recent study of students engaged in argumentation in socio-scientific contexts we have found that if information is provided with an activity then the students tend to use it in their argumentation in addition to, or in preference to, their own ideas and knowledge, thus quality of argumentation is connected to the kinds of evidence available. Exploring the links between quality of socio-scientific argument and the kinds of evidence both provided and used (i.e., scientific, social, economic) could be a subject of further research using different socio-scientific contexts.

With reference to Maria's second question, it is interesting to note that prior to the Bleaksville debate, the *Twenty First Science* teaching unit did include activities where students measured local air quality. However, neither they nor the teacher made specific links between the practical investigation and the debating activity. To make the Bleaksville debate more authentic and relevant, with the possibility of higher quality argumentation, guidance could be provided to help teachers scaffold the links between the activities of the scientific components and the socio-scientific debates. Indeed such links could be a vehicle for helping students to develop scientific argumentation as well as socio-scientific argumentation, through drawing out the kinds of arguments needed in both contexts and evaluating the differences. Such a process would address the distinction between the two forms of argumentation that is the basis of Vic's first question, where he raises the issue of overlap and difference between scientific and socio-scientific argumentation.

Vic also raises the question of how we define "evidence" in a socio-scientific context. The course materials for Bleaksville use the term "evidence statements," even though, as Vic suggests, the statements provide different types of reasons rather than evidence. The term evidence is clearly problematic if its definition is based on observations, measurements or findings collected, analyzed, and interpreted by researchers. In our work on argumentation, "evidence" is defined as information used in arguments to support claims, either as data, warrants or backings. In designing materials for teachers to use in socio-scientific argumentation, curriculum developers are clearly specifying statements that could be used as evidence to support claims, which is helpful to teachers inexperienced in teaching argumentation as well as the students themselves. We agree with Vic's suggestion that strategies to help students identify the reasons used to support different viewpoints and how to challenge these reasons in an appropriate way are important aspects of learning how to engage effectively in socio-scientific argumentation, but such strategies can be achieved through examining the nature and strength of reasons or "evidence" irrespective of how these are labeled. This point leads to Vic's fourth question about the criteria students use in evaluating arguments. In our study on quality of argumentation we did focus on the structural nature of students' arguments and it would have been interesting to explore the criteria students used. However, our study was undertaken in an authentic classroom where *Twenty First Century* activities were being piloted. We would have needed to take a more interventionist stance to explore students' ideas about how they judged evidence. Jackie's intervention was restricted to identification of pros' and "cons" rather than strength of evidence and argument. In our other work with teachers using IDEAS (Osborne, Erduran, & Simon, 2004), we have tried to emphasize the importance of developing criteria for evaluating knowledge claims, but teachers find this unfamiliar and need tools for supporting such a process with students.

Vic's final point is that the field needs to focus more on how teachers modify and adapt curricula and structure reasons for their decisions. Since the publication of IDEAS, we have been re-examining the criticality of guidance and how it relates to teachers' interpretation and enactment of argumentation activities (Simon & Richardson, 2009). There are many layers of interpretation involved,

and enactment is driven by underlying goals and values. Our recent work in developing argumentation practice in whole school science departments has revealed the need for both teachers and students to practice argumentation activities, and our current analysis building on earlier work on teachers' scaffolding of argumentation (Simon, Erduran, & Osborne, 2006) aims to understand teachers' development in this practice.

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