Argumentation as a Tool to Understand Complexity of Knowledge Integration

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Abstract: *Science literacy is a central concern for public discussion of socio-scientific issues related to STEM. Such issues are increasingly present in the school curriculum and places greater responsibility on teachers to be knowledgeable about STEM and especially about how to engage in socio-scientific discussion. This paper reports research conducted with undergraduate teacher education students at the beginning of a course dealing with science literacy at a Canadian university. Groups of 4-5 students engaged in a discussion of one of two topics, one was current and controversial, the other less contentious. Transcripts of the verbal interactions were analyzed using a coding scheme adapted from Duschl (2008) based on the presumptive argumentation schemes of Walton, Reed and Macagno (2008). Results indicated that argument from personal or reported experiences predominated both topics but otherwise different argument schemes were utilized. Social dimensions of a topic were discussed just as often as arguing from evidence even though students had been directed to briefly research the assigned topic before the discussion. The group discussing the less contentious issue was able to adjust their points-of-view and arrive at a consensual solution. The group discussing the more contentious topic was less inclined to change perspectives and failed to achieve a collective position. Moreover, only this group expressed concern over bias in the scientific evidence uncovered in their research. Implications for understanding the integration of knowledge sources and argumentation schemes are discussed in relation to controversial socio-scientific issues.*

Keywords: argumentation, scientific literacy, socioscientific issues, knowledge integration

1. Background

STEM is fundamental to personal, social and national interests and so it is hardly surprising that there is widespread public interest. Public awareness and concern is an important starting point, however participating in discussions of socio-scientific issues relies on a threshold level of scientific literacy. A recent report from a national expert panel in Canada (Let's Talk Science, 2012) emphasized the importance of public engagement with socio-scientific issues. The panel noted that contributing to public discussions relies on achieving basic knowledge of science and a level of understanding the processes of identifying and resolving science-related problems in society. The importance of a general level of science literacy to enable a society to address issues related to STEM has been emphasized many times (Hodson, 2003; Hurd, 2002; Kolsto, 2001; National Research Council, 2011; OECD, 2007; Roth & Barton, 2004; Yore, 2011). Part of the on-going discussion is the consideration of the essential elements of science literacy for all (Norris and Phillips 2003; Yore, Bisanz and Hand, 2003; DeBoer, 2000; Hand et al., 2003). While there are differences in the details of what constitutes scientific literacy, there is consensus that science literacy includes at least knowledge of science and knowledge about science; that is, there is a necessary threshold of science content knowledge, while at the same time an awareness of the fundamental features of thinking and expressing oneself 'scientifically' (Nbina & Obomanu, 2010; Norris & Phillips, 2003). The research reported in this paper is focused on the expression of scientific reasoning by undergraduate teacher education students.

Science educators are sensitive to the distinctive forms of expression that distinguish scientific discourse. From this has arisen a number of pedagogical practices intended to tutor students in the use of scientific forms of expression in order to promote science learning such as the Science Writing Heuristic (Aschbacher & Alonzo, 2006; Keys, et al., 1999; Hand, Wallace & Yang, 2004) and Science Notebooks (Klentschy, 2008; Ruiz-Primo et al., 2004). Incorporating explicit teaching of the forms of science expression in the context of content learning has demonstrated the value of a literacy focus for science education (Yore, Bisanz & Hand, 2003).

The next step is to build on these scaffolds of textual control toward a deeper engagement with logical reflection and argumentation (Osborne, 2010; Pearson, Moje & Greenleaf, 2010) to facilitate the transfer and application of STEM knowledge in lifeworld contexts. The perplexing problem in science education has been the uncertainty of the complex relations between scientific knowledge on the one hand, and reasoning and decision making on the other (Sadler, 2004; Zeidler, Walker, Ackett, & Simmons, 2002). Some researchers report a significant relationship between content knowledge and reasoning (e.g., Hogan, 2002; Sadler & Zeidler, 2005); while other researchers found that the influence of scientific knowledge was minimal on students' reasoning compared to personal or social influences (Kuhn, 1991; Means & Voss, 1996).

These deeper levels of critical reasoning that are characteristic of science literacy are related to forms of argumentation (Duschl & Osborne, 2002; Gillies & Khan, 2009; Martin & Hand, 2007; National Research Council, 2008; Simon, Erduran & Osborne, 2006). Mercier and Sperber (2011) emphasized the importance of argument as reasoning, and Ford (2008) has pointed out that critical dialogue is an essential social practice of science. A number of scholars have proposed that effective argumentative reasoning would increase understanding and that ineffective argumentative reasoning, such as confirmatory bias, results in lack of learning (Gillis, Nichols & Burgh, 2011; Mercer, et al., 2004; von Aufschaiter, et al., 2008). Argumentation has emerged as an important characteristic feature of science literacy.

Toulmin's (1958) model of argumentation is widely recognized and has served to introduce a standard vocabulary of claims, warrants, data, backing to guided much early research (e.g., Nussbaum, 2011; Osborne, Erduran, & Simon, 2004). Science educators and researchers have sought to promote critical reasoning by introducing Toulmin's Argument Pattern (TAP) to students as a vehicle for the evaluation of evidence and construction of explanations as a core discursive activity within a science literacy approach to understanding socio-scientific topics (Duschl, 2007; Osborne, Erduran, & Simon, 2004). TAP has been a promising approach for enhancing students' critical thinking, reasoning and decision-making regarding scientific and socio-scientific issues (Driver, Newton, & Osborne, 2000; Nussbaum 2011; Osborne, Erduran, & Simon, 2004; Roberts & Gott, 2010; Sadler, 2004). When students are faced with a socio-scientific issue they are expected to evaluate data and evidence to support or refute claims and construct their own explanations linking the data and evidence to hypothesis or theories. The interplay of claims, evidence and justification in argumentation engages students' capacity to engage in the evaluation and construction of opinions, explanations and recommendations (Jimenez-Aleixandre & Erduran, 2007; Gillis, Nichols and Burgh, 2011; Mercer, et al., 2004; von Aufschaiter, et al., 2008). The dialogical nature of argumentation also encourages students to understand the development of scientific knowledge through social interactions. However, it has been noted that evidence or logical reasoning may not prevail when interacting about socio-scientific issues. For example, some prefer to only look for backing to support their current views, a condition referred to as confirmation bias, or to ignore evidence that is contrary to personal opinion. Such interaction demonstrates an absence of critical thinking and plausible reasoning and allows erroneous beliefs to persist (Mercier & Sperber, 2011). In such a situation arguments do not serve to promote learning even when the exchanges include the elements of an argument identified by Toulmin (Gilabert, Garcia-Mila, & Felton, 2012). The need for understanding deeper levels of reasoning invites a further consideration of argument structures.

While much attention has been focused on the components that Toulmin (1958) identified for arguments, there are other aspects of his work that have received less notice. In particular that not all the components are necessary for a 'good' argumentation, and that the quality of arguments can only be judged in relation to the context in which they occur. The criteria for a *good* argument vary from one context to another (p. 45). Toulmin recognized that some parts of an argument are consistent across many contexts, "field invariant"; while other parts vary more or less with the context. Toulmin's work remains very influential, nonetheless his proposals are now more than 50 years old and in the intervening years a number of advances in the theoretical understanding and the pedagogical consequences of student learning and use of argument have emerged. Nussbaum (2011) outlined a couple of alternative frameworks to advance the study of argumentation in education. Nussbaum focuses most heavily on the extensive work by Douglas Walton, in particular schemes of plausible arguments. Walton has identified a number of 'schemes" that are employed in arguments made in a variety of contexts. Each scheme is a particular pattern of reasoning and Walton and his colleagues (Walton, Reed & Macagno, 2008) have described 60 schemes, some of them derived from classical arguments and others from more contemporary sources. Each scheme is accompanied "critical questions" that can be applied to examine the quality of the argument. Walton is concerned with the acceptability (plausibility) of an argument, that is, whether it is reasonable to accept an argument. The argument schemes are therefore highly dependent on context and rely on a notion of quality. Based on argumentation schemes and structure, this study looks into students' argumentation on local socio-scientific issues.

2. Research context & Process

2.1 Participants

This study was conducted during a science education course in a university in Western Canada. The focus of course was on scientific and technological literacy and science teaching. The participants in this course were in their final year of Bachelor of Education program with elementary and middle year focus. All of them had previously completed a course about how to teach science, a 'methods' course. None had much more than the minimum level of one science course at university as an entry requirement to their program. Eight of the 16 students in the class volunteered for this study. All students participated in all class activities such as lectures, research on local socioscientific issues, group discussions and presentations. The course instructor was not aware of which students had consented to participate in the research during the conduct of the class.

2.2 Research Design

During the course, students read and attended lectures about the character of socio-scientific argumentation from a Toulmin perspective and were regularly divided into small groups of 4 to 5 to discuss the nature of science and technology in modern society. They discussed the importance of claim, evidence, and justification for reasoning and decision making on scientific and socio-scientific issues. As part of their group discussion, students practiced looking for evidence, supporting claims and making conclusions. They were encouraged to employ the features of argumentation, especially to use evidence to make explicit counterclaims. They participated in group argumentation and presentation based on their group discussions.

Through a process of collaborative decision-making, students identified two local socio-scientific topics for discussion: (1) the viability of a landfill facility and (2) constructing a new sewage treatment facility. Before engaging in group discussions, the students were asked to undertake independent research on the issues. They brought researched information to the class as argumentation resources.

2.2 Data collection and analysis

A video camera and voice recorder were set up to capture the discussion within each group. The audio data was transcribed and students' research papers and field notes were collected. The transcript was organized by speakers' turns and analyzed using a framework derived from Walton's argumentation schemes (2008). Previous research had reported problems differentiating schemes (Duschel 2008; Nussbaum, 2011) and in this current research we chose to conflate schemes from Walton et al. (2008) rather than settle on an uncertain differentiation. For example, there was an unclear boundary between cause and effect, co-relation, and consequences. After several attempts to disambiguate them, we collated cause and effect with co-relation and separated consequence as independent scheme by emphasizing the probability of positive and negative outcomes of action taken. The resulting analytic framework consisted of seven argument types: 1) argumentation from sign, 2) co-relation, 3) consequences, 4) position to know, 5) analogy, 6) popular opinion, 7) commitment, and 8) bias and there are two sub-schemes in position to know- position to know from personal experience and position to know from research (experts, NGOs, etc.)

The two researchers (the first and second authors of this paper) individually coded the transcript based on those schemes and met to cross check their coding several times. During the cross-checking process, they discussed differences in the preliminary coding results and shared their interpretations of each scheme to reach a high level of consistency in coding. Based on revised coding schemes, there was another round of coding and discussion to finalize the coding results. After coded to argumentation schemes, the data was looked into several dimensions of knowledge; scientific, socio-cultural, economic, political, and personal-experiential, ethical, and emotional. Thus, one piece of argumentation scheme could belong to dimension of knowledge, for example, argumentation from expert opinion and scientific knowledge. The results from two discussion groups (L and S) are presented below to exemplify the analysis. L group represents the group which discussed Landfill facility issues and S group represents the group for Sewage facility issues.

3. Research findings

3.1 Types of dialogue

The groups tended to start the discussion by asking questions or displaying knowledge they gathered from the preparatory research. For example, L group started with a question, "*Is the H landfill an effective means of disposal?"* followed by a statement, "*technically there doesn't need a garbage pick up because you can do other thing"* with examples from their research. The students discussed effective and ineffective practices of landfill and their own disposing practices; going back and forth between pros and cons of the facility and examining their practices. The students concluded that the facility was effective so far but needs to improve certain practices for the future. In L-group, the dialogue started with inquiry to ask for evidences on (in)effectiveness of landfill facility and was moving toward possible actions and solutions. S group also began with a question, *"...do we need to build a sewage facility?".* Compared to L group's discussion, there was more controversy in S-group and as a result it was difficult to reach a consensus. Throughout their discussion, the members of both groups engaged in inquiry and persuasion by providing evidence to argue for their opinions. There were two main ideas expressed in the group discussion; the virtue of public-private partnership and uncertainty and concerns about the impact on ocean ecosystems. These two ideas remained unresolved because of uncertainty about the evidence.

Because the level of controversy was different, the groups took different approaches to arguing the issue. L-group consistently asked one another for evidence to support pro and con claims and then cooperatively moved to a conclusion and possible actions while downplaying the differences of opinion. This type of argumentation is called deliberation (refer to Walton's types of argumentation, 2006). S-group, on the other hand, raised more differences from political, scientific-technological, and environmental perspectives. Their discussion drifted toward greater skepticism of the credibility of evidence and a critique of the presentation of the issues in the mass media rather than a resolution of the initial topic. Their discussion remained in inquiry and persuasion types even if their persuasion was not successful on either side.

3.2 Argumentation schemes and knowledge integration

There were used various argumentation schemes in student teachers' discussions such as argumentations from sign, co-relation, consequence, analogy, position to know, popular opinion, commitment, and bias. In both groups' discussion, sign and position to know were the most frequently used argumentation schemes. In L group, argumentation from sign was about 42.3% and position to know was 31.8 % (from personal experiences-13.5%, research and expert opinion-18.3%). In S group, argumentation from sign was 32.1% and position to know was 36.8% (personal experiences-5.7%, research and expert opinion -31.1%). Students explained examples and stories that have been known, practiced, and experienced around the topic. By sharing and quoting the evidence they gathered, or from prior knowledge, students attempted to argue for or against certain positions. The members in both groups provided much information in the scheme of position to know, that is, their personal experiences, research papers, or expert groups. And yet, S group members presented more ideas and evidences from research and expert opinion to back up their claim than L group members.

Other than sign and position to know, there was more consequences (14.4%) and co-relation (5.8%) in L group's discussion whereas there were and more commitment (14.2%) and bias (10.4%) in S group's discussion. Students in L group discussed consequences of further practice and changes in the facility and consumption in the future and also co-relation between everyday practices and the environmental impact. To alleviate the future concerns of the landfill facility and garbage problems, they explained the good and bad consequences of certain actions in individual homes and communities. This led them to look into their everyday action as causes of and solutions to the problems. When students were reaching consensus on the phenomenon, their discussion is more toward solutions and it brings the level of consequences. Students in S-group, on the other hand, used the schemes of commitment and bias more frequently compared to L group members. By summoning expertise from experts or environmental NGOs for evidence, they sometimes presented their own and others' commitments toward the sewage issues and also distress and concerns on how the issue has been taken up in the political realm. There had been a lot of antagonism between opposing sides within S group, which led the students to deny opposing evidence rather than to counter-claim with additional evidence and backing and as a result the exchanges were more an expression of confirmation bias than persuasion. There was a similar portion of popular opinion scheme in both groups (2.9% in L group and 2.8% in S group).

Science and technology related knowledge was presented throughout the conversations. There were also personal, ethical and emotional dimensions of the issues discussed. Social dimension were more frequently examined than science and technology in their reasoning and decision-making. This could be because socio-scientific and environmental problems are deeply embedded in social and human relationships and cultural practice. Scientific knowledge is also a significant part of their discussion as each student had been directed to look for evidence in their research. Even though S-group was generally more skeptical of scientific knowledge they tended to counter claims with social rather than scientific critique. It was interesting to note the students' distrust of science in the public domain even though the participants mentioned how scientific research and data are reliable and the scientists who interpret and discuss the data are reliable. Nonetheless, scientists who get involved in civic and political venues were regarded as less trustworthy and more likely biased. Scientific (including technological, engineering, and mathematical) knowledge was tainted by concerns of bias, which is expected in politicized public debate.

4. Discussion

In this study, both groups aimed to reach answers to their questions and come up with possible suggestions if necessary. In the discussion, participants exchanged information from a variety of sources that they regarded as relevant. Inquiry as dialogical type commonly appeared throughout the dialogue. Based on the knowledge from inquiry process, students attempted to reach a conclusion on the topic and came up with possible suggestions. L-group was able to get close to a conclusion and possible plans whereas S-group did not. It seems when social-scientific issues are less contentious in the moment; there are fewer interactional barriers to arriving at a degree of consensus. But when the issues are more contentious, discussion amongst this group of students failed to reach a conclusion, but rather became stuck around polarized views. The topic of L-group seemed relatively easy to members to agree on ideas and suggestions. It is accepted as a necessary means of disposal in the current situation, which became the basis of developing ideas of individual and communal efforts and actions. And yet, S-group topic was an ongoing debate in the society and there was no common ground set around the issue. The S-group members realized the level of controversy, which over-road any previous training in the course they were taking about the use of argument and evidence to persuade and potentially alter a point-of-view. The immediacy and contention of the topic determined the argument schemes that were employed even though the discussions were not held in a public forum, but rather in the privacy of a small group in the controlled context of a classroom.

In this study, due to the nature of topics, students integrated various knowledges in order to discuss the issues. They explored scientific, socioeconomic, political and experiential knowledge and brought emotional and psychological components. Science and technology related knowledge was important and highly valued evidence and yet it was not the sole, or even main form of argument employed to solve the topic. This knowledge was reexamined in relation to technical application, human behavior and emotion, social practice in the public space. In this argumentation process, science and technology related knowledge is taken to and integrated with diverse dimensions of knowledge. Thus, it is useful to examine how it is integrated and confronted with other knowledge and how members resolve the conflicts in social actions in the discussion of integrated approach in STEM education.

Currently, socioscientific and environmental issues became one of the concerns in the discussion of sustainable social development and this became the important agenda of scientific literacy. Critical reasoning, knowledge integration, and problem solving skills of students as future citizens are required to make the best decision in situation at hand. To understand the process of knowledge integration and role of scientific knowledge, this study attempted to employ argumentation as tool to identify essential knowledge, reasoning, and decision-making processes applied to discussion of socio-scientific issues. This study suggests the nature of knowledge integration during argumentation is complex and more than a simple collection of different knowledges. This complexity needs to be thoroughly examined in the discussion of STEM education and we believe argumentation can be a tool to understand the complexity of knowledge integration in students' reasoning process and scientific literacy development.

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