Informal Reasoning Regarding Socioscientific Issues: A Critical Review of Research

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Abstract: Socioscientific issues encompass social dilemmas with conceptual or technological links to science. The process of resolving these issues is best characterized by informal reasoning which describes the generation and evaluation of positions in response to complex situations. This article presents a critical review of research related to informal reasoning regarding socioscientific issues. The findings reviewed address (a) socioscientific argumentation; (b) relationships between nature of science conceptualizations and socioscientific decision making; (c) the evaluation of information pertaining to socioscientific issues, including student ideas about what counts as evidence; and (d) the influence of an individual's conceptual understanding on his or her informal reasoning. This synthesis of the current state of socioscientific issue research provides a comprehensive framework from which future research can be motivated and decisions about the design and implementation of socioscientific curricula can be made. The implications for future research and classroom applications are discussed. © 2004 Wiley Periodicals, Inc. J Res Sci Teach 41: 513–536, 2004

Social issues with conceptual or technological ties to science have captured the national spotlight during the recent past. Cloning, stem cells, genome projects, global warming, and alternative fuels have become common elements of the national vocabulary as well as the currency of political debates. Regardless of society's reluctance or enthusiasm towards the advent of these issues or its preparedness to deal with them, scientific issues with social ramifications undoubtedly will continue to arise and evolve. Advances in medical science and molecular genetics coupled with the environmental challenges produced by a burgeoning human population guarantee the prominence of these kinds of issues in the present and the future. Because of the central roles of both social and scientific factors in these dilemmas, they have been termed *socioscientific issues*. The suggestion that issues such as those related to biotechnology and environmental challenges can be classified together as socioscientific issues is not meant to imply that science and society represent independent entities. On the contrary, all aspects of science are inseparable from the society from which they arise. However, the topics described by the phrase socioscientific issues display a unique degree of societal interest, effect, and consequent.

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Several science educators have argued for the inclusion of socioscientific issues in science classrooms, citing their central role in the development of a responsible citizenry capable of applying scientific knowledge and habits of mind (Driver, Newton, & Osborne, 2000; Kolstø, 2001a; Zeidler, 1984). Their efforts to infuse socioscientific issues into science curricula are not the first intent on making classroom science more reflective of the society in which it exists as opposed to an isolated, irrelevant academic discipline. The science, technology, and society (STS) movement has sought to educate students about the interdependence of these three domains since at least the early 1980s (Yager, 1996). However, STS education has become quite diffuse over the course of its tenure, representing approaches as disparate as isolated courses focused on particular STS issues, pedagogical strategies that highlight the connections between science and society, and ancillary text boxes in the midst of science textbooks (Pedretti & Hodson, 1995). In contrast, the socioscientific issue movement's aims focus more specifically on empowering students to handle the science-based issues that shape their current world and those which will determine their future world (Driver et al., 2000; Kolstø, 2001a).

Informal Reasoning and Its Relation to Socioscientific Issues

In the context of science, reasoning historically referred to formal reasoning characterized by rules of logic and mathematics. The formal processes of deduction or induction lead thinkers to necessary conclusions, and positivist philosophers of science such as Popper and Carnap argued that these very processes distinguish the scientific enterprise from other ways of knowing the world (Curd & Cover, 1998). T.S. Kuhn (1962) challenged the significance of formal reasoning in science by proposing a novel model of scientific change and progress. T.S. Kuhn disputed the purported rationality of scientific theory change and the perpetual accretion of scientific knowledge. He described episodes of theory change as tumultuous periods during which scientists judge competing theories using a variety of criteria including social influences. An enduring theory rises to prominence through a process more reminiscent of political revolutions than episodes of formal reasoning. T.S. Kuhn's work directed attention to the fact that although formal reasoning may contribute to scientific discovery, it is not the only vehicle for producing progress.

Although the results of science may be presented in the language of formal reasoning and logic, the results themselves originate through informal reasoning (Tweney, 1991). Unlike scientific investigations, the premises of formal reasoning are fixed and unchanging, and conclusions are necessary derivatives. In informal reasoning, on the other hand, premises can change as additional information becomes available, and conclusions are not self-evident (Perkins, Farady, & Bushey, 1991). Informal reasoning involves the generation and evaluation of positions in response to complex issues that lack clear-cut solutions. Thinkers are engaged in informal reasoning as they ponder causes and consequences, pros and cons, and positions and alternatives (Means & Voss, 1996; Zohar & Nemet, 2002). Means and Voss (1996) provided an illustrative description in the following: ''Informal reasoning assumes importance when information is less accessible, or when the problems are more open-ended, debatable, complex, or ill-structured, and especially when the issue requires that the individual build an argument to support a claim'' (p. 140). Postpositivist accounts of science describe the enterprise as a multifaceted set of disciplines which employ informal reasoning (Tweney, 1991).

Socioscientific issues are ideal candidates for the application of informal reasoning (D. Kuhn, 1993). By definition, they are complex, open-ended, often contentious dilemmas, with no definitive answers. In response to socioscientific dilemmas, valid, yet opposing, arguments can be constructed from multiple perspectives. Just as scientists employ informal reasoning to gain insights on the natural world, ordinary citizens rely on informal reasoning to bring clarity to the controversial decisions they face. The citizens of a democratic society built upon science and technology are constantly presented with socioscientific issues, and the processes of informal reasoning allow them to access these issues, formulate positions, and provide supporting evidence (Kolstø, 2001a; Patronis, Potari, & Spiliotopoulou, 1999; Tytler, Duggan, & Gott, 2001).

Rationale

The purpose of this article is to review key topics identified in the empirical literature concerning socioscientific issues and synthesize their findings as they relate to science education research and practice. Although socioscientific issue research remains a relatively new area of concern, influences on socioscientific decision making as well as perspectives toward research are diverse (Driver et al., 2000; Kolstø, 2001a; Zeidler, 2003). The following synthesis of the current state of socioscientific issue research provides a comprehensive framework from which future research can be motivated and decisions about the design and implementation of socioscientific curricula can be made. Assertions that socioscientific issues form an important component of scientific literacy (American Association for the Advancement of Science, 1990; National Research Council, 1996; Siebert & McIntosh, 2001) demand the exploration of how these issues can be most meaningfully incorporated in science curricula and classrooms. Meeting this challenge requires (a) an assessment of what is known and then (b) an assessment of what needs to be known. This article provides a summary of current knowledge, identifies areas which require additional concentration, and makes recommendations for classroom considerations.

Literature Review

The purpose of this review is to organize, integrate, and summarize empirical studies related to informal reasoning regarding socioscientific issues. Socioscientific issues have been the subject of numerous theoretical discussions related to science education (e.g., Bingle & Gaskell, 1994; Driver et al., 2000; Geddis, 1991; Kolstø, 2001a; Zeidler, 1984), but this report focuses on research studies and their findings. Because socioscientific issue research is relatively new in the history of science education, most of the studies reviewed are recent. The report follows a framework that emerges from the research literature itself. Most empirical work related to socioscientific issue informal reasoning addresses four primary themes: (a) socioscientific argumentation, (b) relationships between nature of science (NOS) conceptualizations and socioscientific decision making, (c) the evaluation of information pertaining to socioscientific issues, and (d) the influence of conceptual understanding on informal reasoning. This review explores the research related to these themes to assess the collective significance of existing research, identify inconsistencies and gaps in the findings, and highlight aspects that require additional study. Most studies that investigate informal reasoning in the context of socioscientific issues employ qualitative methodologies, which require elaborations of context for the establishment of trustworthiness (Lincoln & Guba, 1985). To reflect the contextual significance of this type of research, which necessitates a level of detail not necessary for other types of reviews such as meta-analyses, the studies reviewed were limited to those with sound theoretical frameworks and methods as reflected in their publication (or their acceptance for publication) by the major international journals of science education (viz., *International Journal of Science Education*, *Journal of Research in Science Teaching*, and *Science Education*). The sections which follow are organized according to the emergent themes described earlier, and a graphic organizer (Figs. 1–4) is presented for each topic. The organizers present succinct summaries of the empirical highlights

Figure 1. Graphic overview of research related to socioscientific argumentation. SSI = socioscientific issues.

from the studies reviewed. Table 1 presents summary information for each of the empirical studies reviewed.

Socioscientific Argumentation

Argumentation as a field of study is concerned with how individuals make and justify claims and conclusions (Driver et al., 2000; Zohar & Nemet, 2002). Research from a variety of disciplines supports the notion that studying argumentation serves as an effective means of accessing an individual's informal reasoning (D. Kuhn, 1991; Means & Voss, 1996; Zohar & Nemet, 2002). General research trends also suggest that people of all ages have difficulty in constructing well-substantiated arguments (Driver et al., 2000; D. Kuhn, 1991, 1993; Perkins et al., 1991; Perkins & Salomon, 1989). The next section reviews the results of four recent studies which relate specifically to socioscientific argumentation. Figure 1 presents a summary of the major findings.

Kortland (1996) investigated middle-school-student argumentation patterns regarding environmental issues related to waste management and recycling. In the study's first stage, interviews were conducted with students to provide baseline data on argumentation skills for facilitating the design of a classroom intervention. The interview transcripts were analyzed with a set of a priori categories designed by the investigator to assess argumentation patterns. The results suggested that students frequently made both implicit and explicit comparisons between their potential choices, and that in most cases, the criteria offered by students were valid in terms of

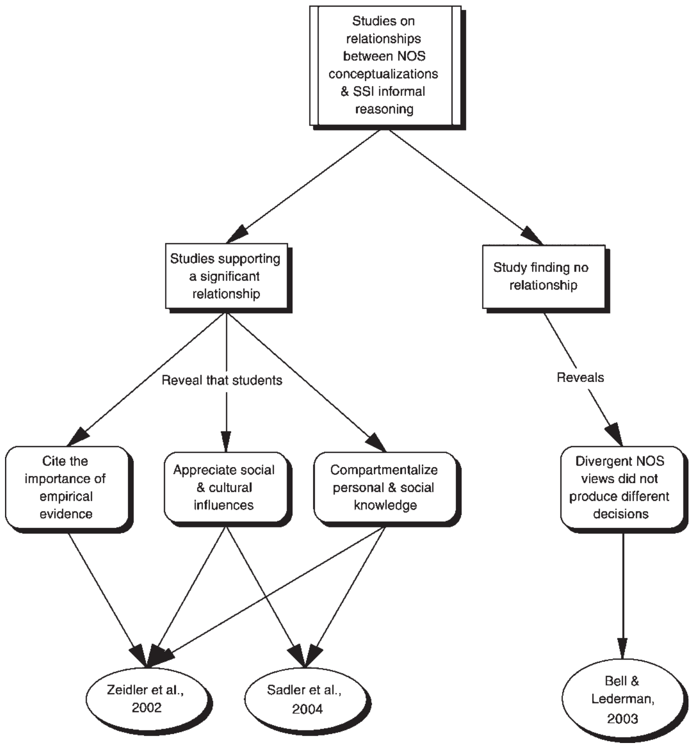

Figure 2. Graphic summary of research related to the influence of nature of science (NOS) conceptualizations on informal reasoning regarding socioscientific issues (SSI).

supporting the original claim. However, the students limited their arguments to include only those factors which provided direct support for their stated position (i.e., no counterclaims or rebuttals were offered), and the clarity of many individuals' overall argumentation was somewhat suspect. Kortland concluded that the students possessed the ability to structure a basic argument, but he noted the limited range, clarity, and application of the arguments advanced.

Kortland (1996) hypothesized that the naïve arguments presented by students were due to two factors: inexperience in the formulation of arguments and lack of knowledge concerning the socioscientific issue of concern. To address these potential problems, the researcher designed and implemented an intervention with a different class of students from the same school during the following year. The intervention extended over ten 45-min class periods and focused on the formation and evaluation of arguments as well as content knowledge related to the socioscientific issues addressed. Students responded to pre- and posttest questionnaires designed to elicit argumentation, and the researcher also observed and recorded a classroom discussion during which students were encouraged to form arguments supporting their ideas concerning the waste issue. By comparing the argument patterns in the first-stage interviews and the classroom discussion, Kortland concluded that the intervention accounted for negligible improvements in argumentation skills. However, analysis of the pre- and posttest questionnaires revealed improved validity and clarity of the criteria used to support student choices. The author suggested that the students maintained the basic level of argumentation evidenced prior to intervention, but improved understanding of the socioscientific issue itself led to more coherent decisions. This

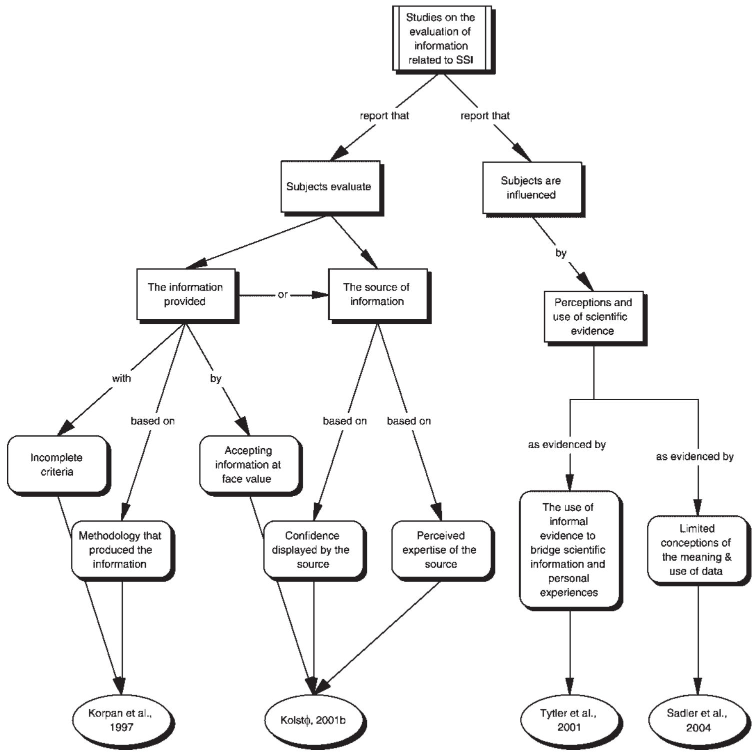

Figure 3. Graphic summary of research related to how individuals evaluate information regarding socioscientific issues (SSI).

topic, the role of conceptual understanding, will be discussed in more depth in an upcoming section of this review.

Contrary to the Kortland (1996) study, a classroom-based case study suggested that middle schoolers are able to develop well-formulated arguments regarding socioscientific issues (Patronis et al., 1999). The students worked for several months in small groups to develop and plan a strategy to deal with a local environmental issue. Each group presented their plan to the entire class and participated in a class discussion regarding the merits and problems associated with each plan. The culminating activity was a class vote for the best proposal. The researchers employed a qualitative analysis, borrowing from the work of Toulmin (1958), to assess the structure and nature of student argumentation demonstrated throughout the learning experience. In the context of this study, structure referred to processes students used to express their ideas, and nature was related "to the different kinds of pragmatic arguments" (p. 748). The authors used the nature category to distinguish between "qualitative arguments" characterized by social, ecological, economic, and practical concerns and "quantitative arguments," which involved numerical calculations most commonly associated with school science. The results indicated that students did formulate reasonable arguments for supporting and refuting the plans that they themselves had developed. The researchers suggested that the personal connections students held with the local issue and the personal investment in the solutions proposed accounted for the better-than-expected patterns of argumentation.

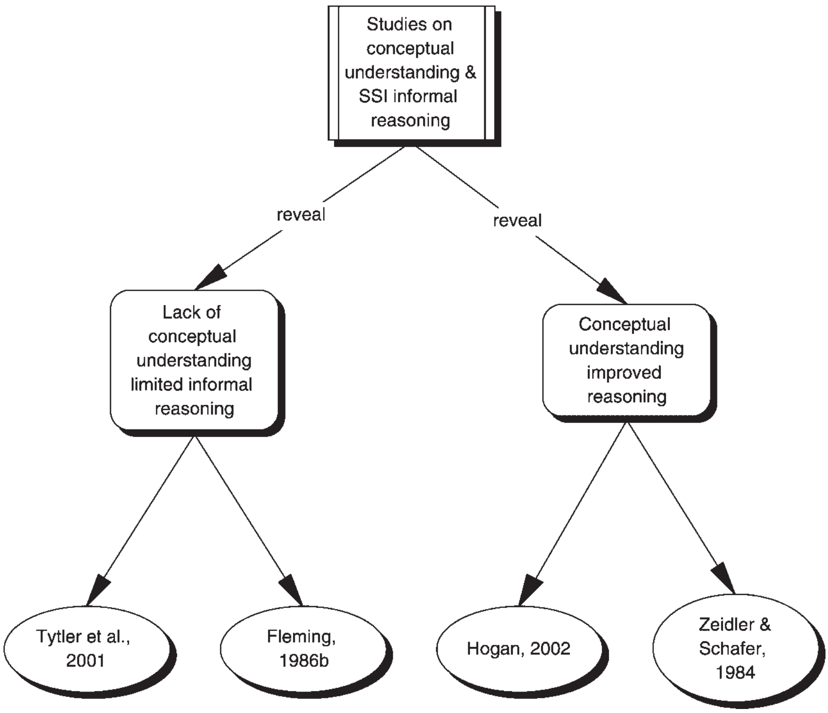

Figure 4. Graphic summary of research related to the influence of conceptual understanding on informal reasoning regarding socioscientific issues (SSI).

While these results are encouraging for educators interested in incorporating socioscientific decision making in the classroom, it is difficult to assess the validity of the claims made by the authors. It seems reasonable that personal interest and investment in an issue could improve argumentation related to that issue, but sufficient documentation is not provided in Patronis et al.'s (1999) article to warrant this conclusion. The qualitative taxonomy provided in the article does not provide a means for assessing the quality of arguments, and the authors do not include enough examples of student arguments to enable a reader to judge the trustworthiness (Lincoln & Guba, 1985) of the conclusions. The report demonstrated that the students in this study made some arguments concerning their potential solutions, but the reader is left wondering whether those arguments are as sophisticated as the authors claim or more reminiscent of the relatively naïve arguments revealed in the Kortland (1996) study.

Jiménez-Aleixandre, Rodríguez, and Duschl (2000) explored classroom argumentation in the context of genetics. They worked with an intact ninth-grade biology class as students learned basic genetics concepts and worked in small groups to resolve a socioscientific issue involving genetic and environmental variability of farm-raised chickens. Argumentation skills were not specifically addressed as a part of the curriculum. The researchers analyzed the transcripts recorded from all small-group discussion sessions, but the research report concentrated on the dialogue of one group composed of four female students because this group's interactions were representative of patterns observed in other groups. The investigators were interested in two aspects of the student discussions: "argumentative operations" and "epistemic operations." Argumentative operations represented the structure of student argument as defined by Toulmin's (1958) argument pattern.

Table 1
Summary information for the empirical studies reviewed

Study	Country	Sample: Age/Grade Level	Sample: N	SSI	Methods
Kortland, 1996[a]	Netherlands	13–14 years	8 (4F, 4M)	Recycling	Structured interviews to elicit argumentation patterns.
			27 (14F, 13M)	Solid Waste & Recycling	Intervention over 10 class periods, pre- and post test questionnaires, classroom discussion.
Patronis et al., 1999	Greece	14 years	1 intact class[c]	Local Environmental Issue	Students designed plans to address a local issue, class sessions video-taped, group discussions audiotaped, individual student interviews.
Jiménez-Aleixandre et al., 2000	Spain	14–15 years	1 intact class[c]	Genetics & Consumer Marketing	Observations and recordings of class meetings and student small-group interactions.
Zohar & Nemet, 2002	Israel	Grade 9	186	Genetic Engineering	Control group received genetics instruction, experimental group received instruction in genetics and argumentation, pre- and posttests of genetics knowledge and argumentation.
Zeidler et al., 2002[b]	United States	Grade & College 9–12	248	Animal Rights	Participants responded to a written questionnaire.
			82	Animal Rights	Participants were engaged in dyadic interviews and completed a second written questionnaire.
Sadler et al., 2004[b]	United States	14–17 years	84	Global Warming	Participants responded to written questionnaire.
			30	Global Warming	Participants participated in semistructured interviews.
Bell & Lederman, 2003	United States	College Professors	21	Fetal Tissue, Cancer, Global Warming	Participants responded to a written questionnaire about SSI's, V-NOS(B),[d] and a semistructured phone interview.

Kolstø, 2001b	Norway	16 years	22	Power Lines & Cancer	Participants read reports about SSI, semistructured interviews.
Korpan et al., 1997	Canada	College	60	Medicine, Environmental Issues	Participants read fictitious news briefs, semistructured interviews about extra information students would like to see.
Tytler et al., 2001	United Kingdom	Adults	3	Local Environmental Issue	Case study of all public documents related to the debate, interviews with 3 people involved in the case.
Fleming, 1986b	Canada	High School	38	Nuclear Power Plants, Genetic Engineering	Semistructured interviews.
Hogan, 2002	United States	Grade 8	24 (8F, 16M)	Invasive Exotic Species	Participant interviews to assess content knowledge, researcher analyzed small-group decision making.
Zeidler & Schafer, 1984	United States	College	191	Environmental Issues	Participants completed DIT, EIT, TEC, EAI,[e] researchers conducted an ANOVA and multiple regression analysis.[f]

[a]Kortland's report describes a two-stage research project.
[b]These studies were conducted in two parts; the second group of participants were subsample of the original participants.
[c]No additional information concerning the number of students in the class was provided.
[d]The V-NOS(B) (Abd-El-Khalick, Bell, & Lederman, 1998) is an open-ended response instrument designed to explore views on the nature of science.
[e]DIT = Defining Issues Test, a general measure of moral reasoning; EIT = Environmental Issues Test, a measure of moral reasoning on environmental problems; TEC = Test of Ecology Comprehension (TEC), a conceptual test of environmental understanding; EAI = Ecology Attitudes Inventory (EAI), composed of three subtests, verbal commitment, actual commitment, and affect related to the environment.
[f]The researchers performed a 2×2 repeated measures ANOVA to assess group (science vs. nonscience majors) differences in moral reasoning applied to different contexts (EIT vs. DIT) and a multiple regression analysis (independent variables: DIT, TEC, and EAI; dependent variable: EIT).

To assess this component, the researchers dissected student dialogue and categorized statements in terms of data, claims, warrants, backing, qualifiers, and rebuttals. The analysis of epistemic operations focused on the kind of knowledge or cognitive operations used in an argument. The a priori list of epistemic operations, derived from fields such as history, philosophy of science, and classroom conceptual ecology, included causality, definition, classification, consistency, plausibility, and appeals to analogies, exemplars, and authority.

Discussions among all the small groups exhibited widely varying argumentation patterns in terms of quality. Arguments ranged from sophisticated, those which included justification and backings, to naïve, those which contained isolated claims with no data support or backing. The group on which the report focused made far more claims than warrants, qualifiers, and rebuttals. Of the argumentative statements expressed, 66% were claims while only 21% were warrants, and 10% reported pieces of data. No qualifiers or rebuttals were offered. More alarming than the relatively limited argumentation was the fact that many students did not contribute to the discussions and appeared unequipped to do so. In the exemplar group, 2 students were responsible for over 75% of the dialogue and virtually all of the argumentation. The other 2 group members contributed little more than comments about the logistics of the assignment. They were either unable or unwilling to produce arguments. The students were very limited in terms of the epistemic operations with which their arguments addressed. Most of the argumentation focused on causality and appeals to analogies. The concentration on causality was due in part to the nature of the assignment itself; the students appeared far less concerned with issues of consistency and plausibility.

In another study of ninth-grade-student argumentation about genetic dilemmas, Zohar and Nemet (2002) assessed the effects of a 12-week intervention. Prior to the intervention, all of the classes had studied basic principles of genetics. During the intervention, students were exposed to advanced genetic concepts related to genetic engineering, applied human genetics, and the social issues associated with these topics. Four classes (87 students), which served as the control group, received "conventional instruction;" these students worked through a specially prepared collection of material that followed a "traditional textbook approach," with no special attention paid to processes of informal reasoning or argumentation. The five classes (99 students) exposed to the experimental treatment received explicit instruction in argumentation skills in addition to the genetics curriculum, and the students practiced argumentation in the context of human genetic dilemmas.

Pre-instruction written tests of argumentation revealed that most students (90%) in both control and experimental groups could formulate simple arguments, which were defined as claims or assertions supported by at least one justification. However, only 16.2% of the respondents referred to correct, specific biological knowledge in support of their positions. Following the intervention, students from the control and experimental groups scored significantly higher on a multiple-choice test of genetics than they had prior to instruction. However, the experimental group outperformed the controls, suggesting that argumentation instruction and practice can lead to improved conceptual understanding. Postintervention analyses of argumentation, which involved written tests similar to the pretest, revealed marked differences between the two groups. Whereas the control group showed no significant improvement in argumentation, students in the experimental group formulated qualitatively improved arguments in contexts similar to the dilemmas they had experienced during the intervention as well as transfer problems that deviated substantially from the material they had already seen. Class discussions with the experimental group also revealed improvements in the use of argumentation skills. Discussions that occurred after instruction included a higher incidence of explicit conclusions (as opposed to implicit claims), an increase in number and complexity of justifications per conclusion, and a decrease in the number of unjustified conclusions. The class-discussion results coupled with the individual written samples led the researchers to conclude that properly designed curriculum integrating socioscientific content and argumentation can improve both conceptual understanding and argumentation.

Summary

Socioscientific issue research supports findings from other disciplines (D. Kuhn, 1991; Perkins et al., 1991) suggesting that most learners do not typically display high-quality argumentation as defined by an ability to articulate and defend contentious positions. Patronis et al. (1999) presented a notable exception: They reported relatively sophisticated argumentation skills among their participants; however, the manner in which they classify these strong skills is not well supported in the article. In terms of argumentation problem areas, reviewed studies cited a tendency for students to make claims without adequate justifications and a glaring lack of attention to opposing positions in the form of counterpositions and necessary rebuttals. Zohar and Nemets (2002) positive result with an argumentation intervention suggested that instruction can be beneficial in the promotion of argumentation skills. However, Kortland's (1996) unsuccessful intervention (with respect to the development of argumentation skills) highlighted the fact that not all instruction for argumentation works well. Based on the results presented herein, the most fruitful interventions would be those which encourage personal connections between students and the issues discussed, explicitly address the value of justifying claims, and expose the importance of attending to contradictory opinions. If teachers expect their students to engage in sophisticated argumentation, students need ample opportunities to practice justifying claims, attending to counterpositions, and dissecting argumentation to increase their awareness of that which constitutes well-reasoned arguments.

Relationships between NOS Conceptualizations and Socioscientific Decision Making

For centuries, philosophers have debated the demarcation of science as distinct from other ways of knowing (Curd & Cover, 1998). Although questions of rationality, realism, objectivity, and empirical underdetermination still plague philosophical explorations of science, science educators have proposed a basic characterization of the scientific enterprise to help nonscientists understand the field's strengths and limitations (Abd-El-Khalick & Lederman, 2000; Aikenhead & Ryan, 1992; Lederman, 1992; McComas, Clough, & Almazroa, 2000). This basic description and characterization of science epistemology has become known as the nature of science. Among the constructs that are central to the consensus view of NOS are the following ideas. Some scientific knowledge is relatively stable whereas less substantiated knowledge is tentative and subject to change given new evidence or reinterpretation of existing evidence. Science relies on empirical evidence, and scientists employ creativity to obtain and interpret this evidence. Scientific research and cultural norms mutually shape one another. The pursuit of scientific progress often encounters (or creates) ethical and moral considerations. Several authors (Kolstø, 2001a; Sadler, Chambers, & Zeidler, 2004; Zeidler, Walker, Ackett, & Simmons, 2002) have suggested that an individual's understanding of NOS inevitably alters the manner in which she or he responds to situations involving science, including socioscientific issues. The claim is that a person's understanding about the epistemology of science will influence the application of the content knowledge. In other words, NOS conceptualizations affect the interpretation of scientific knowledge which, in turn, influences informal reasoning related to issues contingent on that knowledge. This section will review three studies that empirically tested this assumption. Figure 2 presents a summary of these findings.

Exploring relationships between student conceptions of NOS and their reactions to socioscientific issues was the primary goal of research reported by Zeidler et al. (2002). This study involved a diverse group of participants who completed questionnaires and participated in dyadic interviews. The authors concluded that in the context of animal rights issues, beliefs about NOS were related to decision making in at least three distinct ways: (a) Students acknowledged the social and cultural influences affecting how individuals view science. This issue was particularly important as students considered how scientists collected, interpreted, and reported data related to the benefits and problems associated with using animals in research. (b) Several students commented on the importance of empirical evidence in the determination of positions regarding socioscientific issues. Their belief in the centrality of data as a part of the NOS affected their decisions. (c) The authors also noted the tendency for students to compartmentalize personal knowledge and scientific beliefs. Several students felt that knowledge and information produced in the process of science was isolated and independent of their own belief systems. Consequently, the opinions of students who adopted this perspective were impervious to scientific information. The researchers reported "only a few discernible instances of a clear relationship [between NOS and reactions to a socioscientific issue]" (p. 359). However, the patterns revealed suggest that although detecting unambiguous NOS influences may be empirically challenging, a person's beliefs about the practices and epistemology of science can have a profound effect on informal reasoning related to socioscientific issues.

The relationship between NOS conceptualizations and socioscientific decision making also was a research focus for Sadler et al. (2004). Participants read two articles, constructed specifically for the study, that offered opposing positions on the issue of global warming. A follow-up questionnaire was designed to elicit student ideas about the following aspects of NOS in the context of the global-warming debate: data use and interpretation, cultural influences on the progress of science, the evolution and inconsistency of some scientific ideas, and factors which constitute "scientific merit." To improve the trustworthiness of the conclusions drawn from the questionnaires, the researchers interviewed a subset ($n = 30$) of students from the original sample.

Echoing the results of the Zeidler et al. (2002) study, Sadler et al. (2004) found students' appreciation of the social embeddedness of science (or lack thereof) to be a considerable influence on socioscientific decision making. Several students held the belief that economic interests and personal perspectives affected the selection and presentation of data and information related to the issue of global warming, thereby altering the manner in which the students would use that information. However, a minority of the sample articulated the opposite view: Social and cultural factors do not influence the global-warming debate. The adoption of this perspective resulted from the naïve belief that science and its findings are isolated from the broader structure of society. A similar perspective was revealed in the comparison between student ideas about that which constitutes scientific merit and that which they find personally convincing. The students were asked to select both the article that possessed more scientific merit and the article which was more persuasive. Because both articles contained the same types of data in terms of quantity and quality, and both were written in a similar style with comparable rhetoric, the authors hypothesized that students' assessment of merit would influence their determination of persuasiveness. Although the majority of participants did choose the same article for both questions, 40% of the students reported that even though one article had more scientific merit, they found the other article more convincing. This result also supported one of Zeidler et al.'s (2002) conclusions: Students had a tendency to compartmentalize scientific evidence and the information they use to make personal decisions. This apparent exclusion of science from the personal domain unavoidably affects an individual's informal reasoning regarding socioscientific issues.

Bell and Lederman (2003) investigated the relationship between NOS and socioscientific decision making by examining the beliefs and opinions of university professors. All participants had earned doctorate degrees and represented a variety of academic disciplines, including science and nonscience fields. The researchers divided participants into two groups based on divergent views of NOS. The researchers compared the decisions, the factors influencing those decisions, and the reasoning patterns that produced those decisions between the two groups. The results failed to confirm the hypothesized prediction that divergent NOS conceptualizations would produce divergent socioscientific decisions. No significant differences were detected in the decisions made by the participants in each group. The analysis of factors which contributed to those decisions suggested that NOS aspects were considered (at least implicitly) in the determination of a position, but the influence of NOS was relatively minor as compared to personal, social, and moral considerations. Although the two groups held different beliefs on the epistemic status of empirical evidence, every participant in both groups cited the role of scientific evidence as an integral aspect of their decision making. However, the authors concluded that empirical evidence was not a primary factor in the reasoning patterns of either group. In short, the participants reactions and responses to socioscientific issues appeared to be unaffected by their divergent views on the nature of science.

While the results of Bell and Lederman's (2003) study are significant, they may not necessarily inform the question of how NOS conceptualizations influence socioscientific decision making in students or in the general public. The participants were a highly educated group of individuals working in academia. The extent to which this group may differ with respect to their beliefs about the epistemology of science may be minuscule as compared to the views held by secondary students or adults who do not spend most of their time involved in formal education. The fact that professors who adopt divergent philosophical perspectives do not differ significantly in their socioscientific decision making does not necessarily imply that other individuals will not be influenced in their decision making by their perceptions of how science works and what scientific evidence reveals.

Summary

Some differences in views on NOS may not result in distinct socioscientific decisions (Bell & Lederman, 2003), but conceptualizations of certain NOS aspects (viz., social embeddedness, tentativeness, and empirical dependence) seem related to informal reasoning (Sadler et al., in press; Zeidler et al., 2002). These results lend further support to recommendations (Abd-El-Khalick, Bell, & Lederman, 1998; Lederman, 1992; McComas et al., 2000) to promote the development of sophisticated NOS ideas throughout the science curricula. Because students' conceptualizations of NOS contribute to the decisions they make regarding socioscientific issues, students would benefit from learning experiences that encourage the exploration of NOS themes. The studies reviewed here suggest that curricula pertaining to the social, tentative, and empirical aspects of science would be particularly useful for students as they confront socioscientific issues. The fact that students tended to exclude scientific knowledge from their personal knowledge highlights the need to make school science more relevant to students' lives. Ironically, socioscientific issues have been suggested as a means of accomplishing this goal (Cajas, 1999; Pedretti & Hodson, 1995); however, Zeidler et al. (2002) and Sadler et al. (2004) revealed that the presentation of socioscientific issues does not necessarily promote personal connections between students and science content. A research program designed to explore if and how meaningful personal connections that encourage students to integrate knowledge can be advanced using socioscientific contexts would be helpful.

Evaluation of Information Pertaining to Socioscientific Issues

In the context of socioscientific issues, information, data, and knowledge claims possess central importance to informal reasoning. To evaluate alternative positions, one must collect information about those options. Given the complexity of socioscientific issues, most of the populace must rely on the reports of others as their primary information sources, and people often receive conflicting reports. This section will review research that has addressed how individuals negotiate multiple, sometimes contradictory, information in the process of informal reasoning. Figure 3 provides a general summary of the four studies reviewed.

Kolstø (2001b) performed a qualitative study to detect the manner in which students evaluate information and knowledge claims as they prepare for socioscientific decision making. Student responses formed a two-dimensional matrix. The students based their judgments on two factors: the informational statements themselves or the authorities who provided the information. They also showed two general modes of judgment: acceptance or active evaluation. Students accepted or evaluated the information, or they accepted or evaluated the source of information. Some students accepted knowledge claims at face value whereas others reported that any knowledge claims must be subject to evaluation. Students in the second group described ways to test for the reliability of information by seeking independent support for the statements.

Other responses focused on the source of information rather than the knowledge claims themselves. Students were willing to accept information provided by authority figures based on two general criteria. Some sources were deemed legitimate if they conveyed confidence in their research while others gained acceptance because of perceived expertise in a specific area. In other words, information was accepted because its source was an expert. A final group of students was willing to judge the validity of information on its source, but would not accept the authority without an evaluative process. Students providing these responses based their analyses on one of four standards: assessment of risk, interest, neutrality, or competence. Some students equated the credibility of a source with his or her discussion of risk; the authority figures who talked about potential risks associated with the decision to be made were evaluated more positively than those who did not. Some students ascribed more validity to sources with vested interests while others were more likely to respect the information provided by uninvolved, neutral sources. Finally, another group sought independent support of an authority's competence. Although most participants used some evaluative strategies to assess the information they received, Kolstø (2001b) concluded that they tended to engage in very shallow analyses. Even though many students evaluated information and information sources, their conclusions were often short-sighted or inaccurate.

Korpan, Bisanz, Bisanz, and Henderson (1997) assessed how college students evaluate knowledge claims in a less direct manner than the previously cited studies. The researchers provided participants with a series of four news briefs and asked them to identify additional information needed to confirm the reports. The fictitious articles were prepatterned so that each included an acknowledgment of the group performing the research, a description of the issue, and independent support for the findings. The following list provides the most frequently requested types of information: social factors influencing the report, details about a specific item in the text, additional data or statistics, related findings, and research methodologies. The students also made requests for many other types of information not easily classified. One of the most unexpected results was that even though the format of each article was identical, students made very inconsistent information requests. Only in the case of research methodology did a majority of participants (52%) ask for the same type of information in response to all four articles. Participants very rarely requested analogous pieces of information for more than one or two articles. These results suggest that even among quite similar decision-making situations (All articles involved science issues.), context significantly influences an individual's informal reasoning.

Another interesting conclusion of the Korpan et al. (1997) study was the tendency for participants to seek information concerning methodology as opposed to other factors such as the implications of the conclusions. Participants more frequently sought information about how the research was conducted and what factors might have influenced the results. They were less interested in what was found or who conducted the research. These findings contradict those of the Kolstø (2001b) study, which suggested that people were more likely to question the authority of the researcher than the methodology. The apparent discrepancy is most likely due to one of two factors. Kolstø's (2001b) participants were 16 years old whereas the Korpan et al. (1997) participants ranged in age from 17 to 38 years. Different reasoning strategies as a result of age may have contributed to the findings. However, the differences also might have resulted from the research formats. The manner in which the researchers elicited data from their participants might account for the different findings. Given this hypothesis, it is inappropriate to conclude that individuals are generally more likely to focus on either methodology or authority. Both likely factor into informal reasoning processes, but any stronger conclusions require additional research.

Whereas Kolstø (2001b) and Korpan et al. (1997) investigated how participants responded to scientific evidence in an artificial context, Tytler et al. (2001) explored how individuals interacted with evidence in an actual socioscientific dilemma. The researchers conducted a case study of a community's struggle over a local environmental issue by analyzing all publicly accessible documents related to the debate including reports on public meetings, newspaper editorials, public register documents, and government reports. The authors also conducted semistructured interviews with three members of the community representing diverse perspectives.

Tytler et al.'s (2001) analysis focused on how individuals who were not professional scientists construed, interpreted, and applied evidence as it related to the issue facing their community. The researchers concluded that the public relied on three major classes of evidence: scientific evidence, informal evidence, and wider issues that impinge on evidence. Scientific evidence included material data, sometimes referred to as "hard evidence." Although the public seemed to recognize the importance of material data, they did not rely on this class of evidence very often in the formulation and support of positions. Informal evidence, defined as common sense, circumstantial evidence, and personal experience, contributed far more significantly to the decisions made by the public. The authors suggested that community members used informal evidence as a means to bridge scientific or technical assertions with their own personal, political, and practical understandings. This "reconstruction" or "contextualization" of science for application in local settings has been documented by other researchers (Layton, 1991; Wynne, 1991). The final type of evidence employed (i.e., broader issues that impinge on evidence) dealt with the manner in which the issue was framed. This category of evidence represented personal values related to the environment, the economy, and moral commitments. The authors contended that these perspectives altered the manner in which individuals responded to the scientific and informal evidence.

In several of the studies already reviewed, evidence emerged as an important component in the resolution of socioscientific issues. During the Kolstø (2001b) and Korpan et al. (1997) studies, students assessed the validity of evidence. The academics who participated in the Bell and Lederman (2003) study relied on evidence for their decision making as did the community members from the Tytler et al. (2001) study. Sadler et al. (2004) explored students' understanding of scientific evidence by asking participants to identify and describe the use of data cited in two different position articles regarding global warming. The authors were surprised to learn that only about half (47%) of the high-school students participating were able to identify and explain the use of data in the context of the global-warming issue. Fifty-three percent of the students held naïve views about the meaning of data, including 10% of the overall sample who could not make distinctions between scientific data, predictions, and hypotheses. The lack of familiarity with that which constitutes scientific data displayed in the Sadler et al. (2004) sample may have contributed to the tendency to rely on informal evidence, as opposed to scientific evidence in the Tytler et al. study (2001).

Summary

The research reviewed in this section revealed a wide range of approaches used by individuals to evaluate the efficacy of reports they receive regarding socioscientific issues. However, the studies pointed to the fact that the analyses made were typically shallow and inconsistent. Participants did not frequently engage in the kind of comprehensive reflection and evaluation needed to assess the usefulness of information related to complex issues. It seems as though the participants recognized the need to evaluate the information provided, but lacked the skills and strategies to do so. These findings draw attention to the need for the development of curricula aimed at helping students build robust understandings of the nature of scientific evidence and data, including an understanding of what constitutes data, and strategies for critically evaluating the content and sources of scientific information commonly made available to the public.

The Influence of Conceptual Understanding on Informal Reasoning

One of the primary goals for science education has been the promotion of conceptual understanding of science content knowledge (Jenkins, 1990; Laugksch, 2000). It seems intuitively obvious that science students should learn science concepts. However, what students are able to do with that conceptual understanding is considerably less obvious. Research on transfer, the application of learned knowledge in novel situations and contexts, suggests that classroom learning is infrequently applied in all but the most similar circumstances (Detterman, 1993; Haskell, 2001). From this vantage, conceptual understanding of science content would not appear to be a very significant factor in nonschool contexts such as real-life socioscientific issues. However, a common assumption among science educators holds that understanding science content is necessary for informed (as opposed to whimsical or poorly thought-out) decisions regarding socioscientific issues (American Association for the Advancement of Science, 1990; National Research Council, 1996; Patronis et al., 1999; Pedretti, 1999).

Research from the broader traditions of psychology and education has produced mixed results with respect to the extent to which conceptual understanding influences informal reasoning. In reviewing 30 years of research from the cognitive sciences, Perkins and Salomon (1989) concluded that decision making requires a basic understanding of pertinent concepts. In the context of a socioscientific issue such as genetic engineering, this claim is analogous to asserting that an individual must have some basic knowledge of heredity to meaningfully engage in informal reasoning. Beyond this most fundamental application of knowledge, the influence of conceptual understanding on informal reasoning, argumentation, and decision making is rather minimal according to current research. D. Kuhn (1991) reported that no studies have shown a significant relationship between knowledge base in a content area and the cognitive skills used in that area. In a study involving students from many different grade and ability levels, Perkins et al. (1991) concluded that the quality of informal reasoning is independent of conceptual understanding of related content knowledge. Means and Voss (1996) reported that knowledge is related to informal reasoning and argumentation. However, they concluded that while increased knowledge confers quantitative differences in reasoning, such as the number and type of claims and justifications offered, the quality of reasoning and argumentation is not significantly affected by conceptual understanding. The remainder of this review explores the link between informal reasoning and conceptual understanding in studies involving socioscientific issues. Figure 4 summarizes these findings.

Results from a few studies already reviewed addressed the relationship between informal reasoning and conceptual understanding. In their study of argumentation patterns in response to genetic dilemmas, Zohar and Nemet (2002) reported that although the control-group scores on a conceptual test of genetics significantly improved as a result of instruction, argumentation from the same group remained unchanged. This result implies that argumentation skills do not necessarily improve with greater conceptual understanding. As mentioned earlier, argumentation and informal reasoning are related in that informal reasoning is expressed through argumentation, but they represent different processes. The conclusion that argumentation skills were independent of knowledge gains does not necessarily preclude a link between informal reasoning and conceptual understanding, but the study does not support that link.

In the community case study based on a local environmental issue (Tytler et al., 2001), members of the general public relied more frequently on ‘‘informal evidence’’ than ‘‘scientific evidence’’ (Recall that informal evidence was defined to include common sense, circumstantial evidence, and personal experience whereas scientific evidence was delineated as hard evidence or material data). The scientific evidence was most frequently referred to and applied by science experts or professional scientists involved in the debate. The nonscientist participants used informal evidence ‘‘as a bridge between technical assertions and personal or practical or political understandings’’ (p. 825). It might have been the case that the general public lacked the necessary conceptual knowledge to access the scientific evidence. This is certainly not the only interpretation of the patterns reported: The public might have understood but chose to ignore the scientific evidence in favor of the informal evidence. Regardless of the actual content knowledge of these participants, this case revealed a situation in which conceptual understanding could have potentially affected socioscientific decision making.

In a pair of articles, Fleming (1986a,b) explored high-school-student reasoning by means of a qualitative analysis of semistructured interviews based on socioscientific issues. He concluded that the dominant reasoning pattern involved social knowledge, which included individuals’ ideas about themselves, morality, and society. However, the author also was interested in the influence of nonsocial cognition, defined as the use of knowledge about the physical world (i.e., scientific content knowledge). The focus of the second article (Fleming, 1986b) was an assessment of how students used their understanding of science in the analysis of socioscientific issues. The researcher distinguished between the meaningful application of scientific knowledge and simply using science terms. Whereas 91% of the respondents incorporated science terminology in their interview responses, few students actually drew on scientific knowledge in the articulation of their positions. These results could be interpreted in two ways: The students could have possessed the science knowledge, but chose to rely on social knowledge or they could have lacked the science knowledge, making its application impossible. Fleming (1986b) opted for the latter conclusion:

> Adolescents’ knowledge of the physical world appeared to be restricted to a few words heard in science class. Knowledge of the physical world is rarely, if ever, used when analyzing and discussing socioscientific issues. School science is the source of the colloquial expressions. It is not, from students’ perspectives, a source of useful information for analyzing socioscientific issues. (p. 698)

It would be reasonable to expect that older students possess greater conceptual understanding of ideas that underlie socioscientific issues and, therefore, would be more likely to apply that knowledge in the resolution of those issues. However, a study with students younger than any of those cited previously in this section provides the first strong evidence for a positive association between conceptual understanding and informal reasoning. Hogan (2002) worked with a group of eighth-grade students to explore their content knowledge and decision making related to an environmental issue. The researcher also interviewed an environmental scientist with extensive experience handling the type of problem encountered by the students in their group work.

Not surprisingly, the reasoning of the professional scientist who specialized in ecology revealed a richer collection of background knowledge, a greater appreciation for pertinent issues, and more sophisticated justifications and explanations. The student groups addressed the same themes that the scientist considered important, but each individual group typically adopted a narrow focus, concentrating on only one or two themes. The author suggested that the limited knowledge of a group of any three participants, as compared to the knowledge of the scientist, restricted the group's ability to consider multiple factors leading to their relatively naïve management decisions. Concluding that middle schoolers do not reason about environmental issues as well as environmental scientists is not particularly significant; however, a trend related to the link between informal reasoning and conceptual understanding developed among the student groups. The members of one group possessed more knowledge of the content than the other groups, and the author repeatedly commented on the relative superiority of this group's reasoning:

> [The groups reasoning was] impressive in structure as well as content. (p.362)
>
> [They] displayed the ability to synthesize a range of information, draw well-supported inferences, and thoroughly consider the ramifications of alternative decisions. (p. 362)
>
> [They] displayed the most integrative and thorough reasoning about the management decision. (p. 363)

Zeidler and Schafer's (1984) work with college students also substantiates the link between conceptual understanding and informal reasoning. The researchers selected two groups of undergraduates for their analysis: environmental science majors and nonscience majors. Each participant completed a series of assessments related to moral reasoning, and environmental issue affect and knowledge. Whereas the science majors scored higher on the content knowledge test, both groups displayed positive attitudes toward the environment. No significant differences between the groups emerged in response to a general measure of the moral reasoning, but the science majors outperformed the nonscience majors on a measure of moral reasoning in the context of environmental issues (i.e., EIT) (Iozzi, 1978). The fact that both groups displayed positive attitudes toward the environment suggested that the differences in conceptual understanding contributed to the disparity in moral reasoning, in environmental contexts, between the groups. This hypothesis was examined by means of a multiple regression analysis. All variables tested, including the ecology comprehension test, significantly contributed individually to performance on the EIT. While moral reasoning, the target of EIT scores, is not synonymous with informal reasoning, moral reasoning forms an integral part of informal reasoning (Andrew & Robottom, 2001; Solomon, 1994; Zeidler, 1984). Zeidler and Schafer's (1984) research challenged past findings (Iozzi, 1977) that suggested moral reasoning was independent of context. By revealing the context dependence of moral reasoning, Zeidler and Schafer uncovered a possible relationship between conceptual understanding of material and moral reasoning regarding issues related to that material. Because moral reasoning is a component of informal reasoning in the context of socioscientific issues, it follows that conceptual understanding may be an important variable for informal reasoning.

Summary

All studies reviewed in this section support the notion that conceptual understanding of the material that underlies socioscientific issues is important for informal reasoning regarding those issues. The findings of Tytler et al. (2001) and Fleming (1986b) suggested that a lack of understanding impeded informal reasoning, and Hogan (2002) and Zeidler and Schafer (1984) produced evidence to support a positive relationship between conceptual understanding and informal reasoning. However, this evidence requires further empirical substantiation. Hogan's evidence rested largely on a comparison of a middle-school student's and a professional scientist's reasoning patterns, which we expect to be divergent; and Zeidler and Schafer focused specifically on moral reasoning, which is only a small subset of informal reasoning. These studies reveal an important trend, but additional research that can more robustly describe the relationship between conceptual understanding and informal reasoning is needed.

Summary and Implications

Before summarizing the findings related to socioscientific informal reasoning and argumentation, NOS, evaluation of information, and conceptual understanding, a trend across all of the research should be noted. Personal experiences of the decision makers emerged as a consistent influence on informal reasoning related to socioscientific issues (Bell & Lederman, 2003; Fleming, 1986a,b; Patronis et al., 1999; Sadler et al., 2004; Tytler et al., 2001; Zeidler & Schafer, 1984; Zeidler et al., 2002), but its effect differed across contexts. In some cases, personal experiences and knowledge were held in abeyance from scientific knowledge (Sadler et al., 2004; Zeidler et al., 2002) whereas in other studies personal experience seemed to mediate scientific knowledge (Patronis et al., 1999; Tytler et al., 2001). The difference between these two sets of studies is related to the extent to which participants were engaged with the issue. Tytler et al. (2001) and Patronis et al. (1999) focused on local issues that produced direct impacts on their participants. Sadler et al. (2004) and Zeidler et al. (2002) used general issues with more global effects. Although all issues explored were authentic in that they represented real problems, those which encouraged the integration of personal and scientific knowledge were more accessible to the participants; the issues involved immediate problems in their communities. Individual reasoners perceived a greater personal stake in the debates and their resolutions. This suggests that if educators desire to use socioscientific issues as a means of making science more relevant to students' lives (Cajas, 1999; Pedretti & Hodson, 1995), then they need to select local issues. The alternative is developing strategies to help students envision the connections that exist between more global issues and themselves. Researchers and practitioners may perceive significant impacts of general socioscientific issues such as global warming and genetic engineering, but their students may possess vastly different perceptions. Therefore, curricula that include these kinds of issues require components that help students integrate classroom science experiences with their personal lives.

Based on the literature, the promotion of argumentation skills appears to be a difficult educational goal. Of the four reports that investigated argumentation in the context of socio-scientific issues, only one (Zohar & Nemet, 2002) reported significant gains in argumentation skills in response to intervention. However, two of the studies that failed to enhance argumentation skills did not explicitly address argumentation during the course of the intervention. Furthermore, argumentation and the informal reasoning that underlies it are complex processes that require time and practice to develop (Berkowitz, Oser, & Altof, 1987; Driver et al., 2000; Means & Voss, 1996). The studies reviewed suggest that students would benefit, in particular, from instruction related to dealing with contradictory evidence, the formation of counterarguments, and the importance of providing justifications for claims.

The studies that examined the influence of NOS conceptions on socioscientific decision making report mixed results. In a study involving college and university professors (Bell & Lederman, 2003), researchers did not detect significant differences in decision-making patterns despite divergent views on NOS. However, studies involving high-school and college students (Sadler et al., 2004; Zeidler et al., 2002) reported significant interactions between NOS conceptions and socioscientific decision making. This discrepancy might be attributable to how NOS was used and explored in each of the studies. While the authors of all three studies share a common notion of NOS, their participants' levels of NOS understanding were vastly different. The students were concerned with NOS aspects such as empirical evidence and social embeddedness whereas the differences in NOS conceptions held by the professors involved epistemological and methodological issues. The combined results suggest that basic ideas concerning NOS may influence informal reasoning associated with socioscientific issues, but discrepancies in the more philosophical aspects of NOS do not affect informal reasoning.

Given the fact that socioscientific issues often involve scientific ideas from the frontiers of research, most people must rely on outside sources of information to form positions regarding these issues. Information of this type is transmitted to decision makers through a variety of sources including newspapers, magazines (both news magazines and special-interest magazines), the Internet, politicians, teachers, friends, and family. Research on how people evaluate information pertaining to socioscientific issues suggests that most individuals are ill-prepared for the task. Individuals usually adopt two strategies: evaluation of the information provided or evaluation of the information's source. The strategies themselves are valid, but the manner in which individuals carry out the evaluations is questionable. The studies cited revealed that individuals often accept information at face value, use inconsistent evaluative criteria, and focus on superficial elements of the information and/or source (Kolstø, 2001b; Korpan et al., 1997). In addition, research on the interpretation of scientific evidence revealed a limited capacity for many individuals to perceive and use scientific data (Sadler et al., 2004; Tytler et al., 2001). These findings suggest that information evaluation needs to be a strong component of socioscientific issue curricula and instruction. In particular, many students require direct instruction in how to use strategies for evaluating scientific reports as well as experiences in discriminating between scientific evidence and other forms of information.

The studies related to the influence of conceptual understanding on informal reasoning regarding socioscientific issues suggest some tentative, yet consistent, trends. Two of the studies reviewed (Fleming, 1986b; Tytler et al., 2001) revealed that a lack of conceptual understanding limited informal reasoning. The other reports (Hogan, 2002; Zeidler & Schafer, 1984) suggested that conceptual understanding improved informal reasoning on socioscientific issues. While these conclusions seem intuitively obvious, they are relatively unique within the broader literature base of informal reasoning and conceptual understanding (D. Kuhn, 1991; Means & Voss, 1996; Perkins et al., 1991). Given the lack of evidence from other fields regarding the link between conceptual understanding and informal reasoning and the tangential nature of the findings reported herein (None of these studies were specifically focused on the role of conceptual understanding.), additional work in the area is necessary. Future research needs to specifically address how conceptual understanding is related to informal reasoning in the context of socioscientific issues.

Conclusions

The articulation of the overall goals of science education is one of the helpful accomplishments of the science education reform documents (American Association for the Advancement of Science, 1990; National Research Council, 1996). The ideas are not revolutionary in that the sentiments of the documents have historical foundations that span a century (Laugksch, 2000), but the collection and communication of these ideas bolster their significance and serve to unify goals of science education. Consider the vision laid out in the opening lines of *Science for All Americans* (American Association for the Advancement of Science, 1990):

> Education has no higher purpose than preparing people to lead personally fulfilling and responsible lives. For its part, science education . . . should help students to develop the understandings and habits of mind they need to become compassionate human beings able to think for themselves and to face life head on. It should equip them also to participate thoughtfully with fellow citizens in building and protecting a society that is open, decent, and vital. (p. xiii)
>
> Critics might argue that these idealistic aims are beyond attainment in real-life science classrooms complete with limited supplies, expanding class roles, discipline problems, extracurricular distractions, and so on. But if science educators are not aiming to help students lead productive lives, capable of thinking for themselves and equipped to participate meaningfully in society, then why do science educators teach?

Incorporating socioscientific issues in classroom science is one path towards realizing the lofty goals laid out in the reform documents. Socioscientific issues are by no means the only way of promoting scientific literacy, but they can provide a powerful vehicle for teachers to help stimulate the intellectual and social growth of their students. If we want students to think for themselves, then they need opportunities to engage in informal reasoning, including the contemplation of evidence and data, and express themselves through argumentation. As the cited research (Driver et al., 2000; Jiménez-Aleixandre et al., 2000; Kortland, 1996; Patronis et al., 1999; Zohar & Nemet, 2002) suggests, socioscientific issues can provide a context for informal reasoning and argumentation. To participate thoughtfully in societies which depend on science and technology, individuals require some appreciation of the nature of science considerations, and the literature supports the interrelatedness of socioscientific issues and NOS considerations (Bell & Lederman, 2003; Sadler et al., 2004; Zeidler et al., 2002). This review is not suggesting that by simply being exposed to socioscientific issues, students will become better informal reasoners capable of analyzing complex arguments and will develop mature epistemologies of science. On the contrary, the reviewed research suggests that producing these kinds of changes are quite difficult to achieve. However, socioscientific issues can provide a forum for working on informal reasoning and argumentation skills, NOS conceptualizations, the evaluation of information, and the development of conceptual understanding of science content.

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