The Role of Moral Reasoning on Socioscientific Issues and Discourse in Science Education

Edited by
Dana L. Zeidler

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Edited by

DANA L. ZEIDLER
University of South Florida, Tampa, U.S.A.

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Dana L. Zeidler
University of South Florida
Tampa, FL

INTRODUCTION

Norman G. Lederman

I remember moving into my graduate student office at Syracuse University in 1979 as if it was yesterday. Directly across the hall was another graduate student office with the door closed. On the door was an index card with the following quote:

> Nothing happened in 1945 except that we changed the scale of our indifference to man; and conscience, in revenge, for an instant became immediate to us. Before the immediacy fades in a sequence of televised atomic tests, let us acknowledge our subject for what it is: civilization face to face with its own implications. The implications are both the industrial slum which Nagasaki was before it was bombed, and the ashy desolation which the bomb made of the slum. And civilization asks of both ruins, 'Is You Is Or Is You Ain't Ma Baby?' [1]

The quotation focused around an individual's viewing and reaction to the destruction in Nagasaki following the dropping of a nuclear bomb. The quote was from Bronowski's *Science and Human Values* and it was pasted to the door of Dana Zeidler's office. What goes around comes around in educational circles and I was unavoidably reminded of the quotation on Dana's door when reading this volume in preparation for the writing of this *Foreword*. I am not simply reminiscing about my first day as a PhD student, but rather I think the Bronowski quote cuts to the core of the text you are about to read.

I remember growing up in New York during the 1950s and 60s, and starting to see concerns about natural resources surfacing in newspapers and on TV. I remember an interview with Jane Fonda on TV, sometime during the 60s where she adamantly described a not so pleasant future if we Americans continued to burn fossil fuels without regard for the environment. I really didn't understand what the fuss was about, but I was a Jane Fonda fan. I had seen *Barbarella*. I do remember that immediately after finishing the interview she got back into her chauffeured limousine and drove away, probably to another interview about the environment. In

[1] As Bronowski was observing the after-effects of the first atomic blast, a ship's loudspeaker in Nagasaki harbor broadcast popular dance tunes from the 1940's. One song was entitled "Is You Is Or Is you Ain't Ma Baby?" See: Bronowski, J. (1965). *Science and human values*. New York: Harper & Row, Publishers.

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my mind, I thought this to be an interesting contradiction. However, I wasn't interested enough to think about it much during the remainder of the day, month, or year. I liked the movie *Barbarella.*

During my first few years as a faculty member at Oregon State University, I was interviewing a ninth grade student in Harrisburg, Oregon about his views on science. The student seemed to understand that scientific knowledge was tentative so, playing devil's advocate, I asked him if and how science influenced any decisions he made. After all, he believed all knowledge was subject to change. The ninth grade student replied, "Let me put it to you this way, I won't go out and play with nuclear waste, but I'll still eat my Twinkies." It reminded me a bit of Jane Fonda years ago. About five years later, I observed a teacher in Philomath, Oregon attempting to bring relevancy into her classroom by having the students debate the pros and cons of attempts to rescue the spotted owl from extinction. The debate was a disaster with little science learned, but much learned about human nature when an emotionally charged issue is at hand. In my mind, there is a common theme that runs through my reminiscing. That theme is that nothing has changed. People remain people. Unfortunately, this theme should not translate into the observation that neither has the public school science curriculum changed, at least when it comes to the inclusion. Quite simply, if actions are manifestations of beliefs, we continue to believe that if students posses more in-depth subject matter knowledge on a scientifically-based social issue they will make more informed decisions. We have continued over the years to ignore the complexity of humans when it comes to making decisions that affect our lives, livelihood, culture, and country.

The goal of scientific literacy or the development of an informed citizenry is not new. Neither is the use of socioscientific issues in science instruction. Indeed, few would debate that students' abilities to grapple with such real world problems is a hallmark of what we desire for ALL as a consequence of science curriculum. This edited volume marks the first in-depth attempt to elaborate the full theoretical and practical complexity of attempting to focus science curriculum around socio-scientific issues.

Zeidler, and invited authors, have appropriately used moral reasoning as a reference point and missing component to discuss the intricacies of achieving the goal of scientific literacy. In the opening section, readers are provided with an extensive review of the research related on moral reasoning, addressing past, present, and future. The natural conclusion is that student reasoning ability is not enough to accomplish the goals of current reform efforts and this conclusion provides a smooth transition into a series of chapters that explicate all the other factors that contribute to the development of functional scientific literacy.

Section II focuses on nature of science and its relationship to students' handling of socioscientific issues. The three chapters clearly point to the complexity of this relation ship as well as the points of contention that exist among researchers on nature of science and the inclusion of socioscientific issues in science instruction. Rather than nature of science influencing moral reasoning or vice versa, the complex relationship is quite possibly shown to be reciprocal.

Section III of the volume primarily focuses on the increasingly important area of argumentation and discourse in the classroom. Zeidler, Osborne, Erduran, Simon, and Monk do an excellent job of establishing potential standards for the evaluation of the arguments used by students during the consideration of socioscientific issues. And, critical to the techniques addressed in this are the considerations presented by Duschl in his contributed chapter. Berkowitz and Simmons present science educators with a perspective that is not typically included in the mainstream, science education literature: character education. Although the chapter reminded me of the lipservice provided to moral character by the *Cardinal Principles of Secondary Education* in 1917, the authors clearly and concisely present an in-depth review of the literature, a review that validly represents the complexity of character education.

In many ways Section IV brings the volume full circle by emphasizing the importance of cultural values and the role they play in students' decisions on scientific issues, not to mention the role such values play in a teacher's decision to attempt to provide *Science for All*. Perhaps the most vexing problem facing teachers who choose to use socioscientific issues in science instruction, is student diversity and how this diversity manifests itself in a wide variety of strongly held values and beliefs that can not be ignored if education is to be inclusionary and fair to ALL students.

This text provides a good balance of theoretical research and practical advise for teachers. Section V provides a variety of approaches classroom teachers can use to address students' moral development and socioscientific issues. Finally, in Section VI, Zeidler and Lewis review what has been done as well as acknowledge all the work that still remains.

It is my hope and prediction that readers of this volume will become energized to seriously address the multi-faceted problems and challenges associated with helping students achieve functional scientific literacy. However, with enthusiasm (as in prior attempts) often come inadvertent omissions that can serve to critically compromise the best of intentions. So, as you read and carefully consider the conclusions and recommendations presented in the following pages, I offer as cautions/concerns what I offered graduate students considering the use of socioscientific issues in their classrooms at the beginning of my career. These cautions/concerns fall into two categories: teacher knowledge/skills and issue selection.

Teacher Knowledge/Skills

1. Does the teacher possess in-depth knowledge of the science involved in the socioscientific issue?
2. Does the teacher possess in-depth knowledge of moral and ethical development of his/her students and how to enhance such development?
3. Does the teacher possess in-depth knowledge of argumentation and how to evaluate the quality of arguments?

Socioscientific Issue Selection

1. Is the issue truly scientifically based? That is, was the issue caused by the advancement of science and/or technology and will students learn science by considering the issue? For example, the debate about evolution and

creationism is not really the result of the development of scientific knowledge.

2. Is the issue developmentally appropriate for students? Can six grade students meaningfully discuss in-vitro fertilization or abortion?
3. Is the issue too polarizing to allow for productive discussion? Don't forget the emotionally charged topic of spotted owls in Philomath, Oregon.
4. Can you allow students to arrive at a decision different from your personal beliefs and can you fairly grade students who come to a decision that is different from what you believe? Remember, if you are using a true issue there is no single correct answer.

Whenever we teach science and the complex set of personal and societal factors that encircle the knowledge itself, we must ask, "Is You Is Or Is You Ain't Ma Baby?"

SECTION I: INTRODUCTION

CHAPTER 1

THE ROLE OF MORAL REASONING AND THE STATUS OF SOCIOSCIENTIFIC ISSUES IN SCIENCE EDUCATION

PHILOSOPHICAL, PSYCHOLOGICAL AND PEDAGOGICAL CONSIDERATIONS

Dana L. Zeidler & Matthew Keefer

INTRODUCTION

In the early part of the 20th century, John Dewey advocated a "progressive" philosophy of science in American education. This view entailed re-evaluating how science was typically taught to children in school as well as adults in college. Dewey's contention was that teaching science as "ready-made knowledge" consisting of facts, principles, and laws divorced from the social activity of science was not sufficient to develop an informed populace capable of using science as a method of inquiry into any subject.

> Science has as yet had next to nothing to do with forming the social and moral ideals for the sake of which she is used… (Science) has remained a servant of ends imposed from alien tradition…science must have something to say about what we do, and not merely about how we may do it most easily and economically…When our schools truly become laboratories of knowledge-making, not mill fitted out with information hoppers, there will no longer be the need to discuss the place of science in education. (Dewey, 1974 / 1910, p.192)

In the latter part of the 20th century, many science educators reaffirmed the importance of envisioning science not as an isolated subject but understanding the role of science in relation to other areas of life (Aikenhead, 1992; Aikenhead, Fleming, & Ryan, 1987; Bybee, Powell, Ellis, Giese, Parisi, & Singleton, 1991;

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The Role of Moral Reasoning on Socioscientific Issues and Discourse in Science Education, 7-38.

Sabar, 1979; Solomon & Aikenhead, 1994; Yager & Lutz, 1995; Zeidler, 1984). The Science-Technology-Society (STS) approach, for example, has been one attempt to emphasize collateral learning by connecting science and the advancement of technology in the student's social world. While those who promote STS approaches clearly support the incorporation of environmental concerns and decisions, advocates of Science, Technology, Society and Environment (STSE) education tend to make more explicit connections with respect to examining science within a larger social, cultural and political context. Proponents of the latter approach also emphasize the importance of contextual decision-making with ethical, individual and social consequences (Pedretti, 2001).

As the 21st century unfolds, professional associations in science recognize the importance of broadly conceptualizing scientific literacy to include informed decision-making, the ability to analyze, synthesize and evaluate information, dealing sensibly with moral reasoning and ethical issues, and understanding connections inherent in socioscientific issues (Zeidler, 2001). To achieve a practical degree of scientific literacy necessarily entails practice and experience in developing habits of mind (i.e. acquiring skepticism, maintaining open-mindedness, evoking critical thinking, recognizing multiple forms of inquiry, accepting ambiguity, searching for data- driven knowledge) advocated in Project 2061 (AAAS, 1989). Habits of mind may suffice when arriving at individual decisions based on an informed analysis of available information. However, it may not be sufficient in a world where collective decision-making is evoked through the joint construction of social knowledge. In the real world of dirty sinks, and messy reasoning, arriving at ideal personal decisions through objective evaluation of neutral evidence is a phantom image.

The focus of this book is to examine factors associated with reasoning about socioscientific issues. Accordingly, socioscientific issues are equated with the consideration of ethical issues and construction of moral judgments about scientific topics via social interaction and discourse. Under this framework, science teaching is viewed as a microcosm of society that must entail, among other kinds of thinking, the following characteristics:

- Processes of Inquiry
- Discourse
- Conflict
- Argumentation
- Negotiation
- Compromise
- Decision-Making
- Commitment

This partial list of features associated with reasoning about socioscientific issues takes on increased importance if teachers understand that the development of meaningful concepts requires (under this framework) the joint construction of scientific knowledge that is at once personally relevant and socially shared.

Consider the high priority various countries have assigned to the moral and ethical dimensions of science education. For example, in the United States, the American Association for the Advancement of Science initiated Project 2061 to set a vision of life-long science literacy. There are five major criteria that *Project 2061: Science for All Americans* recommends in the selection of science content that may provide a "lasting foundation" for all subsequent learning – both in the classroom and in the world. There is an unmistakable emphasis on issues of scientific discourse and reasoning. These criteria are worth repeating here.

- Utility: Will the proposed content knowledge or skills significantly enhance the graduate's long-term employment prospects? Will it be useful in making personal decisions?

- Social Responsibility: Is the proposed content likely to help citizens participate intelligently in making social and political decisions on matters involving science and technology?

- The Intrinsic Value of Knowledge: Does the proposed content present aspects of science, mathematics, and technology that are so important in human history or so pervasive in our culture that a general education would be incomplete without them?

- Philosophical Value: Does the proposed content contribute to the ability of people to ponder the enduring questions of human meaning such as life and death, perception and reality, the individual good versus the collective welfare, certainty and doubt?

- Childhood Enrichment: Will the proposed content enhance childhood (a time that is important in its own right and not solely for what it may lead to in later life)? (AAAS, 1989, p.21)

The importance of not divorcing science from its social function is again strongly reiterated in *Benchmarks for Science Literacy* (AAAS, 1993). Accordingly, cultural issues (i.e. the cultural-embeddedness of science) are a priority of terms of what it means to be scientifically literate. Furthermore, the prominence of cultivating "Habits of Mind" like curiosity, openness to new ideas, skepticism, critical-response skills (e.g., argumentation and discourse issues) is clearly recognizable throughout the document:

> Even today, it is evident that family, religion, peers, books, news and entertainment media, and general life experiences are the chief influences in shaping peoples views of knowledge, learning, and other aspects of life… To the degree that schooling concerns itself with values and attitudes – a matter of great sensitivity in a society that prizes cultural diversity and individuality and is wary of ideology – it must take scientific values and attitudes into account when preparing young people for like beyond school. (AAAS, 1993, p. 285)

In the United States, the National Research Council has extended the seminal work of Science for All Americans and Benchmarks by introducing the National Science Education Standards. At the core of the now familiar eight content standards (Unifying concepts and processes, science as inquiry, Physical science, Life science, Earth and space science, Science and technology, science in personal and social perspective, and History and nature of science) lie four central goals that define scientific literacy. These include the application of scientific processes to derive personal choices and the ability to engage intelligently in public discourse and debate in matters of scientific and technological importance:

> School science reflects the intellectual and cultural traditions that characterize the practice of contemporary science. To develop a rich knowledge of science and the natural world, students must become familiar with modes of scientific inquiry, rules of evidence, ways of formulating questions, and ways of proposing explanations. The relation of science to mathematics and to technology and an understanding of the nature of science should also be part of their education. (National Science Education Standards, NRC, 1996, p. 21)

Progressive visions of scientific literacy that entail a commitment to the moral and ethical dimensions of science education and the personal development of children are by no means limited to the U.S. For example, in the United Kingdom, King's College has taken the lead in holding a series of working seminars concerning the successes and failures of science education to date, current science education needs of children, a suitable model for a science curriculum, and implementation issues. Those seminars lead to the development of a report, Beyond 2000: Science Education for the Future, in which a broad conceptual framework provides direction for contemporary science education curriculum concerns. It is clear that deliberate and explicit attention has been given to nature of science issues in the context of socioscientific concerns:

> To sustain a healthy and vibrant democracy, such issues do not require an acquiescent (nor a hostile and suspicious) public, but one with a broad understanding of major scientific ideas who, whilst appreciating the value of science and its contribution to our culture, can engage critically with issues and arguments which involve scientific knowledge. For individuals need to be able to understand the methods by which science derives the evidence for the claims made by scientists; to appreciate the strengths and limits of scientific evidence; to able to make a sensible assessment of risk; and to recognize the ethical and moral implications of the choices that science offers for action. (Millar & Osborne, 1998, p. 2004)

Beyond 2000 goes on to stress the cultural embeddedness of science whereby the fusion of science in culture becomes intertwined and inseparable. "In the popular mind, science-and-technology is often seen as a single entity. It would therefore be artificial to separate the two and attempt to teach only 'pure' science.… Technology is not simply applied science – it is the cultural response of people to problems and opportunities they have perceived that has shaped the ways we live and work" (Millar & Osborne 1998, p. 2018). Science education, therefore, should stress that political and religious commitments, economic factors, technical feasibility as well as ethical implications influence our understanding of socio-scientific issues.

The next example is also indicative of the attention moral and ethical concerns have received in science education. For example, the Council of Ministers of Education in Canada has recently set in place the Pan-Canadian Science Project. The project selected science as its first area for collaboration on school curriculum to help strengthen the personal and professional educative experiences of citizens in terms of contributing to the social, economic, and cultural development of Canada, as well as contributing positively to international commitments. The Common Framework of Science Learning Outcomes K to 12 (also known as the Framework) reflects a vision of science literacy that clearly is linked with providing opportunities for all students to develop proclivities for inquiry, problem-solving, and decision-making. The use of case-based issues to explore connections among evaluating evidence and implementing personal and social decisions (e.g. those involving STSE issues) is of paramount concern:

> Science literacy is an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them. Diverse learning experiences… will provide students with many opportunities to explore, analyse, evaluate, synthesize, appreciate, and understand the interrelationships among science, technology, and society, and the environment that will

> affect their personal lives, their careers, and their future. Specifically, science education aims to prepare students to critically address science-related societal, economic, ethical, and environmental issues. (CMEC's Pan-Canadian Science Project, 1997, p. 2, 3)

As a final example, we invite readers to consider other professional science education organizations like the Queensland School Curriculum Council and Australian Science Teachers Association. These Australian organizations have also advocated for broader conceptualizations of scientific literacy similar to those described above. Just as the notion that process can be product, science can also be equated with social and cultural contexts. In such a view, core scientific values subsume broader cultural values such as democratic processes, social justice, ecological and economic sustainability and peace. Cultural values like these are no longer viewed as abstract concepts but set in the context of real places and events, past and present (see QSCC, 2001 and Goodrum, Hackling & Rennie, 2001).

The intent of the above examples is not to provide a comprehensive review of contemporary science education curricula in all parts of the world but to merely point out that major segments of the international science education community appear to have revisited (purposefully or not) and embraced Dewey's progressive contention that education must deal with the intellectual and moral growth of students and envision school as an "embryonic typical community" (1978/1909). Accordingly, students should be provided with experience that will have direct impact and relevance to their present and future social experiences. Kolstø (2001a) emphasizes that it is only through experience will students develop the attitudes and skills necessary to examine and effectively reason about socioscientific issues and suggests that in order to help promote scientific literacy for citizenship, it is useful to think of teaching about controversial socioscientific issues via content-transcending topics such as science as a social process, limitations of science, values in science, and critical attitude. It has been argued elsewhere (Zeidler, 1984; Zeidler, Walker, Ackett & Simmons, 2002) that in order to achieve scientific literacy, it is necessary to include moral and ethical issues in an interdisciplinary science curriculum. The central argument is based on the premise that if citizens are expected to make rational, informed decisions about their society (one that is permeated by science and technology) then as students they ought to be provided with the necessary experiences in which to practice and apply this kind of decision-making. While STS and STSE curricula provide the impetus toward that end, it is less clear what a conceptual framework might entail that links together a common understanding of key issues that impact a child's reasoning and understanding of moral and ethical issues embedded in science.

It may be argued that science educators and science teachers ought to view themselves as moral agents in decisions to emphasize the moral dimension of teaching (i.e. socioscientific issues). Such a view of teaching requires reflective (and reflexive) moral action to constantly provide opportunities for students to engage in analysis and dialogue of meaningful life experiences (Beyer, 1997; Cummings, Dyas, Maddux, & Kochman, 2001; Ratcliffe, 1997).

The authors writing for this volume share a common conviction that in order to ensure key experiences, science educators (and other researchers and practitioners in the wider educational community) must put forward a coherent framework that enables educators and curriculum specialists to better understand the moral growth of the child. The framework that we have selected because of its utility in addressing scientific discourse in terms of the psychological, social, and emotive growth of the child is derived from a moral reasoning perspective. Accordingly, this framework entails the following seminal educational themes: Moral Reasoning/ Development, Cognitive Reasoning/Development, Emotive Belief Systems, and Moral/Character Education. Such a framework should be viewed as a tentative model that envelopes four broad issues of pedagogical importance central to the teaching of socioscientific issues and derived from contemporary visions of science literacy: 1) Nature of Science Issues; 2) Classroom Discourse Issues; 3) Cultural Issues; and 4) Case-Based and STSE Issues. These issues can be thought of as entry points in the science curriculum through which broader seminal educational themes are filtered (see Figure 1 below).

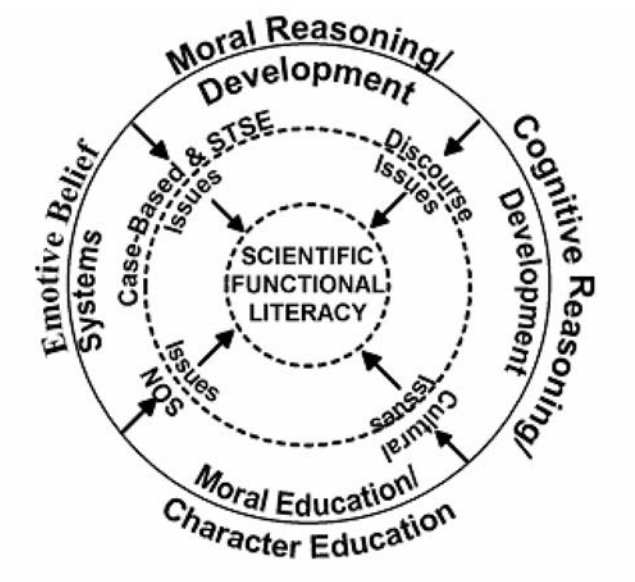


Figure 1. Socioscientific Elements of Functional Scientific Literacy

While the broad educational themes found on the outer rim of Figure 1 are derived in part from a neo-Kohlbergian perspective, they do not preclude (and in fact, invite) the use of post-modern perspectives of moral reasoning, growth and development. The literature review that follows in this chapter emphasizes the complementary influences each of these viewpoints has had in understanding how empirical observations of psychological development connect not only to philosophical positions of education but are also grounded in pedagogical means and ends. At the same time, the inner rim of this figure contains issues related to scientific literacy and were identified because of the central role they play in moving fluidly between the broader educational themes and science education practices. For example, Nature of Science Issues become important to the focus of this book because they reveal how varied epistemological views influence the way in which evidence is selected and evaluated, and is considered to have bearing on students' preinstructional views of socioscientific issues. Discourse Issues hold the key to how students frame their positions, build a case for argument, become aware of fallacious reasoning, and consider how belief convictions influence their emotions and moral commitments to moral issues. Cultural Issues remind us that discourse is futile without mutual respect and tolerance of dissenting views, while underscoring that the decisions students make are the result of realizing that as moral agents, we are impacted by normative values as well as cultural beliefs about nature. STSE and Case-based Issues enable science educators to move beyond STS curriculum (which does not pay explicit attention to the moral dimensions of socioscientific issues) and considers the cultivation of ethical awareness by examining how power and authority are embedded in the scientific enterprise.

The aim of this book is to flesh out a more detailed understanding of what is meant by a functional view of scientific literacy by examining elements of these four issues. Attention to these areas necessarily entails delving into moral and ethical dimensions of science education. The contributions to this volume represent a concerted effort to identify and discuss important theoretical and pedagogical elements surrounding the framework of this model in science education.

A COGNITIVE-DEVELOPMENTAL MODEL: TRADITIONAL KOHLBERGIAN MORAL DEVELOPMENT

Few would argue the point that Lawrence Kohlberg, up to his death in 1987, was instrumental in contributing to our psychological understanding and educational ramifications of moral development. Kohlberg's research, while not necessarily encompassing all elements of "Morality," did enjoy wide educational appeal because of its coherence with a cognitive-developmental framework. In truth, Kohlberg never intended to search for a grand-unified theory of morality with a capital 'M' but to merely identify a "rational reconstruction of ontogenesis" in connecting individuals' reconstructions of justice to the unfolding of Piagetian operations (Kohlberg, 1986, p. 486). It is important to understand the seminal concepts of Kohlberg's contributions in order to situate the research of moral reasoning in a framework that can continue to be added to, fine-tuned and revised. But it is equally important to first understand the parameters that guided Kohlberg's research. Kohlberg's overarching concern was to attend to several issues of justice brought to light in Aristotle's Nicomachean Ethics: 1) Distributive justice – disbursing desirable assets of a group (or society); 2) commutative justice – formulating consensual contracts (verbal or written); and 3) corrective justice – deriving corrective principles in unjust transactions. In addition, Kohlberg believed that an essential element of higher stages of moral reasoning necessarily included the capacity to employ a forth issue of procedural justice – applying reversible and universalizable validity checks in the process of deriving moral decisions in 1 through 3 above. This forth element clearly gives Kohlberg's theory Kantian overtones (discussed later in this chapter) since a concern for making judgments universalizable is analogous to evoking Kant's categorical imperative. It is within these parameters that one has to consider that aspect of moral reasoning first discussed in this chapter. This is our starting place. Other elements of moral reasoning relevant to the study of socioscientific issues will be considered later in this introduction. Perhaps one last caveat is in order before proceeding in this introductory chapter:

> Deliberate or rational moral education may be an idea whose time has not come, any more than it had in Socrates' and Plato's Athens or Dewey's America, but a programme of research… needs, I believe, to be steered by its implication for educational practice, whether or not it has wide-scale chances of implementation. (Kohlberg, 1986, p. 544)

The theory of moral development that Kohlberg developed finds its origins in several theories (cited chronologically) that share a unifying theme of social and cognitive development (Baldwin, 1906; Dewey, 1930; Mead, 1934; Piaget, 1965; Loevinger, 1966; Kohlberg, 1966, 1968, 1969a, 1969b, 1984, 1987). The important feature to note is that these individuals viewed stage development as something that was not directly a product of maturation – that children's interaction with the physical and social environment contributed to development. The salient characteristic of stage development is that different levels of thought or reasoning occur in invariant stage-like sequences that require distinct qualitative changes in cognitive structure from one stage to the next over the course of development. By "restructuring" or interweaving novel information gained from interacting with the social and physical world with pre-existing conceptions, new understandings and ways of thinking are possible. Stage development, therefore, does not entail abrupt beginnings and endings; rather, it is a continuous process of transformations over the span of development. The essential features of conventional Piagetian stage development provide the basis for under-standing the context of Kohlberg's research and theory of moral development. Again, it is important to remember that the transformations of cognitive stages are sequential and hierarchical in nature, represent underlying patterns of thought–organization ("structured wholes"), and are a function of biological, cultural, and intellectual development (Flavell, 1971; Flavell, Miller & Miller, 1993).

Kohlberg held a structuralist position on which the assertion of universal moral stages is made. This position differs from other (psychological) theories of moral growth, which are dependent upon content or situational and cultural specific experiences.

> Content tells us what a person believes, which is obviously dependent upon culturally variable experiences, whereas structure tells us how a person thinks about the content of his beliefs, which reasoning, so the theory goes, is universal. (Lickona, 1976, p.9)

Consequently, it is the thought process, the logic behind the reasoning and judgments of an individual that are expressed through words and actions that are of central importance in observing and understanding moral development in the traditional Kohlbergian sense. In the study of moral development one investigates prescriptive valuing judgments expressed by people to the extent that those judgments represent the underlying cognitive processes making them. Moral reasoning judgments, then, entail prescriptive judgments of right and good applied to social situations (Kohlberg, 1986). Therefore, moral reasoning is based on specific features of thought processes throughout different stages of development, and reflects the individual's interpretation of rules, principles (i.e. justice) in conflict situations. One's *reasons* for moral action when choosing from various competing alternatives in a given situation reflect an overall mental structure, which arises through interactions between the individual and his/her environment.

An individual is said to progress through six different stages of moral reasoning and does so in a sequential manner. The speed with which one may do this can vary between individuals, and it is possible to become fixated at any one level of development as well. Kohlberg (1971, 1973a, 1973b) asserts that his model is in alignment with the formal criteria of cognitive developmental theory (increasingly complex differentiation and integration) as formulated by the structural traditions of Piaget (1960). Moral development then occurs along a parallel plane in juxtaposition but distinct from cognitive development. Studies by Colby and Kohlberg (1975), Keasy and Keasy (1974), Kohlberg, (1981 & 1985), Kohlberg and Turiel (1971), Kuhn, Langer, Kohlberg, & Haan (1977) and Zeidler (1985) have clearly developed a general correspondence between stages of moral and cognitive development. Cognitive development is under-stood to be necessary but not sufficient condition for moral development to occur. Hence, if we are to consider formal operations in the cognitive domain, those operations are a necessary but not sufficient condition for the parallel moral stage of post conventional (principled) moral reasoning. Appendix A depicts the progression for stages of moral development. Note how the progression of social awareness for each stage of development may be likened to a horse fitted with "blinders." As development progresses, the blinders are flared out and broadened – allowing for increased attention to and awareness of the peripheral social world surrounding that individual. At the advanced post conventional stage of development, the blinders are removed altogether as the individual becomes fully immersed in a social environment attempting to navigate in and negotiate with all surrounding elements in that social world.

If one understands the claim that higher moral stages correspond to a greater psychological equilibration of moral judgment, then one can understand the justification of higher stages being "better" or more developmentally sophisticated. The concept of developmental sequentiality provides a foundation on which Kohlberg justifies the superiority of higher stages of moral development. Kohlberg evoked a deontological theory of morality that is formalistic (i.e., impersonality, ideality, universalizability, preemptiveness) while realizing that there exist developmental levels of moral reasoning which increasingly fulfill the formal form of the philosopher (Kohlberg, 1971). Hence, the claim that the higher stages of moral judgment are better or more moral than the lower stages is to be understood in a formalistic context – higher stages of moral reasoning *better* fulfill the criteria of impersonality, universalizability, etc. To Kohlberg, then, the empirically verified notion that individuals prefer the highest stage of reasoning they can comprehend, legitimizes the notion that the higher stages of moral adequacy of principled reasoning is rooted in a naturalistic position similar to Rawls (1963 & 1971) and Kant (1970). Succinctly, the naturalistic view holds that adequate, rational moral judgments are universal, must be reversible, consistent, and prescriptive in nature (Kohlberg, 1971 & 1973b). The criteria of adequate, rational moral judgments are met with increasing adequacy as one progresses through the higher stages of moral development. Just as reversibility is essential if one is to have full equilibration of logical thought in formal operations, so too is reversibility essential in the parallel realm of principled moral thought:

> To say that rights and duties are correlative is to say that one can move from rights to duties and back without change or distortion. Universalizability and consistency are fully attained by the reversibility of prescriptions of actions. Reversibility of moral judgment is what is ultimately meant by the criterion of the fairness of the moral decision. (Kohlberg, 1973b, p. 641)

Accordingly, given any person's position in a given situation, the right solution can be reached if reversibility is applied, for each claim could then be considered impartially. A reversible solution then is the right solution from any individual's perspective, for any individual involved in the moral decision: it is the ability to reverse a moral perspective.

Universal solutions can be achieved under this framework because the notion of universalizability grows out of reversibility. What is right or fair in a conflict situation is something that all rational beings would choose in that particular situation. Rawls (1971) arrives on similar ground in his conception of fairness (which was derived from Kant). Rawls maintains that the principles of justice are arrived at from any initial position when they are chosen behind a "veil of ignorance" of our own or another's position. Applying this principle to solving a moral dilemma on post conventional levels of reasoning one finds that individuals, when faced with competing alternatives, will make a decision knowing the probabilities of outcome of the decision for every person involved, but without necessarily knowing his/her position (who he/she will be) in that situation. It is in this sense that the initial position is fair and that from which principles of justice can be agreed upon.

> Among the essential features of this situation is that no one knows his place in society, his class position or social status, nor does any one know his fortune in the distribution of natural assets and abilities, his intelligence, strength, and the like. I shall even assume that the parties do not know their conceptions of good or their special psychological propensities. The principles of justice are chosen behind a veil of ignorance. This ensures that no one is advantaged or disadvantaged in the choice of principles by the outcome of natural choice or the contingency if social circumstances. (Rawls, 1971, p. 12)

From the above discussion one is able to view the concept of sequentiality, reversibility and universalizability as being the central component of Kohlberg's stage concepts of moral development. While Kohlberg's theory of moral development may not capture all aspects of post conventional reasoning [e.g., see Gilligan (1977 & 1982), who describes another form of moral reasoning in terms of responsibility of choice and empathy] inasmuch as it is based on a theory of rights and justice, it has extensive empirical support which enabled researchers to analyze moral reasoning from the perspective of natural rights, social contract and utilitarianism. As previously mentioned, Kohlberg's theory is rooted in philosophical propositions and supported by empirical observation. The empirical nature of Kohlberg's work has extended into different cultural environments. Cross-cultural data (Kohlberg, 1969b & 1971a) from the U.S., Taiwan, Mexico, Turkey and Great Britain have added support to Kohlberg's theory, revealing the same sequential patterns of moral reasoning. In addition, Kohlberg has found no important differences in the development of moral reasoning among Catholics, Protestants, Jews, Buddhists, Moslems and atheists (Kohlberg, 1971a). To reiterate, although the content of situations may vary, the basic moral principles, the reasoning of individuals, reflects a universal order.

KOHLBERG'S ACCOUNT OF RESOLVING MORAL CASES

The connection between Kohlberg's characterization of moral judgment and the use of rules in the resolution of moral cases is a formal one. Kohlberg states that the "notion of a rule or principle in turn requires logically that moral judgments are universalizable prescriptions" (Colby & Kohlberg, 1987a, p. 10). Hence, the defining features of moral judgments turn out to be a logical and necessary requirement of rules and principles. X ought to do Y means that everyone ought to do Y in like situations. To articulate and apply these deontic rules and principles is to enter into the discourse of morality. For example, in Kohlberg's famous Heinz dilemma, Heinz should steal the drug (judgment and choice of moral action) because of the principle that the value of life takes precedence over property rights (principled moral justification). Heinz should perform this action defended by principle only, and not because (say) she is his wife, that he loves her, or any other reason that might pertain to his own character or personal exigencies. To be fully mature (in a principled sense), moral rules must be universalizable.

In discussing the relation between moral judgment and correct moral action, Kohlberg describes deontic judgments, that is, judgments of ought, as deductions from a stage or principle. Principles of this character imply two things. First, since they are required in situations where rules or norms conflict, such principles constitute a "method of choice" that enables the agent to choose between them. Kohlberg, then, speaks cryptically about a second implication of principles in providing "the spirit underneath the law rather than the rule itself; [the] attitude or idea that generates rules" (Kohlberg & Candee, 1984, p. 62). A fully mature principled judgment, Kohlberg concludes, requires "a hierarchical preference" for a chosen norm according to two formal features – universality and prescription. The problem is that this specification cannot unambiguously determine which moral norms ought to be preferred.[1] How then can Kohlberg reconcile the claim that "[h]igher stages are more moral in their form" with the claim".... that there is a "moral method" for arriving at moral judgment which can lead to substantive agreement about what is right and wrong and just in moral problem situations" (Kohlberg & Candee, 1984, p. 61). The problem for Kohlberg is to explain how a theory, which specifies the forms of moral reasoning, can ever relate itself to substantive moral content.[2]

Kohlberg's answer is that we must look to the "hierarchical preference" that the most principled (highest stage) subjects employ and find consensus. The reason given is that it is "only at stage five that the hierarchies become consensual, because only at that stage are they directly derivable from principles" (Kohlberg & Candee, 1984, p. 64). (As stage six never received the degree of empirical validation that stage five did, the burden fell to stage five subjects.) Kohlberg argues that there are certain intrinsically higher moral principles such as life, conscience, and contract that hold precedence over other norms such as law, punishment, and authority in the sense that the latter are extrinsic or derived from the former. According to such a view "morally right action is that which would be chosen by Stage 5 moral principles and which is, in fact carried out with at least an intuitive sense of those principles in mind" (Kohlberg & Candee, 1984, p. 70). But how do these guiding principles tie in with the qualitatively different principles of the preceding stages? We are still faced with the unlikely proposition that "fully moral reasoning" only appears at the principled stage. To circumvent this difficulty what was required was the construction of a substage type A and B for each of the earlier stages. Type A and B individuals are described as follows:

> Type A makes judgments more descriptively and predictively, in terms of the given "out there." Type B makes judgments more prescriptively, in terms of what ought to be, of what is internally accepted by the self. The Type B orientation presupposes both awareness of rules and a judgment of their fairness. (Colby & Kohlberg 1987a, p. 321)

In the Type B orientation we find the missing thread that ties the purely formal characterizations of the theory to substantive moral action throughout the course of development. A description of the manner in which moral judgment guides behavior at the four preceding stages is then given by Kohlberg as follows:

> Type B responses [at any stage] reflect the Stage 5 "right answers" to our dilemmas and an intuitive understanding of the core reasons for these choices. A type B person is someone who intuitively or in his "heart" or "conscience" perceives the central values and obligations in the dilemma articulated rationally by Stage 5 and uses these intuitions to generate a judgment of responsibility or necessity in the dilemma. (Kohlberg & Candee, 1984, p. 63)

Kohlberg's solution to the judgment/action problem is to tie moral judgment to moral action through the actions supported by the moral principles that his most mature subjects would choose. A problem with this re-formulation is that it puts somewhat narrow constraints on what can be considered a moral action in response

[1]There are only six norms that Kohlberg's measure of moral reasoning addresses. These are: life, law, conscience, punishment, contract and authority.

[2]It should be noted that this section examines Kohlberg's view of rules and principles *only* as they pertain to the adjudication of moral dilemmas. These remarks do not address Kohlberg's, and others', view of meaning or substance of the higher, post-conventional stages (Kohlberg, Boyd, & Levine, 1990).

to a moral conflict. According to this view, moral actions are (only) those actions that are justified by the kind of principles that his most mature subjects would choose. For example, in Heinz dilemma, the “right answer” to which all fully autonomous deliberators will converge, is that Heinz should steal the drug on the basis of the principle that appeals to the priority of the norm of life over law. The implication here suggests that the idea of severing stage theory completely from content might prove to be untenable (i.e., actions and responses need to be in line with what morality requires).

In summary, principles or rules provide a basis for moral judgments. Such judgments, when identified in situations of moral conflict, provide a decisive “commitment to action,” i.e., the action that is justified by the application of a rule or principle should be carried out. In Kohlberg's formulation *rules and principles* can be contrasted with other kinds of *reasons*. Only use of the former will make a solution to a moral conflict a *moral* solution, while other uses of reasons are relevant only to the description of cases, or pertain to more specific “preferential” characteristics of agents (Colby & Kohlberg, 1987).[3] The problem is that Kohlberg is left open to the charge that he has placed an arbitrary constraint on what constitutes an adequate judgment in facing a moral conflict. In response to these criticisms Kohlberg, in later writings, narrowed the scope of his own investigations and attempted to specify, more precisely, some of his own assumptions. In particular, Kohlberg stated that he:

> assumed that the core of morality and moral development was deontological, that is, it was a matter of rights and duties or prescriptions. My assumption about the deontological form of mature moral judgment was associated with the assumption that the core of deontological morality was justice or principles of justice. My assumption concerning the centrality of justice derived directly from Piaget's (1932/1965) own study of the development of moral judgment and reasoning. (Kohlberg, 1984, p. 225)

This understanding of what constitutes good moral judgment and moral action has not been without its critics. One of the most radical challenges has been Gilligan's (1982) formulation of a morality of care which she presents as an alternative to Kohlberg's insistence that fully mature moral reasoning is reasoning relies on the application of norms and principles.

CAROL GILLIGAN’ S CARE ORIENTATION

Kohlberg’s conception of moral maturity dominated the research on moral development for several decades, and constituted the standard by which other research programs were modeled and compared (Kuhn, 1962; Lakatos, 1978). Carol

[3] One objection to this account of being guided by a rule is that it rests on a supposed logical relation between the formal character of moral judgments and performance of moral actions. As such, it cannot account for those who may adopt a more contextual approach to the resolution of conflicts by applying judgments of the form: “Only persons' committed to these values, with these sorts of character, ought to do X in Y kinds of situation.” Furthermore, some types of reasons can be classified as “agent neutral” and, yet, would seem to fail Kohlberg's criteria for universality. For example, the reason that “Husbands ought to care for their wives because they love them” would not be treated by Kohlberg as a principled response to a moral conflict. While Kohlberg, and others, may hold that to apply these moral judgments is to exhibit less than mature reasoning, they cannot claim that to be guided by such a judgment is to make a logical error.

Gilligan has posed a serious threat to this grand and general scheme, suggesting a more narrative contextual approach to moral reasoning (what she calls an "ethic of care"), which far from applying abstract moral rules to particular cases, treats each case in terms of a host of considerations any or all of which may have some role in arriving at a judgment or an action.

By analyzing women's' responses to these dilemmas Gilligan (1982) identified two qualitatively different modes of moral reasoning which she characterizes as moral orientations of justice and care. She further hypothesized that these orientations are gender related, and suggested that different orientations might be grounded in different understandings of human relationships (Gilligan, 1982). Women, Gilligan argues, apply a contextual or "relational" problem-solving strategy to moral conflicts because they are disposed (generally) to perceive such conflicts in accordance with the "parameters of connection." Men, on the other hand, are more likely to apply a "logic" of rules and principles to the resolution of moral conflicts because they are disposed (generally) to perceive such conflicts in terms of justice and fairness.

Gilligan traces the origin of gender differences in moral reasoning to early socialization of girls and boys. In a manner not dissimilar from Piaget, she postulates that differential experience of social relationships may explain the origin of the differences she has observed between men and women's moral thinking (Gilligan, 1982 & 1987; Gilligan & Wiggins, 1987). In explicating these origins, Gilligan cites Nancy Chodorow's psychoanalytic account of how different developmental challenges produce qualitatively different gender identities for both girls and boys (see Chodorow, 1987 & 1989). Chodorow argues that girls, being of the same sex as their primary caretaker, do not need to sever their emotional attachment to their mothers in order to establish a secure gender identity since, according to Chodorow, "mothers tend to experience their daughters as more like, and continuous with themselves" (quoted in Gilligan, 1982, p. 7). The result is that girls "in identifying themselves as female, experience themselves as like their mothers, thus fusing the experience of attachment with the process of identity formation" (Gilligan, 1982, p. 7-8). On the other hand, since young boys are of the opposite sex of their primary caretaker they must sever or separate themselves from their emotional attachment to their mothers in order that their gender identity to be secured.

It seems then, that women's embeddedness in the culture of relationship suggests that attachment may be viewed as an intrinsic part of their developmental progression. That young boys need to differentiate and abstract themselves from the mother-child relationship, on the other hand, suggests a view of attachment as that-which-must-be-overcome in order to obtain full developmental maturity. The important point that Gilligan wishes to press is not just that women may have one less obstacle toward developmental maturity than have men, but, that a particular model of male development has been appropriated as the model of human development. The extent to which this development is rooted in Kohlberg's moral theory, Gilligan argues, is striking. This feminist reformulation suggests Kohlberg's characterization of fully mature "principled" moral reasoning as "impartial," "pre-emptive," "universalizable" favor the developmental challenges of the male gender.

GILLIGAN'S ACCOUNT OF RESOLVING MORAL CASES

Gilligan has described the goal of her research as providing a better specification of "the relationship between the understanding of moral problems and the strategies used in resolving them" (Gilligan & Attanucci, 1988, p. 224). Gilligan criticized Kohlberg's approach to moral problem-solving on the grounds that it "takes the mode of action for granted" (e.g., steal or not steal) and focuses solely on the sophistication of the action's (or inaction's) justification. Gilligan noticed that many of the women she interviewed take for granted only the "necessity for action" and then consider "what form it should take" (Gilligan, 1982, p. 31). When proper attention is paid to both of these modes of response, two different moral orientations come into focus. One orientation, Gilligan claims, displays a sophistication in understanding "the logic of justification," while the other is equally sophisticated in "understanding the nature of choice" (Gilligan, 1982, p. 31-32).

Gilligan follows Kohlberg in her understanding of the meaning of moral rules. Rules and principles are, for both, the sign or entrance requirement for understanding a moral conflict as a conflict of justice (Attanucci & Gilligan, 1988; Gilligan, 1982 & 1987; Kohlberg & Colby, 1987). For both, application of an abstract rule or principle indicates a deontic orientation of justice in the framing and resolution of moral conflicts. Concerning the issue of resolving moral cases, Gilligan certainly does not deny that women understand the use of rules or norms. Nor does she question the development of the concept of justice in their thinking. Rather, men and women differ, Gilligan suggests, in "their approach to conflict resolution – that is, [in] their use rather than their understanding of the logic of rules and justice" (Gilligan, 1987, p. 22). Gilligan notes that, although people are aware of both perspectives, they tend to adopt one or the other in defining and resolving moral conflict. Since moral judgments organize thinking about choice in difficult situations, the adoption of a single perspective may facilitate clarity of decision. But the wish for clarity may also imply a compelling human need for resolution or closure, especially in the face of decisions that give rise to discomfort or unease. Thus the search for clarity in seeing may blend with a search for justification, encouraging the position that there is one right or better way to think about moral problems.

Gilligan's challenge to Kohlberg's approach to resolving moral cases was not predicated on the use of a norm or rule in the adjudication of a moral conflict.[4] Rather, it is the reduction of mature moral problem-solving to include only "principled" or "rule-based" approaches that constitutes her objection. First, she argues that a care or "relational" moral reasoning strategy is as valid an orientation to resolving moral cases as the application of general, rules and abstract principles. Second, since women are more likely to articulate and frame moral conflicts using this moral "voice", the bias towards or against it is, at base, a gender bias. A rich

[4]It is not clear whether Gilligan would wish to claim that adopting a justice orientation represents a greater temptation to view moral dilemmas as having one right answer. Gilligan does express concern toward "the tendency to focus on one perspective and the wish for justification" (Gilligan, 1987, p. 20). Gilligan also recognizes the problem of neglecting justice issues when adopting the perspective of care (Gilligan, 1987).

body of empirical data was collected that is congruent with these claims (Gilligan & Attanucci, 1988; Johnston, 1988; Langdale, 1988; Lyons, 1983 & 1987).

However, other researchers have questioned the validity of Gilligan's two claims. For example, several researchers report that gender is an inconsistent predictor of moral reasoning (Pratt, Golding, Hunter & Sampson, 1988; Walker, 1989; Walker, DeVries & Treventhan, 1987). While past studies reported consistent gender differences in moral orientation in men and women's responses to self-chosen dilemmas (see above), when the context of these dilemmas were analyzed, it became clear that these differences reflected the content of the dilemma. Women are more likely to select dilemmas of a relational nature to discuss while men were more likely to choose dilemmas of an impersonal (nonrelational) character (Pratt, Golding, Hunter & Sampson, 1988; Walker, DeVries & Treventhan, 1987). These results suggest that Gilligan's claims may conflate two aspects of moral reasoning – content and reasoning.

Women may indeed focus on different content but the modes of thought used in planning action and in justifying courses of action may be the same as men. These problems also suggest that there may be conceptual inconsistencies with Gilligan's formulation as well. Specifically, we may question why use of a rule should indicate an orientation to see moral conflicts as problems of justice. Or, we might question why use of a narrative strategy should indicate a disposition to see conflicts in terms of "a web of relationships that is sustained by a process of communication" (Gilligan, 1982; p. 32). These lingering questions opened the door for broader, classical and neo-Kohlbergian conceptualizations of moral discourse.

RECENT TRENDS IN MORAL DEVELOPMENT: NEO-KOHLBERGIAN RESEARCH AND IMPLICATIONS FOR SOCIOSCIENTIFIC DISCOURSE

While Kohlberg provided educators and researchers interested in the area of moral reasoning and development with a rich conceptual basis to raise important questions about the nature of moral education, new questions emerged about the adequacy of the assumption that all one has to do to bring about changes in moral behavior was to induce changes in moral stages or structures. Questions also emerged about the distinction between reasoning about formal societal constructs (e.g. laws, duty, social institutions) and engaging in the resolution of differences among individuals via argumentation and discussion during face-to face interactions. The former deals with what Rest, Narvaez, Bebeau and Thoma (1999) term "macromorality" while the latter deals with issues of "micromorality." The difference can be likened to examining the ontological, epistemological and axiological (macro) traditions of a Kuhnian scientific paradigm shift and investigating the nature(s) of science among scientists as they struggle to make collective decisions while engaged in the everyday activity of science. Once this distinction is made, it opens up a more robust conceptualization of the complex relationship that exists in moral reasoning and action and has implications for decisions related to pedagogy. For example, researchers point out that the role of affect and emotions in moral functioning had been overlooked in past research and the particular realm of one's life (e.g. family, school, peers, workplace, intimate relationships) play a normative role in moral decision-making and character formation (Berkowitz, 1985; Nucci, 1989; Turiel, 1998; Zeidler & Schafer, 1984, Zeidler et al., 2002).

A cautionary note is in order here. Consideration of the factors identified above may not provide researchers and educators with a "complete" view of morality but rather a view that encompasses more facets of moral development that move beyond traditional Kohlbergian ideas of emphasizing content-free structure to the exclusion of these or other normative factors. Some of these factors have been recognized in what is referred to as the "Four-Component Model" by some in an attempt to synthesize more recent diverse literature in the area of moral development (Narvaez & Rest, 1995; Rest et al., 1999; Thoma, 1994a & 1994b). In this model, four psychological processes are understood to give rise to observable behavior and are identified as:

- Moral sensitivity (interpreting the situation, role taking how various actions would affect the parties concerned, imagining cause-effect chains of events, and being aware that there is amoral problem when it exists);
- Moral judgment (judging which action would be most justifiable in a moral sense);
- Moral motivation (the degree of commitment to taking the moral course of action, valuing moral values over other values, and taking personal responsibility for moral outcomes); and
- Moral character (persisting in a moral task, having courage, over-coming fatigue and temptations, and implementing subroutines that serve a moral goal). (Rest, et al., 1999, p. 101)

It is not coincidence that Figure 1 (see above), while not identical with Rest's model, subsumes the same factors (trends). Both views allow for the primacy of tacit knowledge in the process of making individual and socially constructed decision-making – a pivotal factor when understood in terms of scientific literacy and in the context of socioscientific decisions. It is also not serendipitous that more holistic representations of conventional and post conventional reasoning are found in more recent cross-cultural research (Snarey & Keljo, 1991) and in research on preconventional thought in early childhood (Killen, 1991).

In reviewing recent research in the area of moral issues related to psychology, philosophy and development, the realization that any one myopic view of morality falls short of depicting the complex multidimensional aspects of moral growth and education becomes evident (Berkowitz, 1997 & 1998; Lickona 1991; Nucci 1989; Rest, 1985; Rest et al., 1999; Walker, 1989; Walker et al., 1995). For example, Berkowitz (1997) presents an anatomy of a moral being – a tentative taxonomy of constituent 'organelles' that from a 'moral cell' as it were. These include moral behavior, moral character, moral values, moral reason, moral emotion, moral identity and meta-moral characteristics. While elements of the Rest's Four Component Model are clearly present (see above), Berkowitz's contention is that one must consider all these elements in order to attend to the moral education of the entire moral person. It is of interest to point out that the last element in the taxonomy (meta-moral characteristics) call attention to those characteristics of the moral person that may not be moral in themselves but act as catalysts (i.e. enabling factors) in the practice of moral behavior (e.g. empathy, emotions, practical reason, self-determination). It is not a stretch of the imagination to draw connections between these meta-moral factors and those related to scientific habits of mind and the nature of science (e.g. science involves open-mindedness, respecting others arguments, human creativity and imagination). These are important features to keep in mind while considering the role of moral reasoning and discourse on socio-scientific issues because they reflect core micromorality issues (see above).

Turiel (1998) offers a comprehensive review of research pertaining to many of the same micromorality issues but further stresses the importance of macromorality factors such as cultural content, the construction of moral judgments through social interactions, and reciprocal interactions between culture and context. These factors help to form the emotional attributions affiliated with socio-moral judgments. It is understood that the salient features regarding socioscientific issues perceived by someone during decision-making may be greatly impacted by emotional and cognitive conflicts due to varying degrees of ambiguities and contradictions inherent between culture and context.

LOOKING FORWARD TOWARDS THE PAST: CAN A CLASSICAL "VIRTUE-ETHIC" ACCOUNT PROVIDE MORE INCLUSIVE VIEWS OF MORALITY?

According to classical theory, the central or distinguishing feature of human action is that it is intentional. Intentional action is rational to the extent that it is responsive to reason. Intentional action is action undertaken for a reason, and reasons carry normative force when they support or explain actions as good or valuable in some aspect or to some degree. According to this classical view, reasons can be distinguished from rules by considering their role in practical rationality.

> The reasons for an action are considerations that count in favor of that action... That considerations which establish the disadvantages of the action… does not in the least show that the reasons [for the action] do not exist, nor does it show that the reasons are subject to an "exception". The original reason is still there. The inference drawn from it (that the action ought to be done) is still valid. The conflicting considerations merely state that there are conflicting reasons, that is, that there is also a sound inference to the conclusion that the act ought not to be done. Rules are different. Usually each rule is based on a number of reasons, and they reflect a judgment that within the scope of the rule those reasons defeat various, though not necessarily all, conflicting reasons. Rules are, metaphorically speaking, expressions of compromises, of judgments about the outcome of conflicts. (Raz, 1990, p. 187)

The contrast here is between reasons, which count for or against a particular action, and rules, which constitute practical solutions to moral conflicts. Rules are important to practical rationality primarily in their role as preformed decisions, i.e., as practical solutions to (moral) conflicts. Raz writes: "Having a rule is like deciding in advance what to do. When the occasion for action arises one does not have to reconsider the matter for one's mind is already made up. The rule is taken not merely as a reason for performing its norm act but also as resolving practical conflicts by excluding conflicting reasons" (Raz, 1990, p. 73). As compromises or generalizations of previous practical decisions they preempt the need for protracted deliberation in each particular case (Nussbaum, 1986; Raz, 1990 & 1986). Note that guidelines for research on human subjects, experimentation with animals, and the physician's creed, for example, are all forms of prescriptive rules in science and medicine.

Accepting the "exclusionary" quality in applying the rule in a particular case does not mean that the reasons that argue against performance of the action lose their force. There are no exceptions to reasons and, so, conflicting practical reasons need not be dismissed when the decision to act on the basis of a rule in undertaken. This point has important implications for contemporary theories of moral development and reasoning about socioscientific issues, as we will discuss below.

The classical understanding of the role of norms and rules in moral problem-solving is important for several reasons. First, it categorically denies that there is any important difference between different kinds of moral thinking; whether the distinction refers to the deontic justice and care orientations or the triadic distinction of domain theory –e.g., of distinct moral, social, and personal value domains (Turiel, 1998; Nucci, 2001). Moral agents act and make choices on the basis and balance of reason(s). There is no conceptual difference to be made between the knowledge needed to understand what morally matters to others and the knowledge we need to understand what is relevant to our own moral benefit. That is, acquiring practical or functional knowledge of our own valuable pursuits instructs us in the duties that we owe to others, just as being able to identify the duties we owe to others requires knowing what is necessary for living a meaningful life (Keefer, 1996). Second, classical theory provides a wider or more inclusive characterization of the moral domain. According to classical understanding, the moral domain pertains not only to duties owed to others but includes all that is needed to equip us to know, to desire, and to choose to do what is good or valuable. To know the good we must (already) have some experience in choosing it, consistently choosing the good requires that we know and desire the good.

THE CLASSICAL ACCOUNT OF RESOLVING MORAL CASES

The classical account of the use of rules in resolving moral cases provides an alternative explanation for Gilligan's proposal to link contextual or narrative reasoning to a substantive ethical orientation (i.e., the ethic of care). For example, Johnston (1988) found that subjects of both genders, who spontaneously adopt the justice perspective, nonetheless, tend to agree that the solution suggested by practitioners of the care orientation is the better solution. According to Gilligan this "raises a number of questions as to why and under what conditions a person may adopt a problem-solving strategy that he or she sees as not the best way to solve the problem" (Gilligan, 1987, p. 27). She concludes that the "demonstration that [subjects] know both orientations and can frame and solve problems in at least two different ways means that the choice of moral standpoint is an element of moral decision" (Gilligan, 1987, p. 27). The assumption Gilligan makes is that if there are different ways to frame and resolve moral dilemmas then there are different "structures" of moral thinking.

The classical view provides an explanation for these different ways to structure solutions to moral conflicts that is not based on the assumption of two different structures of moral thinking. Rules, which rule out other considerations, also have ceteris paribus (all things being equal) conditions, which may or may not be met. In the world of practical action one could argue that they are rarely (if ever) all met. If they are not, even exclusionary reasons may fail a challenge and fail to overrule these considerations (including in some cases, a lower order rule).[5] For example, these exclusions might include relevant facts and social knowledge that render an act supported by a prescriptive "ought" conclusion ineffectual or frustrated. A case in point, taken from Kohlberg's Heinz dilemma, is that although "life is to be valued over property" is treated as an exclusionary reason, the ceteris paribus conditions may not be met, that is, all things may not be considered equal in the particular case. This decision transforms the reasoning task into the problem of providing a solution in which certain values, otherwise threatened, are protected or preserved. For example, some subjects argue that if stealing the drug would only secure a single dose of the drug, or if Heinz were to get caught and imprisoned, then the exclusionary rule may not justify the conduct and other avenues ought to be sought. That is, a more protracted or narrative strategy is adopted that may be characterized as an indication of a care orientation to moral thinking. And at the core of socioscientific issues from a progressive stance is an acceptance of rhetoric and emotive consideration as legitimate avenues in exercising functional scientific literacy.

Extending the model of rules as exclusionary reasons to the issue of moral dilemmas, the "better solution" that deliberative subjects generate is explained by their refusal to accept the conflict as meeting the ceteris paribus conditions of any exclusionary rule or principle. Of course, using such a strategy avoids the need to choose between either "horns" of the dilemma. We can contrast this with a "justice" or deontic solution, which, in applying the norm or rule as decisive, ostensibly chooses between the horns of the dilemma, and focuses instead on the justification of one's choice. The fact that subjects, looking back on either of these two outcomes, express their preference for the first should not come as a surprise (Keefer & Olsen, 1995). It could be argued that, in a certain sense, such an outcome represents the only solution to the dilemma. While classical theory is in clear sympathy with the "Care" orientation's press for a more practical (as opposed to principled) approach to the resolution of moral cases, it provides a more inclusive account practical rationality that does not rely on a bifurcation of morality or the moral response.

CLASSICAL THEORY AND THE PRIORITY OF VALUES OVER PRINCIPLES

An exclusionary reason cannot provide an ultimate justification, Raz (1990) argues, but must be justified by appeal to more fundamental values. In classical theory, it is the value underlying the principle, rather than the principle itself, that provides the ultimate ground, or foundation for justification. This view of moral justification can be contrasted with the more deductive character of moral justifications outlined in Kohlberg's deontic perspective above:

> There may be some cases where such [deductive] judgments can seem to be justified by reference to a universal principle, but such judgments are few, and such justifications do not take account of the complexity of moral values. In most cases we justify a moral judgment by giving reasons for it, and the right way to arrive at a moral judgment is to consider the various factors in favour of or against the action. *In deciding what is the right action an agent deliberates by considering what his values are to be*, [italics

[5] For example, that you may break an oath of confidentiality in order to save a life is an exception (for some) to the rule to always uphold an oath.

> added] how they will apply, and even whether in the light of his assessment of the situation they need to be altered. (Milligan, 1980, p. 59)

How actions are understood as good or valuable derives from the value of the goal that is pursued and not the will or desires of the agent who pursues it. The fact that an action or behavior satisfies an agent's desire is not a reason for performing it; it is reason only that makes actions intelligible for practical deliberation and rational for us to perform. Classical theory is strongly committed to a value-centered as opposed to a hedonistic understanding of practical rationality. Close to a century of behaviorism makes this simple point both difficult to understand and difficult to grasp the extent of its radical implications.

Chief among implications most relevant to this volume is that the justification of moral actions in general and decisions concerning socioscientific issues in particular must rely on discussion, rhetoric, and argument concerning the normativity of different values. We have already outlined classical theory's defense of a more open-ended deliberative approach to moral cases. What we need to add here is to emphasize the use of classroom discourse regarding socioscientific issues, using what Raz calls "the long route" to moral justification, as a crucial additional ingredient of effective moral education. What is needed is a better understanding of the properties and discursive contexts best suited to accomplishing this goal (Keefer, Zeitz & Resnick, 2000; Zeidler, et al., 2002).

MORAL REASONING, DISCOURSE AND SOCIOSCIENTIFIC ISSUES

In this chapter it was proposed that in the process of realizing a functional view of scientific literacy, science educators must strive to convey Dewey's sense of progressive science education. Under this view, the pursuit of socioscientific issues becomes both process and product through social interactions and discourse. If science education is equated with a microcosm of society, then issues of inquiry, discourse, argumentation, decision-making (etc.) become a focal point for both development and instruction. The discussion of socioscientific issues will entail, at times, moral dilemma discussions. Teachers need not be experts at assessing moral development to effectively engage their students in interesting discourse. While real-life controversies provide authentic contexts for students to utilize more relevant curriculum materials as in STSE topics, the use of hypothetical dilemmas may also serve the purpose to activate moral schema, tap prior knowledge and facilitate moral reasoning (Berkowitz, 1996; Keefer & Ashley, 2001; Rest et al., 1999). Teachers who make decisions about the use of moral dilemma discussions can benefit from heterogeneity and diversity in their classrooms (consistent with science education reform goals) and understand that this undertaking is not an add-on model to an already overstuffed curriculum but part of a set of integrated strategies to be used throughout the academic year.

It is interesting to note the general developmental correspondence between transactive discussions (the extent to which one's reasoning influences that of another) and the dissonance one may experience when evidence is confronted that does not immediately fit into their past experiences. Transactive discussions evolve from naïve perspectives of egocentric thinking to mutually shaped understanding of social and physical phenomena. Berkowitz, Oser and Althof (1987, p. 337-339) outline a preliminary stage scheme for sociomoral discourse which reveals how discourse becomes better coordinated among individuals as they form more "mature" judgments:

Stage 0 Preargumentation – does not recognize a need for discourse. Idiosyncratic/irrelevant.

Stage 1 Single Reason Argumentation– isolated justifications, unconnected or loosely related arguments. Pragmatic argument to maintain chosen position

Stage 2 Maintaining Connections – exchange multiple justifications with some logical coherence, identify a central thesis, search for shared solution.

Stage 3 Counterevidence – use of counterevidence, attempts at falsification, defends against such strategies.

Stage 4 Shared Analysis – mutual discourse, each argument is critically examined and understood to be subject to counter argumentation. Reasoning about the argument.

Stage 5 Ideal Discourse – Discussants recognize that everyone in a discussion must strive toward the most just or best solution.

The parallel to how students cope with coordinating their prior knowledge with events, evidence and concepts that shape the physical world and how a student begins to align their reasoning with those of others as they progress through stages of sociomoral discourse is striking. Zeidler (1997) has noted that student' beliefs and convictions about moral, ethical, or personal opinions are similarly rigid as are their preinstructional beliefs about various scientific phenomena. How students react when anomalous data is presented in conflict with their own scientific beliefs and how students respond to different social, moral, and ethical beliefs held by others in conflict with their own convictions certainly overlap. However, subtle differences are also present. It may be one thing to evaluate the trustworthiness of different knowledge claims about scientific concepts and another to be influenced by normative ethical claims about socioscientific issues (Sadler, Chambers & Zeidler, in press; Zeidler et al., 2002).

Decision-making in real life settings has been equated with the "art of conflict resolution" between one's inner goals, others' goals, as well as confronting conflicts that entail which evidence should be considered for evaluation, and how to evaluate it (Svenson, 1996, p. 204). Science teachers may (erroneously) assume that students understand the empirical nature of evidence but recent research has demonstrated confusion among students in recognizing and interpreting data relative to socioscientific issues (Sadler, Chambers & Zeidler, in press). This finding is also consistent with Kolstø (2001b) who found students' decisions about empirical evidence while considering socioscientific topics to be mostly based on superficial contextual information. Nor can teachers assume students will automatically keep an "open mind" as they engage in discourse on socioscientific topics. Preliminary choices are often formed early in the decision process and like scientific misconceptions, may quickly become fixed and resistant to new information (Svenson, 1996).

Neo-Kohlbergian research has lead those concerned with moral reasoning to realize that simply possessing the reasoning competence to make decision consistent with available structure does not ensure performance at that level across all contexts. Kohlberg came to realize and accept this towards the end of his research (Colby & Kohlberg, 1987). Other researchers have confirmed the lack of coherence between the ability to form higher moral judgments and the likelihood of exercising that reasoning in varied contexts (Carbendale & Krebs, 1992; Wark & Krebs, 1996). With the keen interest in recent years of couching science in real world problems, this issue becomes increasingly important. As we have pointed out, socioscientific issues by their very nature occur in a world where the ceteris paribus conditions are unlikely to be met. Krebs, Denton and Wark (1997) and Sadler and Zeidler (in press) have revealed there are numerous normative factors that have been found to affect moral decision-making (e.g., type/context of dilemma; amount of probing and time for reflection; affective/ motivational states sense of moral identify; commitment to a decision). This is precisely the reason we have advocated for a "classical account" in conceptualizing moral education and resolving moral cases as this view is consistent with neo-Kohlbergian research allowing for broader conceptualization of moral domains. To that end, the contributing authors of this book have explored four broad themes relevant to a holistic view of moral domains as they pertain to education in general, and science education in particular: 1) Nature of Science Issues; 2) Classroom Discourse Issues; 3) Cultural Issues; and 4) Case-based and STSE Issues. There are three chapters for each of these themes, which offer the reader a variety of views related to issues of research and pedagogy. It is our hope that these works will help inspire others whom share our common conviction as to the importance of moral discourse in science education to further explore these topics and help transform the research base into practice.

REFERENCES

American Association for the Advancement of Science. (1989). *Science for all Americans*. Washington, D.C.: American Association for the Advancement of Science.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy: Project 2061*. New York, New York: Oxford University Press, Inc.

Aikenhead, G.S. (1992). The integration of STS into science education. *Theory into Practice, 31*(1), 27-35.

Aikenhead, G. S., Fleming, R. W., & Ryan, A. G. (1987). High school graduates' beliefs about science-technology-society: I. Methods and issues in monitoring student views. *Science Education, 71*(2), 145-161.

Baldwin, J. (1906). *Social and ethical interpretations in mental development*. New York: MacMillan.

Berkowitz, M. W.(1985). The role of discussion in moral education. In M. W. Berkowitz & F. Oser (Eds.), *Moral education: Theory and application* (p.197-218). Hillsdale, NJ: Lawrence Erlbaum Associates.

Berkowitz, M. W. (1987). The development of sociomoral discourse. In W. M. Kurtines & J. L. Gewirtz (Eds.), *Moral development through social interaction*. New York: J. Wiley & Sons.

Berkowitz, M. W. (1996). *The "plus one" convention revisited...and beyond.* Paper presented at the annual conference of the Association of Moral Education, Ottawa, Canada.

Berkowitz, M. W. (1997). The complete moral person: Anatomy and formation. In J. M. DuBois, (Ed.), *Moral issues in psychology: Personalist contributions to selected problems*. New York: University Press of America, Inc.

Berkowitz, M. W. (1998). Finding common ground to study and implement character education: Integrating structure and content in moral education. *Journal of Research in Education, 8*(1), 3-8.

Berkowitz, M. W., Oser, F. & Althof, W. (1987). The development of sociomoral discourse. In W.M. Kurtines & J.L. Gewirtz (Eds.), *Moral development through social interaction* (337-345). New York: J. Wiley.

Beyer, L. E. (1997). The moral contours of teacher education. *Journal of Teacher Education, 48*, 245-253.

Bybee, R. W., Powell, J. C., Ellis, J. D., Giese, J. R. Parisi, L., & Singleton, L. (1991). Integrating the history and nature of science and technology in science social studies curriculum: A rationale. *Science Education, 75*(1), 143-155.

Carpendale, J. I. & Krebs, D. L. (1992). Situational variation in moral judgment: In a stage or on a stage? *Journal of Youth and Adolescence, 21*, 203-224.

Chodorow, N. (1987). Feminism and difference: Gender, relation, and difference in psychoanalytic perspective. In M. Walsh (Ed.), *The psychology of woman* (p. 249-264). New Haven: Yale University Press.

Chodorow, N. (1989). *Feminism and psychoanalytic theory*. New Haven: Yale University Press. Cambridge: Polity Press.

Council of Ministers of Education Canada (CMEC) Pan Canadian Science Project. (1997). *Common framework of science learning outcomes: K-12*. [On-line]
Available: http://www.qscc.qld.edu.au/kla.sose.publications.html.

Colby, A. & Kohlberg, L. (1975). The relationship between the development of formal operations and moral judgment. In D. Bush and S. Feldman (Eds.), *Cognitive development and social development: Relationships and implications*. New York: Lawrence Erlbaum Associates.

Colby, A., & Kohlberg, L. (1987). *The measurement of moral judgment. Vol. 2: Standard issue scoring manual*. New York: Cambridge University Press.

Cummings, R., Dyas, L., Maddux, C.D. & Kochman, A. (2001). Principled moral reasoning and behavior of preservice teacher education students. *American Educational Research Journal, 38*(1), 143-158.

Dewey, J. (1930). *Experience and conduct*. In C. Murchison (Ed.), Psychologies of 1930. Worcester: Clark University Press.

Dewey, J. (1974). Science as subject-matter and as a method. In D. Archambault (Editor), *John Dewey on education* . Chicago, Illinois: University Chicago Press. [1910]

Dewey, J. (1978). *Moral principles in education*. Carbondale, IL: Southern Illinois University Press. [1909]

Flavell, J. H. (1971). Stage-related properties of concept development. *Cognitive Psychology, 2*, 421-453.

Flavell, J. H., Miller, P. H. & Miller, S. A. (1993). *Cognitive development*. Prentice Hall: Englewood Cliffs: NJ.

Gilligan, C. (1977). Woman's conceptions of self and morality. *Harvard Educational Review, 47*(4), 481-517.

Gilligan, C. (1982). *In a different voice: Psychological theory and women's development*. Cambridge: Harvard University Press.

Gilligan, C. & Attanucci, J. (1988). Two moral orientations: Gender differences and similarities. *Merrill-Palmer Quarterly, 34*, 223-237.

Gilligan, C., & Wiggins, G. (1987). The origin of morality in early childhood relationships. J. Kagan, & S. Lamb (Eds.), *The emergence of morality in young children* (p. 277-305*)*. Chicago: University of Chicago Press.

Goodrum, D., Hackling, M. & Rennie, L. (2001). *The status and quality of teaching and learning of science in Australian schools: A research report prepared for the Department of Education, Training and Youth Affairs* (DETYA) [Online] Available:
http://www.detya.gov.au/schools/Publications/reports/science/chap2.htm#2.2.1.

Hampshire, S. (1983). Fallacies in moral reasoning. In A. MacIntyre, & S. Hauerwas (Eds.), *Changing perspectives in moral philosophy*. Notre Dame, IN: Notre Dame University Press.

Johnston, K. (1988). Adolescents' solutions to dilemmas in fables: Two moral orientations - two problem solving strategies. In C. Gilligan, J. Ward, J. Taylor & B. Bardige (Eds.), *Mapping the moral domain*. Cambridge, MA: Harvard University Press.

Kant, I. (1970). The metaphysics of morals. In H. Reiss (Ed.), *Kant's political writings*. Cambridge: University Press.

Keasy, T., & Keasy, C. (1974), The mediation role of cognitive development in moral judgment. *Child Development, 45*, 291-298.

Keefer, M. W., (1996). The inseparability of morality and personal well being: The duty virtue debate in moral education - revisited. *The Journal of Moral Education, 25*(3), 277-290.

Keefer, M. W., & Ashley, K.D. (2001). Case-based approaches to professional ethics: A systematic comparison of students' and ethicists' moral reasoning. *The Journal of Moral Education, 30*(4*)* 377-398.

Keefer, M. W., Olson, D. (1995) Moral reasoning and moral concern: An alternative to Gilligan's gender based hypothesis. *Canadian Journal of Behavioral Sciences, 27*(4), 420-437.

Keefer, M. W., Zeitz, C.M., & Resnick, L.B (2000). Judging the quality of peer-led student dialogues. *Cognition and Instruction, 18*(1), 55-83.

Killen, M. (1991). Social and moral development in early childhood. In W. M. Kurtines & J. L. Gewirtz, (Eds*.), Handbook of moral behavior and development. Volume 2: Research* (p. 115-138). Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

Kohlberg, L. (1966). A cognitive developmental analysis of children's sex-role concepts and attitudes. In E. Maccoby (Ed.), *The development of sex differences*. Stanford, CA: Stanford University Press.

Kohlberg, L. (1968). Early education: A cognitive-developmental approach*. Child Development, 39*, 1013-1062.

Kohlberg, L. (1969a). *Stages in the development or moral thought and action*. New York: Holt, Rinehart & Winston.

Kohlberg, L. (1969b). The cognitive-developmental approach to socialization. In D.A. Goslin (Ed.), *Handbook of socialization theory and research*. Chicago: Rand-McNally.

Kohlberg, L. (1971). From is to ought: How to commit the naturalistic fallacy and get away with it in the study of moral development. In T. Mischel (Ed.), *Cognitive development and epistemology* (p. 151-232). New York, New York: Academic Press, Inc.

Kohlberg, L. (1973a). Implication of developmental psychology for education: Examples from moral development. *Educational Psychologist, 10*, 2-14.

Kohlberg, L. (1973b). The claim to moral adequacy of a highest stage of moral judgment. *The Journal of Philosophy, Vol. LXX*(18), 630-636.

Kohlberg, L. (1981*). The philosophy of moral development: Moral stages and the idea of justice*. San Francisco: Harper & Row Publishers, Volume 1.

Kohlberg, L. (1984). The psychology of moral development: The nature and validity of moral stages. In L. Kohlberg. (Ed.), *Essays on moral development: Vol. 2: The philosophy of moral development*. San Francisco: Harper & Row.

Kohlberg, L. (1985). The just community in theory and practice. In M. Berkowitz & F. Oser (Eds.), *Moral education*. Hillside, NJ: Erlbaum.

Kohlberg, L. (1986). A current statement on some theoretical issues. In S. Modgil & C. Modgil (Eds.), *Lawrence Kohlberg: Consensus and controversy* (p. 485-546). Philadelphia: The Falmer Press.

Kohlberg, L. (1987). The cognitive-developmental approach to moral development. In P. F. Carbone Jr. (Ed.), *Value theory and education* (p. 226-243). Malabar, Florida: Robert E. Krieger Publishing Company.

Kohlberg, L., Boyd, D. & Levine, C. (1990). The return of stage six: Its principle and moral point of view. In T. Wren (Ed.), *The moral domain: Essays in the ongoing discussion between philosophy and the social sciences* Cambridge, MA: MIT Press.

Kohlberg, L., & Candee, D. (1984). The relationship of moral judgment to moral action. In W. M. Kurtines, & J. L. Gewirtz (Eds.), *Morality, moral behavior and moral development*. New York: John Wiley and Sons.

Kohlberg, L. & Turiel, E. (1971). Moral development and moral education. In G. Lesser (Ed.), *Psychology and educational practice*. Glenview, IL, Scott Foresman & Company.

Kolstø , S. (2001a). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socioscientific issues. *Science Education, 85*(3), 291-310.

Kolstø. S. (2001b). "To trust or not to trust, …" - pupils' ways of judging information encountered in a socio-scientific issue. *International Journal of Science Education, 23*(9), 877-901.

Krebs, D. L., Denton, K. & Wark, G. (1997). The forms and functions of real-life moral decision-making. *Journal of Moral Education, 26*(2), 131-145.

Kuhn, D., Langer, J., Kohlberg, L., & Haan, N.S. (1977). The development of formal operations in logical and moral judgment. *Genetic Psychology Monographs, 95*, 97-188.

Kuhn, T. (1962) *The structure of scientific revolutions*. Chicago: Chicago University Press.

Lakatos, I. (1978) *The methodology of scientific research programmes*. New York: Cambridge University Press.

Langedale, S. (1988). Adolescents' solutions to dilemmas in fables: Two moral orientations - two problem solving strategies. In C. Gilligan, J. Ward, J. Taylor & B. Bardige (Eds.), *Mapping the moral domain*. Cambridge, MA Harvard University Press.

Lickona, T. (1976). Critical issues in the study of moral development and behavior. In T. Lickona (Ed.), *Moral development and behavior: Theory, research and social issues*. New York: Holt, Rinehart and Winston.

Lickona, T. (1991). *Educating for character*. New York: Bantam.

Loevinger, J. (1966). The meaning and measurement of ego development. *American Psychologist, 21*, 195-217.

Lyons, N. (1982). *Conceptions of self and morality and modes of moral choice: Identifying justice and care in judgments of actual moral dilemmas*. Unpublished doctoral dissertation, Harvard University, Cambridge MA.

Lyons, N. (1983). Two perspectives: On self relationships and morality. *Harvard Education Review, 53*(2), 125-45.

Lyons, N. (1987). Ways of knowing, learning and making choices. *Journal of Moral Education, 16*(3), 226-239.

Mead, G.H. (1934). *Mind, self and society*. Chicago: University of Chicago Press.

Millar, R. & Osborne, J. (Eds.), (1998). *Beyond 2000: Science education for the future*. London: King's College School of Education.

Milligan, D. (1980) *Reasoning and the explanation of actions*. Atlantic Highlands NJ: Humanities Press.

Narvaez, D. & Rest, J. (1995). The four components of acting morally. In W. Kurtines & J. Gewirtz (Eds.), *Moral behavior and moral development: An introduction* (p. 385-400). New York: McGraw-Hill.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academic Press.

Nucci, L. P. (1989). Challenging conventional wisdom about morality: The domain approach to values education. In L. P. Nucci (Ed.), *Moral development and character education* (p. 183-203). Berkeley, CA: McCutchan Publishing Corporation.

Nucci, L. P., (2001) *Education in the moral domain*. Cambridge: Cambridge University Press.

Nussbaum, M. (1986). *The fragility of goodness: Luck and ethics in Greek tragedy and philosophy*. Cambridge: Cambridge University Press.

Pedretti, E. (1997). Septic tank crisis: A case study of science, technology and society education in an elementary school. *International Journal of Science Education, 19*(10), 1211-1230.

Pedretti, E. (1999). Decision-making and STS education: Exploring scientific knowledge and social responsibility in schools and science centres through an issues-based approach. *School Science and Mathematics, 99*(4), 174-181.

Pedretti, E. (2001*). Teaching through science, technology, society and environment (STSE) education: Pre-service teachers' delights and dilemmas*. Paper presented at the National Association for Research in Science Teaching, St. Louis, MO.

Piaget J. (1965). *The moral judgment of the child* (M. Gabain, Trans.). Glencoe, Il: New York: Free Press (originally published in 1932).

Piaget, J. (1960). The general problems of the psychological development of the child. In F.M. Tanner and Barbel Inhelder (Eds.), *Discussion on Child Development, Volume IV. The Fourth Meeting of the World Health Organization Study Group* on the Psychobiological Develop of the Child (3-27). Geneva, 1956. London: Faristock Publication.

Pratt, M. W., Golding, G., Hunter, W., & Sampson, R. (1988). Sex differences in adult moral orientations. *Journal of Personality, 56*, 373-391.

Queensland School Curriculum Council (QSCC) (2001). *Studies of society and environment*. [On-line]. Available:http://www.cmec.ca/science/framework/index.htm.

Radcliffe, M. (1997). Pupil decision-making about socioscientific issues within the science curriculum. *International Journal of Science Education, 19*(2), 167-182.

Rawls, J. (1963). The sense of justice. *Philosophical Review, 72*(3), 281-305.

Rawls, J. (1971*). A theory of justice*. Cambridge: Harvard University Press.

Raz, J. (1990). *Practical reason and norms*. Princeton, NJ: Princeton University Press.

Raz, J. (1986). *The moral of freedom*. Oxford: Clarendon Press.

Raz, J. (1998). *Engaging reason: On the theory of value and action*. Oxford: Clarendon Press.

Rest, J. (1985). An interdisciplinary approach to moral education. In M.W. Berkowitz & F. Oser (Eds.), *Moral education: Theory and application* (p. 9-25). Hillsdale, NJ: Lawrence Erlbaum Associates.

Rest, J., Narvaez, Bebeau, M. J., & Thoma, S. J. (1999). *Postconventional moral thinking: A neo-Kohlbergian approach*. Mahwah, New Jersey: Lawrence Erlbaum Associates.

Sabar, N. (1979). Science, curriculum, and society: Trends in science curriculum. *Science Education, 63*(2), 257-268.

Sadler, T. D., Chambers, W. F. , & Zeidler, D.L. (in press). Student conceptualizations of the nature of science in responses to a socioscientific issue. *International Journal of Science Education.*

Sadler, T. D. & Zeidler, D.L. (in press). The morality of socioscientific issues: Construal and resolutions of genetic engineering dilemmas. *Science Education*.

Snarey, J. & Keljo, K. (1991). In a gemeinschaft voice: The cross-cultural expansion of moral development theory. In William M. Kurtines & Gewirtz, J.L. (Eds*.), Handbook of moral behavior and development. Volume 1: Theory* (p. 395-422). Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

Solomon, J. & Aikenhead, G. (1994). *STS education: International perspectives in reform*. New York: Teachers' College Press.

Svenson, O. (1996). Decision making and the search for fundamental psychological regularities: What can be learned from a process perspective? *Organizational Behavior and Human Decision Processes, 65*(3), 252-267.

Thoma, S. J. (1994a). Moral judgment and moral action. In J. Rest & D. Narvaez (Eds.), *Moral development in the professions: Psychology and applied ethics* (p. 199-211). Hillsdale, HJ: Lawrence Erlbaum Associates.

Thoma, S. J. (1994b). Trends and issues in moral judgment research using the Defining Issues Test. *Moral Education Forum, 19*, 27-39.

Turiel, E. (1998). The development of morality. In W. Damon & N. Eisenberg (Eds.), *Handbook of child psychology* (p. 863-932). New York: John Wiley & Sons, Inc.

Wark, G. & Krebs, D.L. (1996). Gender and dilemma differences in real-life moral judgment. *Developmental Psychology, 32*, 220-230.

Walker, L., (1989). A longitudinal study of moral reasoning. *Child Development, 60*, 157-166.

Walker, L., J., Pitts, R.C., Henning, K.H., Matsuba, M.K. (1995). Reasoning about morality and real-life moral problems. In M. Killen & D.Hart (Eds,), *Morality in everyday life* (p. 371-408). New York: Cambridge University Press.

Walker, L., de Vries, B., & Trevethan, S. (1987). Moral stages and moral orientation. *Child Development, 58,* 842-858.

Yager, R. & Lutz, M. (1995). STS to enhance total curriculum. *School Science and Mathematics, 95*(1), 28-35.

Zeidler, D.L. (1984). Moral issues and social policy in science education: Closing the literacy gap. *Science Education, 68*(4), 411-419.

Zeidler, D. (1985). Hierarchial relationships among formal cognitive structures and their relationship to principled moral reasoning. *Journal of Research in Science Teaching, 22*(5), 461-471.

Zeidler, D. L. (1997). The central role of fallacious thinking in science education. *Science Education, 81*(1), 483-495.

Zeidler, D. L. (2001). Participating in program development: Standard F. In D. Siebert & W. McIntosh (Eds.), *College pathways to the science education standards* (p. 18-22). Arlington, VA : National Science Teachers Press.

Zeidler, D. L. & Schafer, L.E. (1984). Identifying mediating factors of moral reasoning in science education. *Journal of Research in Science Teaching, 21*(1), 1-15.

Zeidler, D. L., Walker, K. A., Ackett, W. A., & Simmons, M. L. (2002). Tangled up in views: Beliefs in the nature of science and responses to socioscientific dilemmas, *Science Education* 86,343-367.

APPENDIX A

THE SIX MORAL STAGES

Level and Stage	**What is Right**	**Reasons for Doing Right**	**Social Perspective of Stage**
LEVEL 1 – PRECONVENTIONAL			
Stage 1 – Heteronomous Morality	To avoid breaking rules backed by punishment: obedience for its own sake, and avoiding physical damage to persons and property.	Avoidance of punishment, and the superior power of authorities.	Egocentric point of view. Doesn't consider the interests of others or recognize that they differ from the actor's; doesn't relate two points of view. Actions are considered physically rather that in terms of psychological interests of others. Confusion of authority's perspective with one's own.
Stage 2 – Individualism, Instrumental Propose, and Exchange	Following rules only when it is to someone's immediate interest; acting to meet one's own interests and needs and letting others do the same. Right is also what's fair, what's an equal exchange, a deal, an agreement.	To serve one's own needs or interests in a world where you have to recognize that other people have their interests, too.	Concrete individualistic perspective. Aware that everybody has his own interest to pursue and these conflict, so that right is relative (in the concrete individualistic sense).

Level and Stage	What is Right	Reasons for Doing Right	Social Perspective of Stage
LEVEL II – CONVENTIONAL			
Stage 3 – Mutual Interpersonal Expectations, relationships, and Interpersonal conformity	Living up to what is expected by people close to you or what people generally expect of people in your role as son, brother, friend, etc. "Being good" is important and means having good motives, showing concern about others. It also means keeping mutual relationships such as trust, loyalty, respect and gratitude.	The need to be a good person in your own eye and those of others. You're caring for others. Belief in the Golden Rule. Desire to maintain rules and authority, which support stereotypical good behavior.	Perspective of the individual in relationships with other individuals. Aware of shared feelings, agreements, and expectations, which take primacy over individual interests, Relates points of view through the concrete
Stage 4 – Social System and Conscience	Fulfilling the actual duties to which you have agreed. Laws are to be upheld except in extreme cases where they conflict with other fixed social duties. Right is also contributing to society, the group, or institution.	To keep the institution going as a whole, to avoid the breakdown in the system "if everyone did it," or the imperative of conscience to meet one's defined obligations (Easily confused with Stage 3 belief in rules and authority; see text).	Golden Rule, putting yourself in the other guy's shoes. Does not yet consider generalized system perspective.

Level and Stage	What is Right	Reasons for Doing Right	Social Perspective of Stage
LEVEL III – POST-CONVENTIONAL, or PRINCIPLED			
Stage 5 – social Contract or Utility and Individual Rights	Being aware that people hold a variety of values and opinions that most values and rules are relative to your group. These relative rules should usually be upheld, however, in the interest of impartiality and because they are the social contract. Some non-relative values like life and liberty, however, must be upheld in any society and regardless of majority opinion.	A sense of obligation to law because of one's social contract to make and abide by lows for the welfare of all and for the protection of all people's rights. A feeling of contractual commitment, freely entered upon, to family, friendship, trust, and work obligations. Concern that laws and duties be based on rational calculation of overall utility, "the greatest good for the greatest number."	Differentiates societal point of view from interpersonal agreement or motives. Takes the point of view of the system that defines roles and rules. Considers individual relations in terms of place in the system.

Level and Stage	What is Right	Reasons for Doing Right	Social Perspective of Stage
LEVEL III – POST-CONVENTIONAL, or PRINCIPLED (continued)			
Stage 6 – Universal Ethical Principles	Following self-chosen ethical principles. Particular laws or social agreements are usually valid because they rest on such principles. When laws violate these principles, one acts in accordance with the principle. Principles are universal principles of justice; the equality of human rights and respect for the dignity of human beings as individual beings as individual persons.	The belief as a rational person in the validity of universal moral principles, and a sense of personal commitment to them.	Prior-to-society perspective. Perspective of a rational individual aware of values and rights prior to social attachments and contracts. Integrates perspectives by formal mechanisms of agreement, contract, objective impartiality, and due process. Considers moral and legal points of view, recognizes that they sometimes conflict and finds it difficult to integrate them. Perspective of a moral point of view from which social arrangements derive. Perspective is that of any rational individual recognizing the nature of morality or the fact that persons are ends in themselves and must be treated as such. Note: From Kohlberg (1986, pp 488-9)

SECTION II: NATURE OF SCIENCE ISSUES

Chapter 2

SOCIOSCIENTIFIC ISSUES IN PRE-COLLEGE SCIENCE CLASSROOMS

The Primacy of Learners' Epistemological Orientations and Views of Nature of Science

FOUAD ABD-EL-KHALICK

INTRODUCTION

Scientific literacy is a complex, multidimensional construct that lies at the heart of recent national reform documents in science education (e.g., American Association for the Advancement of Science [AAAS], 1990, 1993; Council of Ministers of Education Canada (CMEC) Pan-Canadian Science Project, 1997; Millar and Osborne, 1998; National Research Council [NRC], 1996). Conceptualizing scientific literacy and delineating the specific understandings, ways of thinking, skills, and attitudes that are necessary for preparing a scientifically literate populace are, to say the least, challenging undertakings (see for e.g., DeBoer, 2000; Hurd, 1998; Laugksch, 2000). Nonetheless, the aforementioned reform documents seem to be in agreement about some general components, which are deemed central to scientific literacy. Zeidler and Keefer (this volume) highlighted one of these common components, namely, the need to address the social functions of science in any conceptualization of functional scientific literacy. They further identified, and rightly so, the ability to make informed decisions regarding science-related personal and societal issues as a significant component and outcome of scientific literacy.

To provide students with opportunities to engage in, and practice, this kind of “messy” decision-making, Zeidler and Keefer (this volume) argued for the inclusion of controversial socioscientific issues in an interdisciplinary science curriculum (see also Kolstø, 2001). The authors, nonetheless, were quick to point out that bringing

D.L. Zeidler (ed.),
The Role of Moral Reasoning on Socioscientific Issues and Discourse in Science Education, 41-61.

socioscientific issues into the science classroom entails factoring in issues, such as ethical and moral considerations, and engaging in practices, such as the construction of reasoned arguments and moral judgments through social interaction, which are not typically part of the considerations, practices, and social discourse characteristic of the overwhelming majority of pre-college science classrooms. While necessarily challenging at the theoretical, curricular, pedagogical, and instructional levels, efforts directed toward transforming the science classroom into a "social microcosm," to use Zeidler and Keefer's terms, that promotes the holistic development of learners at the cognitive, social, moral, ethical, and emotional levels are surely a worthwhile undertaking. From an educational research perspective, Zeidler and Keefer continued, the actualization of such a vision for science education necessitates the exploration of issues related to nature of science (NOS), classroom discourse, culture, and case-based and science-technology-society-and-environment (STSE) issues. The authors also invoked several developmental schemes – including moral, cognitive, and discourse development, and their interactions with the aforementioned issues as plausible entry points for developing a research programme that would shed light on the complexities associated with creating and sustaining science classrooms in which the sort of teaching and learning portrayed here would come to fruition in helping students achieve a functional form of scientific literacy.

The present chapter aims to explore the relationship between making informed decisions regarding socioscientific issues and possessing informed views of NOS; the latter being another agreed-upon and central component of scientific literacy (AAAS, 1990; NRC, 1996). In exploring this relationship I will argue that it would be fruitful to reconsider conceptualizations of NOS in current reform and research efforts. At the reforms level, there is a need to address what seems to be the vestiges of the long-standing distinction between the context of discovery and context of justification, which while admitting personal and social factors into the production of scientific knowledge (e.g., intuition, creativity) still portrays decision-making regarding the justification of such knowledge as rather unproblematic (e.g., rational social discourse). At the level of empirical research, there is a need to supplement thinking about NOS from an "aspects" perspective (e.g., inferential, tentative, empirical, and creative NOS) with a consideration of learners' and science teachers' underlying global and scientific epistemological orientations. All this will lead me to argue that the framework developed by Zeidler and Keefer (see Figure 1, this volume) needs to incorporate "epistemological development" as another central axis in addition to moral, cognitive, and discourse development, in order to fruitfully guide the sort of empirical research needed to understand the complexities related to bringing socioscientific issues into the pre-college science classroom.

Before proceeding along the above-outlined lines, a significant question should be asked: Are students' and teachers' epistemological perspectives and views of NOS even relevant to meaningful discussions of socioscientific issues in the classroom? The answer is a straightforward "yes." To illustrate how the two aspects are related, I will refer to a couple of vignettes derived from my research into students' and teachers' views of NOS.

SOCIOSCIENTIFIC ISSUES IN THE CLASSROOM: COMPARTMENTALIZING AND DISMISSING THE DISCOURSE

Science interfaces and interacts with other domains of human activity and thought including the technological, economical, social, cultural, and religious spheres. This multifaceted reciprocity brings about a host of personal and societal issues, which often require a response from individuals in the form of decision-making. Decisions could take the form of making personal choices, such as avoiding the consumption of certain foods with the aim of minimizing one's daily fat intake, or engaging in political public discourse, such as campaigning against the production and/or sale of genetically manufactured foods. Socioscientific issues are markedly different from the sort of end-of-chapter-problems that are usually addressed in science classrooms. These latter problems are usually fully defined, driven by available and focused disciplinary knowledge, algorithmic, and objectively oriented. Engaging the "right" procedure(s) often results in a single right/wrong answer. By comparison, socio-scientific problems are ill defined, multidisciplinary, heuristic, value-laden (invoking aesthetic, ecological, economic, moral, educational, cultural, religious, and recreational values), and constrained by missing knowledge (Chiappetta, Koballa, & Collette, 1998). Engaging the problem most likely would lead to several alternative "solutions" each with an incomplete set of burdens and benefits. Next, an *informed* decision (including not making one) is made. However, given the lack of any algorithms to go about weighing the identified burdens and benefits, a decision regarding socioscientific issues necessarily involves a *judgment call*, which could be an agonizing undertaking. As Zeidler and Keefer (this volume) noted, "in the real world of dirty sinks, and messy reasoning, arriving at... decisions through objective evaluation of neutral evidence is a phantom image" (p. 2).

By bringing socioscientific issues into the science classroom, science educators hope to engage learners in the sort of "real world" problem-solving in which scientific knowledge and ways of thinking are brought to bear on discussing, and making decisions regarding, issues that are immediately relevant to students' lives. It could be seen that such an undertaking would at once allow science educators to achieve several desired goals and outcomes (helping students appreciate the relevancy and social functions of science, engaging students in decision-making and problem-solving, etc.). But would students draw on science to engage socioscientific issues? If yes, how would they use the knowledge and skills they acquire in science classrooms for that purpose? Would science teachers react favorably to incorporating socioscientific issues in their curriculum? Would teachers use such issues as organizing themes to guide their teaching and instructional practices? The answer to each of these questions, I believe, depends to a significant extent on answers to another question: What are those students' and science teachers' epistemological orientations and views of NOS?

In a recent study (Abd-El-Khalick, 2001), I assessed the impact of an explicit, activity-based, reflective NOS instructional approach on elementary teachers views' of the scientific enterprise. NOS instruction was embedded in a physics course for elementary teachers taught by the author. Most of the participants were in their freshman year in college and, thus, were very similar to senior high school students. The *Views of nature of Science Questionnaire–Form C* (VNOS–C) (Abd-El-

Khalick, Lederman, Bell, & Schwartz, 2001; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) was used to assess changes in participants' views of certain *aspects* of NOS. Data analyses indicated that many participants abandoned a pre-instruction scientistic view of NOS, which portrays science as an inductive enterprise in which prescribed methods are strictly followed to objectively generate absolute claims about the natural world. At the conclusion of the study, the majority of participants elucidated more informed views of several target aspects of NOS, such as the tentative, empirical, inferential, and imaginative and creative NOS, and the distinction between scientific theories and laws. During the exit interviews, participants were presented with a hypothetical scenario, which qualifies as a socioscientific issue: The government, they were told, was planning to construct a nuclear reactor near their city. Backed-up by the support of an impressive number of expert scientists, authorities presented evidence indicating that the reactor is a safe and environmentally "clean" alternative to traditional means of generating power. However, environmental activists presented evidence garnered by some scientists to discredit these assertions. As such, the government decided to poll the public before making a final decision. Interviewees were asked, "What would you vote for and why?"

Without exception, the interviewees approached the problem with an initial attempt to ascertain whether the reactor would be "100% safe." When reminded about the tentative nature of scientific claims and the implausibility of achieving definite knowledge, a notion that these students seemed to have internalized, all interviewees chose to disregard weighing in the evidence put forth by expert scientists and voted against constructing the reactor:

> S: I would definitely not construct the reactor.
>
> R: Why?
>
> S: Because it has at least 1% danger. I will keep on testing it several times till I am sure that it is safe.
>
> R: But how will you know that you will get a "sure" answer?
>
> S: I don't know, I will continue trying till I get there… Well, that's the problem, that's what is bothering me. We can't have definite answers in science. All those scientists could just be wrong and we could have a disaster.

None of the interviewees attempted to engage in the sort of reasoning called for in the reform documents (e.g., AAAS, 1990). For instance, they did not attempt to elicit information about what scientists, economists, or environmentalists had to say about the short and long-term benefits and hazards associated with burning fossil fuels versus using nuclear energy.

Further probing indicated that these participants abandoned a scientistic view of science only to adopt a "naïve relativistic" one. The shift from an absolutist scientistic view may be explained, in part, as a result of these participants internalizing that although durable, scientific knowledge is also tentative and never absolute, and that such knowledge is theory-laden and impregnated with "subjective" human elements. However, these very realizations seem to have shifted participants at a deeper epistemological level to an "anything goes" stance. When asked how they felt about the fact that science is not absolute and does not provide definite answers, interviewees indicated that they were "confused" and, as one interviewee put it, felt they were "used:"

> S: I used to think that science is something stable, fixed and it doesn't change. But if you really look into it, many things in it change. It is not fixed… So I don't know to what limit we can say that science is stable the way I learned it.
>
> R: How does this make you feel?
>
> S: Used.
>
> R: Can you explain?
>
> S: You don't want to learn about something and then within a short period relative to your life learn the opposite. It is kind of confusing.

Participants' frustration was aggravated by intolerance for ambiguity. For them, having several possible answers was confusing because one would "not feel conformable about this [controversy] because you read this whole paper saying one thing and another saying another… They [scientists] have to make up their minds." Moreover, even though these participants realized that scientists are "subjective" in the sense that their theoretical commitments, training, and backgrounds influence their interpretations and explanations of data, they "wished" that scientists could be "objective:"

> S: If you have something in mind, always the person whatever he wants to find, he will look for. He will be blind to something else. And even when experimenting, the fact that he is looking for something, will make him look for it [to]… get what he wants.
>
> R: Does this bother you?
>
> S: Yes, but you cannot do anything about it. But it bothers me because when they have to explain things to us they won't do it objectively and they know they are scientists and they should be objective.
>
> R: But you said earlier they cannot be totally objective because they are human?
>
> S: Yes, but I don't know, I hope it can be done.
>
> R: How does it make you feel?
>
> S: I think it makes feel confused because I don't have anything to rely on fully. I wish that they could be more objective so that I would feel more at ease.

This shift in participants' epistemological orientation from "dualism" and "scientism" to "naïve relativism" was expected: It was generally consistent with Perry's (1970 & 1981) scheme for epistemological development during the college years. The shift was also desirable because it seems to be a necessary precursor to internalizing more committed views of relativism in which knowledge claims are perceived to be constructed by social agents working within a critical inquiry framework. Moreover, within such framework, any and all knowledge claims are *not* equally plausible and valid; adjudication between knowledge claims is possible. This latter epistemological orientation, which I believe could be achieved at varying levels of sophistication and depth, seems to be pre- or co-requisite to the sort of discourse revolving around socioscientific issues sought in the aforementioned reform efforts.

If learners ascribe, for instance, to a scientistic and dualistic epistemology in which science is perceived as an objective enterprise concerned with absolute right/wrong answers, they might tend, at best, to compartmentalize their knowledge: Scientific knowledge is not applicable to situations, such as those invoked in socioscientific issues, where a single answer is not tenable. At worst, learners might even become hostile to science or feel betrayed in light of the fact that the perceived exactness of science failed them when they needed it most, that is, in helping them make decisions regarding science-related issues that have immediate and sometimes grave consequences for their own lives. I believe that Millar and Osborne (1998) were right on the mark when they noted that science education should help future citizens develop accurate understandings of NOS in order to avoid ending up with an acquiescent, hostile, or suspicious public, "but one with a broad understanding of major scientific ideas who, whilst appreciating the value of science and its contribution to our culture, can engage critically with issues and arguments which involve scientific knowledge" (p. 2004). Unfortunately, a long-standing line of research into pre-college students' views of NOS indicates that the greater majority of students still harbor the sort of naïve views of science (see e.g., Duschl, 1990; Lederman, 1992; Ryan & Aikenhead, 1992) that would hinder engagement in critical discourse regarding socioscientific issues. Pre-college students generally ascribe to a scientistic and unproblematic epistemology. For instance, they ascribe to a naïve inductive view of generating scientific knowledge, believe that scientific claims are "proven true" by the accumulation of supporting evidence and thus not liable to change, and perceive scientists to be disinterested, objective agents who follow a prescribed universal Scientific Method with the aim of "discovering" natural laws (e.g., Griffiths & Barman, 1995; Horner & Rubba, 1978; Larochelle & Desautels, 1991; Lederman & O'Malley, 1990; Mackay, 1971).

By the same token, if students harbor naïve relativistic views of science, they most likely will dismiss scientific knowledge as irrelevant to decision-making regarding socioscientific issues because human agents would simply distort whatever knowledge claims available to them for the purpose of supporting a predetermined point of view on the issue at hand. Zeidler, Walker, Ackett, and Simmons (2002) were able to confirm this conjecture in their research on how college students conceptualized and reasoned about socioscientific issues. This was also found to be the case with the participants in Abd-El-Khalick's (2001) study. The reader is reminded that these latter participants elucidated informed views of some significant aspects of NOS. Nonetheless, their overarching framework for science was still incompatible with engaging in critical discourse on controversial science-related issues (this point will be explored further below). The above observations could help, at least partially, explain why students in Kolstø's (2001) and similar studies often invoked superficial and contextual factors while considering socioscientific topics rather than factoring in available scientific claims and resources.

Arguments similar to the ones made above could as well be replicated in the case of science teachers. Research also has consistently shown that science teachers harbor naïve views of NOS and ascribe to epistemological orientations that are not markedly different from those of their students (Abd-El-Khalick & Lederman, 2000a). Additionally, our research into science teachers' NOS views and how such views impact their instructional practices related to NOS (e.g., Abd-El-Khalick, Bell, & Lederman, 1998; Bell, Lederman, & Abd-El-Khalick, 2000), shed light on other considerations that need to be factored in if teachers are to seriously entertain the challenge of bringing ill-defined, controversial issues into their classrooms. To start with, even though our participant preservice secondary science teachers explicated informed views of several aspects of NOS following targeted instruction, these understandings did not translate into actual instructional practices during their student teaching: Our participants simply did not teach about NOS in their classrooms. They explicated several factors to account for this incongruency including (perceived or actual) comfort with their own understandings of NOS, time constraints, pressure to "cover" content, accountability toward what "gets tested," supervisors' priorities, and student interest and ability. These contextual and situational factors are obviously significant and deserve careful attention when attempting to introduce socioscientific issues, which by virtue of their messiness and open-endedness I take to be very similar to NOS issues, into the science curriculum.

However, in a recent study that assessed the influence of a philosophy of science course on prospective secondary science teachers' views of the scientific enterprise and teaching about NOS (Abd-El-Khalick, 2002a), another significant factor came into light. At the conclusion of the study, participants seemed to have internalized sophisticated views of several target NOS aspects. Yet, in their reflection papers many noted that they are not likely to address NOS instructionally in their future classrooms. The reasons cited for such a decision were somewhat similar to the ones listed above. In addition, some prospective teachers expressed the concern that their authority as classroom teachers would be compromised – and consequently their ability to manage their students, if they were to present science as a less-than-certain endeavor. As one participant put it:

> Imagine teaching a class where you have to say "This is a law, now a law is not necessarily something that should be true all the time, because it could potentially be changed." How are you ever going to get the students' attention or have them do all the work if you say science is not a sure thing?

It is conceivable that science teachers might react in a similar fashion to the prospect of addressing socioscientific issues in their teaching. After all, by their very nature, socioscientific issues will leave the teacher with less "sure things" to teach about, which could be perceived as a threat to their authority and ability to teach. Again, as the above quote suggests, epistemological orientations regarding scientific knowledge and how students learn come into the picture. It can thus be concluded that efforts to use socioscientific issues as organizing themes for teaching and learning in pre-college science classrooms are bound to come in friction with students' and science teachers' epistemological orientations and views of NOS.

As such, helping students and science teachers internalize more informed views of NOS *might* be one of the essential goals that seem to be pre- or co-requisite to insuring the viability of classroom discourse and social interaction of the sort espoused by the efforts to include socioscientific issues in the life of science classrooms. This objective has been emphasized in recent reform documents in science education (e.g., AAAS, 1990 & 1993; Millar & Osborne, 1998; NRC, 1996). Indeed, much research and development efforts have been devoted to achieving this objective. For comprehensive reviews of the efforts undertaken to enhance pre-college students' and science teachers' NOS views, the reader is referred to Lederman (1992) and Abd-El-Khalick and Lederman (2000a) respectively. However, I believe that much is still to be desired in this regard. The following two sections focus on two domains that might pave the way toward more fruitful research and development efforts that would contribute to the actualization of the vision for science education presented by Zeidler and Keefer (this volume).

REVISING THE LANGUAGE OF THE REFORM DOCUMENTS ON NOS: "MESSY" DECISIONS AS PART OF SCIENCE "PROPER"

The "messiness" of decision-making regarding socioscientific issues is well recognized (e.g., Pedretti, 1999; Zeidler & Keefer, this volume). By-and-large this "messiness" is perceived to result from utilizing scientific knowledge and ways of thinking to confront "real" science-related everyday life problems. The argument goes something like this: Ask scientists which of two ways is more efficient to synthesize a certain derivative of benzene given a limited number of parameters, and you are likely to receive a fairly straightforward answer with a high degree of confidence attached to it. However, when confronting issues of public concern, "scientists can seldom bring definitive answers… Some issues are too complex to fit within the current scope of science, or there may be little reliable information available, or the values involved may lie outside of science" (AAAS, 1990, p. 11). As such, scientists can only assume advisory roles; they bring in "information, insights, and analytical skills to bear on matters of public concern… help the public and its representatives to understand the likely causes of events… [and] estimate the possible effects of projected policies" (AAAS, 1990, p. 11). Science can inform decisions regarding public policy. Yet, the actual decision, such as choosing between two alternative energy policies, will necessarily involve a judgment call that is often influenced by a host of factors including the values of the various players.

The above account is not without merit. After all, scientific laboratories are designed to be controlled environments where scientists shave a host of variables off of complex natural phenomena. In that sense, a scientist's laboratory is markedly different from everyday life settings. However, what is troubling about this account is not what is said, but rather what is not said and strongly implied; namely, that decisions regarding scientific issues proper are somewhat genuinely different (e.g., more straightforward or procedural, and value-free) than ones related to everyday life science-related personal or societal issues. A perceived difference in terms of the *kind* of decisions often made in science and ones that have to be made when confronting socioscientific issues might explain or, at least, reinforce the sort of compartmentalization or dismissal discussed in the previous section. For instance, if students believe that decisions regarding scientific know-ledge are somewhat procedural, completely rational, value-free, and unproblematic, they could as well perceive that "neat" scientific knowledge and ways of thinking are irrelevant to the "messy" world of everyday life decision-making, and that they have to fall back on other factors when making these decisions. (Note that bringing in other factors when making such decisions is not problematic in itself; indeed, it is necessary. Rather, the problem lies in completely factoring out scientific claims and ways of thinking.) By the same token, a similar belief might lead science teachers to perceive dealing with scientific knowledge proper (e.g., chemistry, physics, biology) to be less problematic than dealing with socioscientific issues, because in the latter case more "unsure things" have to be brought into the picture. By comparison, if learners and science teachers come to realize that messiness, and value and judgment calls, are part of the very practice of justifying scientific knowledge and adjudicating between scientific claims, they might be more open to tackling socioscientific issues in the science classroom and hopefully engaging the sort of desired critical social discourse regarding these issues.

At this point three qualifications are warranted. First, I am not arguing that decision-making regarding scientific issues proper are the *same* as ones related to socioscientific issues. What I would like to suggest is that the difference between the two decision-making processes is not one of *kind*, but rather a matter of *degree*. Second, developing an appreciation for the messiness of decision-making in scientific issues proper is necessary but not sufficient to engaging in critical discourse regarding socioscientific issues. Matters pertaining to students' moral and ethical development, as well as cognitive reasoning and discourse abilities are similarly necessary elements. Third, it could be argued that adding another "messy" component of the scientific endeavor into the mix might serve to further alienate students and teachers from science. What needs to be emphasized is that developing an understanding of this messy component (i.e., decision-making) becomes useful in the sense argued here when it is part of a larger epistemological orientation, namely, one in which a committed form of relativism is endorsed. According to this latter epistemological orientation, scientific constructs are constrained by our perceptions of the natural world, and judgments regarding the relative merits of "scientific" claims could be made through critical social inquiry.

However, some might object and argue that the reform documents (e.g., AAAS, 1990 & 1993; NRC, 1996) admitted serendipity, and subjective human elements, such as intuition, creativity, and imagination, into the process of generating scientific knowledge. These documents did not claim that generating scientific claims was unproblematic, neat, or free from the messiness characteristic of other human endeavors. For instance, *Science for All American* (AAAS, 1990) explicitly states that:

> The use of logic and the close examination of evidence are necessary but not usually sufficient for the advancement of science. Scientific concepts do not emerge automatically from data or from any amount of analysis alone. Inventing hypotheses or theories to imagine how the world works and then figuring out how they can be put to the test of reality is as creative as writing poetry, composing music, or designing skyscrapers. Sometimes discoveries in science are made unexpectedly, even by accident. (p. 5)

The same document, nonetheless, continues to argue that:

> Although all sorts of imagination and thought may be used in coming up with hypotheses and theories, sooner or later scientific arguments must conform to the principles of logical reasoning – that is, to testing the validity of arguments by applying certain criteria of inference, demonstration, and common sense. (AAAS, 1990, p. 5)

As such, even though the aforementioned elements were admitted into the process of generating scientific claims, they were barred from the process of justifying those claims. This distinction is reminiscent of a long-standing one, namely, the distinction between the context of discovery and the context of justify-cation, or between the *generation* of scientific claims and their *justification* or *validation* (Gillies, 1998). Many philosophers of science utilized and maintained this distinction since it was first introduced by Hans Reichenbach (Giere, 1988), in one form or another. For instance, the distinction was crucial for Popper's philosophy of scientific method, that is, his theory of conjectures and refutations (or falsificationism). On this distinction, Popper (1934/1992) writes:

> There is no such thing as a logical method of having new ideas, or a logical reconstruction of this process… every discovery contains 'an irrational element,' or a 'creative intuition'… The act of conceiving or inventing a theory, seems to me neither to call for logical analysis nor to be susceptible of it. The question how it happens that a new idea occurs to a man… may be of great interest to empirical psychology; but it is irrelevant to the logical analysis of scientific knowledge. This latter is concerned… only with questions of *justification or validity*... Can a statement be justified? And if so, how? It is testable? Is it logically dependent on certain other statements? Or does it perhaps contradict them? (p. 31-32)

Indeed, Popper (1934/1992) accused philosophers who confused the two contexts of committing *psychologism* (i.e., confusing psychology and philosophy), because the distinction was crucial for his efforts to show that cannons of deductive logic alone can be used to justify scientific theories and claims, thus circumventing the problem of induction. Since then, several philosophers have pointed out the shortcomings of Popper's approach (Gillies, 1998). Nonetheless, the distinction between the generation and validation of scientific knowledge is still echoed in discourse about NOS, with the implication that the latter is somewhat less messy than the former. In what follows, I will briefly present a couple of arguments from philosophy of science to show how scientific decision-making proper does entail both value and judgment calls.

At the turn of the 20^{th} century, Duhem (1904-05/1954) argued that an isolated hypothesis in physics (h) could never be falsified by an empirical observation (O). At first, this suggestion seems untenable because such falsification is possible in accordance with the *modus tollens* in the following way (see Gillies, 1998):

If h, then O, but not-O, therefore not-h

In other words, a certain observation (O) is first logically derived from a hypothesis (h), that is, a prediction is made. Next, an experiment is conducted whereby if (h) were true, then (O) should be observed. According to *modus tollens*, If (O) was not observed, then (h) is not true. (Note that if (O) was observed, it does not follow that (h) is true.) Duhem, however, argued that a scientist cannot subject an isolated hypothesis in physics to experimental testing. A hypothesis can only be tested as part of a system of physical laws (L) in conjunction with auxiliary hypotheses (A). For example, when testing a prediction about the movement of an object in a Newtonian solar system, the whole system, which comprises Newton's three laws of motion (L_1, L_2, L_3) and law of gravity (L_4) and a set of auxiliary hypothesis (A), are put to the test. These auxiliary hypotheses include assumptions, such as that only gravitational forces are at work in the solar system, and simplifications, such as that interplanetary attractions are negligible compared to the attractions between the Sun and the planets. As such, the logical structure of our experimental test should be revised as follows:

If L_1 & L_2 & L_3 & L_4 & A, then O, but not-O, therefore not- (L_1 & L_2 & L_3 & L_4 & A)

In other words, if the experimental observation does not agree with the prediction, the scientist learns that at least one of the components (in this case) of the Newtonian system, that is L_1, L_2, L_3, L_4 or A is unacceptable and should be modified. The experiment, however, does not tell the scientist *which* one of those components should be changed. For instance, the scientist could decide that Newton's laws are not at fault, and blame one or more of the auxiliary hypotheses. Thus, the scientist is under no logical obligation to relegate belief in the validity of, or abandon, the Newtonian system. Indeed, as the history of science shows, for more than a century after the publication of the *Principia*, Newton's followers did not adhere to the logical cannons of *modus tollens*. Despite stubborn disagreements between Newtonian predictions and empirical observations, scientists refused to abandon Newtonian theory, and by continuously modifying and/or adding auxiliary hypotheses they were able to make significant "discoveries" and reach unprecedented levels of accuracy in terms of predicting movements in the heavens (Gillies, 1998).

Duhem (1904-5/1954) goes on to show the impossibility of having a "crucial experiment" in physics, that is, an experiment that conclusively decides between two theories that purport to explain the same phenomenon. It should be noted that Duhem did not believe that his ideas applied to other sciences, such as physiology and some branches of chemistry. Quine (1951), nonetheless, extended these ideas to the whole of science. Although somewhat different, their ideas came to be referred to as the Duhem-Quine thesis, which is now synonymous with the notion of the underdetermination of scientific theories by evidence. Simply put, from a logical point of view, scientists can stick to their theories come what may in terms of empirical evidence. However, and this is what is important for us here, Duhem argued that scientists *do* abandon their theories in light of negative empirical evidence. He explained this by putting forth a theory of good sense (*le bon sens*):

> Pure logic is not the only rule for our judgment; certain opinions which do not fall under the hammer of the principle of contradiction are in any case perfectly unreasonable. These motives which do not proceed from logic and yet direct our choices, these 'reasons which reason does not know' and which speak to the ample 'mind of finesse' but not to the 'geometric mind,' constitute what is appropriately called good sense. (Duhem, 1904-5/1954, p. 217)

After all, Duhem, a physicist by training and a career scientist, learned about the significance of "good sense" firsthand. He was a brilliant logician, yet a largely unsuccessful physicist. Indeed, Duhem almost always sided with physical theories that were later abandoned. He also rejected theories, including the introduction of atoms into physics, Maxwell's electromagnetic theory, and Einstein's theory of relativity, which later prevailed and dominated thinking in the field (Gillies, 1998). All this shows that, when making decisions about science proper, scientists need to, and do, appeal to *le bon sens*, or "reasons"– as Duhem said, "which reason does not know."

In a relatively more recent argument, Kuhn (1977) argued that scientists make *value* judgments when choosing between competing theories. Scientists, he suggested, appeal to a somewhat shared and standard set of criteria to evaluate the adequacy of a scientific theory. These criteria include accuracy, consistency, scope, simplicity, and fruitfulness: (a) Accuracy refers to the agreement of the predictions derived from a theory with empirical observations, (b) consistency pertains to the internal coherence of the theory itself as well as to its consistency with other accepted theories, which are related to the target phenomena, (c) scope refers to the success of a theory in explaining a wide range of observations and phenomena that are different from those for which the theory was initially designed, (d) simplicity is manifest in a theory's ability to bring order to large and seemingly unrelated sets of observations and phenomena, and finally (e) fruitfulness refers to the success of the theory in generating, and guiding research into, new and worthwhile questions.

Applying these criteria when choosing between two rival theories, however, presents two kinds of difficulties. First, individually the criteria are imprecise. They are heuristics rather than sharply defined rules. As such, different scientists may apply the same criterion differently across individual cases. So, even in the rare occasion when two theories are on equal par on four of the aforementioned five criteria, two scientists might still differ in their choice of the more adequate theory because they differ in their application of the fifth criterion to the case at hand. It is more likely though that two theories would differ on more than one of these criteria. And here is where the second difficulty comes into play: The criteria often conflict with one another. Kuhn (1977) presented the shift from geocentric to heliocentric astronomy as a case in point. When it was first introduced, Copernican astronomy was not more accurate in predicting movements in the night skies than the Ptolemaic system. (Indeed, sixty years were to pass before Kepler's work changed this situation.) Nonetheless, the Copernican system was simpler than Ptolemy's, because it virtually did away with the epicycles, equants, eccentrics, and other "tools" that were necessary for the Ptolemaist to accurately predict the movements of bodies in the solar system. This was a case where two theories differed on two criteria, but the differences were antagonistic rather than synergistic: While one theory was more accurate, the other was simpler. In this case, followers of Copernicus valued the simplicity of their system and thus placed more weight on this criterion, while devout Ptolemaists chose to give accuracy more weight. Needless to say, the situation is more complex than presented here and a host of other considerations, factors, and values came into play when scientists made their choices between the two systems. But this fact only serves to reinforce the point being made here, namely, that "*Scientists qua Scientists* [italics in original] make value judgments" (Rudner, 1998, p. 497).

Thus, it can be seen that when justifying scientific knowledge proper, scientists make decisions that require "good Duhemian sense" and invoke values in conjunction with applying "principles of logical reasoning… [such as] criteria of inference, demonstration, and common sense" (AAAS, 1990, p. 5). Addressing this aspect of the scientific endeavor in the reform documents and/or discourse has, at least, three advantages. First, it is an essential aspect of a more accurate representation of NOS. Second, it increases the chances that this very aspect of NOS will be accorded attention and addressed in empirical studies and instructional efforts, in the same manner that other NOS aspects emphasized in the reform documents (e.g., the tentative, empirical, creative, and social NOS) are receiving increased attention. Third, internalizing this NOS aspect will hopefully help students and science teachers realize that the processes of making decisions regarding scientific and socioscientific issues are not markedly different, in the sense that messy and value-laden decision-making is also an essential aspect of science. This realization could in turn encourage students and teachers to engage the sort of desired critical discourse regarding socioscientific issues rather than dismissing such discourse as extra-scientific and thus extraneous to the sort of goals that are legitimately pursued in pre-college science classrooms.

At this point, I will turn to addressing the final, and probably most crucial message to be presented here, namely, that attention to NOS in pre-college science classrooms needs to go beyond focusing on students' acquisition of specific aspects of NOS to addressing students' epistemological orientations, and that consequently, we need to be concerned with directing more research efforts into attempting to understand how students acquire their global epistemological orientations and how these epistemologies develop during the school years. Such research focus, I will argue, is essential to complementing the research framework put forth by Zeidler and Keefer (this volume) to facilitate understanding the complexities associated with, and consequently actualizing, the goal of incorporating socioscientific issues in pre-college classrooms.

EPISTEMOLOGICAL ORIENTATIONS AND THEIR DEVELOPMENT DURING THE SCHOOL YEARS: BROADENING AND DEEPENING OUR NOS RESEARCH AGENDA

The reform documents (e.g., AAAS, 1990; NRC, 1996) adopted what could be described as an "aspects approach" to NOS. Under this approach, students are expected to internalize understandings related to somewhat discrete characteristics of the scientific endeavor. For instance, the introductory chapter on NOS in *Science for All Americans* (AAAS, 1990) lists several of these aspects including that "scientific ideas are subject to change," "scientific knowledge is durable," "science demands evidence," "science is a blend of logic and imagination," "science is a complex social activity," and "there are generally accepted ethical principles in the conduct of science" (p. 2-12). These aspects, no doubt, resonate with an underlying scientific epistemology, which, however, is not explicitly elucidated in this and similar documents (see also NRC, 1996).

There are definite advantages to an aspects approach to NOS. First, such an approach provides an accurate framework that guides research efforts related to NOS in science education while avoiding the pitfalls of engaging in discourse about contentious NOS issues, such as the nature of "reality," or attempting the (futile) program of exactly defining and reaching consensus on "The NOS." (It should be noted that the phrase "NOS" is used throughout this chapter instead of the more stylistically appropriate "the NOS" because of the author's lack of belief in the existence of a singular NOS or agreement on what the phrase specifically means.) Second, an aspects approach allows targeted NOS instructional efforts. Indeed, several colleagues and myself have advocated and worked within an aspects approach to NOS. We were successful, I believe, in developing research-based instructional materials and approaches that positively impacted the understandings of several NOS aspects of preservice secondary science and elementary teachers as well as pre-college students (see for e.g., Abd-El-Khalick, 2001 & 2002a; Abd-El-Khalick et al., 1998; Akerson, Abd-El-Khalick, & Lederman, 2000; Bell et al., 2000; Khishfe & Abd-El-Khalick, 2002; Lederman & Abd-El-Khalick, 1998). To be sure, much is still desired in terms of promoting more informed views of NOS among pre-college students and teachers, and helping teachers address NOS instructionally in meaningful and sustained ways.

However, results from my own research with attempting to enhance the views of NOS of elementary teachers (Abd-El-Khalick, 2001) and secondary science teachers (Abd-El-Khalick, 2002a) that were alluded to in a previous section, indicate that articulating informed views of certain NOS aspects might not reflect an accurate, overarching, and consistent framework for thinking about NOS, that is, an informed epistemological orientation. Learners' views of a set of NOS aspects should not be confused with their overarching scientific epistemologies, or their *deep-seated, core, more basic, and even tacit* views of the nature of scientific knowledge and how such knowledge is generated and validated (this will be referred to here as *scientific epistemology*). These latter views might be intimately related to even more global and generic epistemological views about the entities that make up the universe and how these entities interact, such as having a mechanistic versus a mystical view of the interrelationship between events and phenomena (this will be referred to here as *global epistemology*). As noted earlier, in Abd-El-Khalick (2001) several preservice elementary teachers explicated informed views of the tentative, empirical, inferential, creative, and theory-laden aspects of NOS. Yet, further probing indicated that as a result of internalizing these views, participant teachers have shifted from a scientistic framework to adopting a generalized naïve relativistic NOS framework, which – in the sense that was elaborated above, alienated them from science when tackling a socioscientific issue.

Some legitimate questions to be asked here would be: Is it possible for learners to express informed views of certain NOS aspects and yet ascribe to a naïve scientific epistemology? Does this inconsistency reflect on student views or on our success in impacting their views? I think that while it is plausible to attribute such inconsistency to our efforts in impacting learners' NOS views, the possibility that students could express informed views of specific aspects of NOS and still ascribe to a naïve scientific epistemology is more likely. Indeed, research has shown that students' and teachers' NOS views are fluid, situated, and compartmentalized. For instance, college students could reconcile belief in a universal "Scientific Method" with the simultaneous belief that scientists use creativity and imagination when generating scientific knowledge (Abd-El-Khalick, in press). Seemingly inconsistent views of NOS actually made sense to participants in the Abd-El-Khalick (in press) study, because these views were explicated within a set of varied and personalized images of science. Participants' views were organized into several flexible (and sometimes inconsistent) frameworks rather than a single unified and coherent structure. The majority did not ascribe to views that were solidified into well thought-out structures. Thus, views of specific NOS aspects might not tell much about underlying scientific epistemologies. As shown above, these latter conceptions might be crucial to how students and teachers receive and interact with controversial socioscientific issues.

We should avoid seeing the trees for the forest and be more concerned with learners' and science teachers' more deep-seated and underlying epistemological views of science. I am not arguing that an aspects approach to NOS as described above is not fruitful or that it should be, in any respect, abandoned. Rather, I am suggesting that such an approach should be complemented with a concern with, and emphasis on, underlying epistemologies. To my mind, this is similar to the situation often faced when thinking about curriculum versus instructional goals. Some researchers and teachers often conflate and/or equate the two. Instructional goals, nonetheless, are more atomistic and only means to achieving curricular goals, which are often holistic in that they target the whole individual (Ornstein & Hunkins, 1993). In the same way that achieving the content *Benchmarks* (AAAS, 1993) and *Standards* (NRC, 1996) is only a means to achieving scientific literacy, internalizing informed views of certain NOS aspects is only a vehicle to achieving critical and informed views of scientific epistemology. This is another situation in which the whole is larger than the sum of its parts.

Ascertaining the difference between learners' views of specific NOS aspects and their underlying scientific epistemologies would lead to asking many fruitful research questions, such as: What is the nature of learners' scientific epistemologies? Are these epistemologies fluid or characterized by a set of rigid core beliefs? Are they articulated or tacit? Are scientific epistemologies related to learners' global epistemologies? What are the factors that shape a learner's global epistemology? What is the relationship between learners' scientific epistemologies and views of specific NOS aspects? Do such epistemologies hinder or facilitate the acquisition of more informed NOS views? How do scientific epistemologies respond to explicit instruction versus more contextual aspects of the learning environment? Etc. To be sure, researchers have addressed, to some extent, questions of the sort raised here (for a review of these efforts see Hofer & Pintrich, 1997). However, Hofer and Pintrich (1997) noted that the overwhelming majority of these research efforts did not focus on adolescents and younger students, or investigate the contextual nature of learners' epistemologies (e.g., in the context of learning school science), despite a clear shift in cognitive psychology from a general toward a more domain-specific view of learning (Sternberg, 1989). It could be seen that questions regarding learners' epistemological views raised here might require a re-conceptualization of current NOS research goals and methods. In this regard, I should emphasize that the sort of research called for here is genuinely different from research in which convergent, forced-choice, paper-and-pencil instruments were used to assign learners labels, such as inductivist, verificationist or hypothetico-deductivist, which suggested that students and teachers firmly held coherent, consistent philosophic stances (e.g., Dibbs, 1982; Hodson, 1993). These labels were more an artifact of the sort of convergent NOS instruments that were used by some researchers than a genuine representation of learners' views of knowledge and knowledge-making (Abd-El-Khalick et al., 2001). Indeed, the use of the term "epistemological orientations" (as compared to "epistemologies") in this chapter is intended to suggest that young learners' might not posses well-articulated coherent epistemological views, but rather more tacit, fragmented or inarticulate epistemological schemes that nevertheless influence their views of knowledge and knowledge-making.

Thinking of scientific and global epistemologies as underlying frameworks for making sense of knowledge and knowledge-making as compared to a set of particular instructional outcomes (e.g., a set of NOS aspects), brings to light additional research questions. In particular, such a conceptualization raises questions regarding the development of epistemological views during the school years and consequently questions regarding the developmental appropriateness of the sort of NOS understandings articulated by the reform documents as desired learning outcomes for pre-college students. For instance, it is likely that the well-documented difficulties associated with the long-lived, yet somewhat unsuccessful, attempts undertaken to help pre-college students internalize more informed conceptions of specific aspects of NOS might be, at least partly, related to the developmental inappropriateness of such aspects and the interaction of the learning of these aspects with students' global epistemologies. These difficulties might not be solely explicable in terms of "inadequate" curricula and instructional approaches or "inadequate" science teacher views and practices. For example, eighth graders might find it difficult to come to terms with the notion that scientific knowledge is "durable but necessarily tentative" (a NOS outcome specifically articulated in AAAS, 1990, p. 2-3) if they ascribe to a dualistic "right/wrong" view of knowledge! At this point, it should be noted that by "development" as used here I am not referring to the predetermined unfolding of certain abilities or schemes as a result of maturation, that is, the sort of "genetic epistemology" reminiscent of Piaget's work. Rather, I am referring to "development" that occurs as a result of the interaction between active meaning-making learners and their social and educational milieu, including both formal and informal settings, interactions, and experiences.

Little is known about the development of epistemological views during the school years. As noted above, research on epistemological development has been mostly undertaken with college students and adults starting with the landmark study by Perry (1970) in which he investigated the development of the intellectual (and moral) views of undergraduate (mostly male) Harvard students. Perry argued that during their college years, students journey through nine positions, which can be characterized in terms of students' perceptions of knowledge. These positions were grouped into four categories: dualism (right/wrong, received knowledge), multiplicity (subjective knowledge), relativism (procedural knowledge), and commitment (constructed knowledge). In an equally significant study, Belenky, Clinchy, Goldberger, and Tarule (1986) focused on women's views of knowledge. Their sample included adult women from all walks of life: from elite college students to blue-collar single mothers. Unlike Perry, Belenky et al. chose not to represent the ways women think about knowledge in terms of developmental stages. Nonetheless, they found that women move through five different "ways of knowing" as they mature and gain experiences: (a) silence: women feel mindless, voiceless, and subject to external authority, (b) received knowledge: women feel that they could receive knowledge but not create it, (c) subjective knowledge: women perceive truth and knowledge to be private and subjectively intuited, (d) procedural knowledge: women believe that they could learn, apply, and communicate knowledge through applying objective procedures, and (e) constructed knowledge: women view knowledge as contextual and believe they can create knowledge through objective and subjective means. Similarly, using a longitudinal design to investigate the views of senior high school students all the way to doctoral level students, King and Kitchener (1994) developed a hierarchical seven-stage reflective judgment model in which learners move from a naïve "knowing is seeing" stage to a stage in which knowledge is viewed as constructed through a social process of reasoned inquiry.

The above summary is not a comprehensive review of the research on the epistemological development of college students and adults. It was meant to show that the above models are somewhat consistent and that most senior high school and undergraduate college students ascribe to a dualistic right/wrong view of knowledge that is perceived to be handed down by authorities, which is similar to a scientistic view of NOS. To be sure, as a result of their college education and life experiences, many learners (some do not) move through several stages leading to more informed views in which knowledge is perceived to be constructed by human agents working within a critical inquiry framework. What is very interesting though, is that the aforementioned models of epistemological development correspond in their stages, at least *prima facie*, to models of cognitive, moral, and sociomoral discourse development (e.g., Berkowitz, Oser & Althof, 1987; Kohlberg, 1987) deemed by Zeidler and Keefer (this volume) as essential to understanding and facilitating discourse regarding socioscientific issues in pre-college classrooms. The only caveat though is that the desired epistemological orientations seem to be internalized long after students leave their high school classrooms. Moreover, as previously noted, research shows that pre-college students' views of NOS are largely naïve and uninformed. Probably there is good reason why researchers have not examined epistemological development during the school years: After all research in this area seems to suggest that little might be going on in terms of epistemological development during these years. In light of these arguments, one could ask: If epistemological orientations and views of NOS have primacy for engaging in social discourse regarding controversial socioscientific issues – as is suggested by the title of this chapter, does this mean that this sort of discourse is doomed in pre-college classrooms?

Fortunately, I believe that the situation is not nearly as gloomy for several reasons. First, we simply do not know enough about epistemological development during the school years. For instance, are pre-college students' epistemological orientations and views of NOS, naïve as they may be, the result of certain limitations imposed by cognitive, metacognitive, reasoning, and linguistic development (i.e., are these views innate)? Or are these views simply shaped by the way science is taught in pre-college classrooms (i.e., are these views learned)? In a recent study, Abd-El-Khalick (2002b) investigated the development of middle and high school students' views of the nature of scientific knowledge and knowing through a cross-sectional design. In this study, the *Perspectives on Scientific Epistemology* (POSE) open-ended questionnaire was first developed – this instrument was derived from the *VNOS–C* (Abd-El-Khalick et al., 2001; Lederman et al., 2002), and then administered to 456 students in grades 7, 9, 11, and 12. This administration was followed with individual interviews with a 10% sample of participants. Preliminary findings indicate that certain naïve views of NOS could be attributed to schooling. For instance, grade 7 students elucidated a multiplicity of means through which they believed scientific knowledge was developed including doing experiments and tests, serendipity, "making it up," trial and error, and agreement among scientists. Irrespective of the accuracy of these means of generating knowledge, grade 7 students explicated flexible views on the topic. By grade 12, the larger majority of students noted that scientists follow "The Scientific Method" to generate knowledge. As a result of schooling, these students' views of knowledge-making became rigid and one-dimensional. Furthermore, I believe that investigating pre-college students' epistemological orientations might be more fruitful and fascinating than assumed by inference from studies that examined epistemological development during the college years and adulthood. In a project currently underway, I am interviewing students in grades 3 through 12 regarding their epistemological views. Although it is still very early to make any sort of conclusions, it would be safe to report that I was mesmerized when listening to a *sixth grader* eloquently articulate her belief that two individuals or scientists can look in the same direction and toward the same object and still literally see two different things, and then provide a clear example to support this belief!

The suggestion (implied in the title of this chapter) that epistemological orientations and views of specific NOS aspects are somehow pre-requisite to engaging in critical discourse regarding controversial socioscientific issues is nothing more than attempting an intriguing title. Again, I think that we know little in this regard. I believe I established that epistemological orientations and views of NOS are crucial to the success of incorporating socioscientific issues in pre-college science classrooms. However, how epistemological views influence and/or are influenced by a learning environment centered on socioscientific issues, remains to be understood. It might turn out that epistemological orientations are indeed pre-requisite to the target critical discourse, or alternatively we might learn that such views are impacted and positively changed by engaging in such discourse. In a similar way, epistemological development might turn out to be prior to or otherwise facilitated by moral, cognitive, linguistic, and discourse development. Or it might turn out that all of these aspects are reciprocal and interact in significant synergetic ways. What seems obvious though is that many significant and worthwhile research questions could emerge from the conceptualization attempted here; I believe this is the major goal and a mark of a good framework for research.

CONCLUSION

In the above pages I tried to present a convincing case for the following major points: Properly conceptualized, the process to be engaged by pre-college students when making decisions regarding socioscientific issues is similar to the one engaged by scientists when making decisions regarding the justification of scientific knowledge proper. Both processes require the application of rational critical discourse *and* necessarily invoke value judgments and "good sense." It follows that the sort of epistemological orientations underlying critical scientific discourse are crucial to engaging in critical discourse on socioscientific issues. These arguments serve to highlight the significance of factoring in epistemological orientations and NOS views, and investigating their development during the pre-college years, if we are *serious* about meaningfully incorporating socioscientific issues in school science curricula. As such, "epistemological development" needs to be incorporated as a major axis in any research framework, such as the one suggested by Zeidler and Keefer (this volume, Figure 1), that is meant to guide research on creating and sustaining learning environments centered on controversial socioscientific issues. Finally, the above pages raised a number of research questions related to the development of NOS views and epistemological orientations during the pre-college years and their interaction with the development of other crucial aspects, including cognitive, moral, and discourse development.

REFERENCES

Abd-El-Khalick, F. (in press). Over and over and over again: College students' views of nature of science. In L. B. Flick & N. G. Lederman (Eds.), *Scientific inquiry and nature of science: Implications for teaching, learning, and teacher education* (p. to be assigned). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Abd-El-Khalick, F. (2001). Embedding nature of science instruction in preservice elementary science courses: Abandoning scientism, but . . . *Journal of Science Teacher Education, 12*(3), 215-233.

Abd-El-Khalick, F. (2002a, January). *The influence of a philosophy of science course on preservice secondary science teachers' views of nature of science*. Paper presented at the annual meeting of the Association for the Education of Teachers in Science, Charlotte, NC.

Abd-El-Khalick, F. (2002b, April). *The development of conceptions of the nature of scientific knowledge and knowing in the middle and high school years: A cross-sectional study.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, New Orleans, LA.

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education, 82*(4), 417-436.

Abd-El-Khalick, F., & Lederman, N. G. (2000a). Improving science teachers' conceptions of the nature of science: A critical review of the literature. *International Journal of Science Education, 22*(7), 665-701.

Abd-El-Khalick, F., & Lederman, N. G. (2000b). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching*, *37*(10), 1057-1095.

Abd-El-Khalick, F., Lederman, N. G., Bell, R. L., & Schwartz, R. S. (2001). Views of nature of science questionnaire (VNOS): Toward valid and meaningful assessment of learners' conceptions of nature of science. In P. Rubba, J. Rye, W. DiBiase, & B. Crawford (Eds.), *Proceedings of the 2000 Annual International Conference of the Association for the Education of Teachers in Science* (p. 212-272). Pensacola, FL: Association for the Education of Teachers in Science. (ERIC Document Reproduction Service No. 453 083)

Akerson, V. L., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching, 37*(4), 295-317.

American Association for the Advancement of Science. (1990). *Science for all Americans.* New York: Oxford University Press.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy: A Project 2061 report.* New York: Oxford University Press.

Belenky, M. F., Clinchy, B. M., Goldberger, N. R., & Tarule, J. M., (1986). *Women's ways of knowing: The development of self, voice and mind.* New York: Basic Books.

Berkowitz, M. W., Oser, F., & Althof, W. (1987). *The development of sociomoral discourse*. In W. M. Kurtines & J. L. Gewirtz (Eds.), *Moral development through social interaction* (p. 337-345). New York: Wiley.

Bell, R. L., Lederman, N. G., & Abd-El-Khalick, F. (2000). Developing and acting upon one's conceptions of the nature of science: A follow-up study. *Journal of Research in Science Teaching, 37,* 563-581.

Chiappetta, E., Koballa, T., & Collette, A. (1998). *Science instruction in the middle and secondary schools (4th ed.).* Upper Saddle River, NJ: Merrill.

Council of Ministers of Education, Canada (CMEC) Pan-Canadian Science Project. (1997). *Common framework of science learning outcomes K to 12* [On-line]. Available: http://www.cmec.ca/science/framework/Pages/english/CMEC%20 Eng.html

DeBoer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching, 37*(6), 582-601.

Dibbs, D. (1982). *An investigation into the nature and consequences of teachers' implicit philosophies of science.* Unpublished doctoral dissertation, University of Aston, England.

Duhem, P. (1954). *The aim and structure of physical theory*. (P. P. Wiener, Trans.). Princeton, NJ: Princeton University Press. (Original work published 1904-5)

Duschl, R. A. (1990). *Restructuring science education.* New York: Teachers College Press.

Giere, R. N. (1988). *Explaining science: A cognitive approach.* Chicago, IL: The University of Chicago Press.

Gillies, D. (1998). *Philosophy of science in the twentieth century: Four central themes.* Cambridge, MA: Blackwell.

Griffiths, A. K., & Barman, C. R. (1995). High school students' views about the NOS: Results from three countries. *School Science and Mathematics, 95*(5), 248-255.

Hodson, D. (1993). Philosophic stance of secondary school science teachers, curriculum experiences, and children's understanding of science: Some preliminary findings. *Interchange, 24,* 41-52.

Hofer, B. K., & Pinrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational research, 67*(1), 88-140.

Horner, J. K., & Rubba, P.A. (1978). The myth of absolute truth. *The Science Teacher, 45*(1), 29-30.

Hurd, P. D. (1998). Scientific literacy: New minds for a changing world. *Science Education, 82(*3), 407-416.

Khishfe, R., & Abd-El-Khalick, F. (2002). The influence of explicit reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science. *Journal of Research in Science Teaching, 39*(7), 551-578.

King, P. M., & Kitchener, K. S. (1994). *Developing reflective judgment: Understanding and promoting intellectual growth and critical thinking in adolescents and adults.* San Francisco: Jossey Bass.

Kohlberg, L. (1987). The cognitive-developmental approach to moral development. In P. F. Carbone Jr. (Ed.), *Value theory and education* (p. 226-243). Malabar, Florida: Robert E. Krieger Publishing.

Kolstø, S. (2001). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socioscientific issues. *Science Education, 85*(3), 291-310.

Kuhn, T. S. (1977). *The essential tension: Selected studies in scientific tradition and change.* Chicago, IL: The University of Chicago Press.

Larochelle, M. & Desautels, J. (1991). 'Of course, it's just obvious': Adolescents' ideas of scientific knowledge. *International Journal of Science Education, 13*(4), 373-389.

Laugksch, R. C. (2000). Scientific literacy: A conceptual overview. *Science Education, 84(*1), 71-94.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*(4), 331-359.

Lederman, N. G., & Abd-El-Khalick, F. (1998). Avoiding de-natured science: Activities that promote understandings of the nature of science. In W. McComas (Ed.), *The nature of science in science education: Rationales and strategies* (p. 83-126). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. (2002). Views of nature of science questionnaire (VNOS): Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497-521.

Lederman, N. G., & O'Malley, M. (1990). Students' perceptions of tentativeness in science: Development, use, and sources of change. *Science Education, 74,* 225-239.

Mackay, L. D. (1971). Development of understanding about the nature of science. *Journal of Research in Science Teaching, 8*(1), 57-66.

Millar, R., & Osborne, J. (Eds.) (1998). *Beyond 2000: Science education for the future.* London: King's College.

National Research Council (1996). *National science education standards.* Washington, DC: National Academic Press.

Ornstein, A. C., & Hunkins, F. (1993). *Curriculum foundations, principles, and theory.* Boston, MA: Allyn and Bacon,

Pedretti, E. (1999). Decision-making and STS education: Exploring scientific knowledge and social responsibility in schools and science centres through an issues-based approach. *School Science and Mathematics, 99*(4), 174-181.

Perry, W. G. (1970). *Forms of intellectual and ethical development in the college years: A scheme.* New York: Holt, Rinehart, and Winston.

Perry, W. G. (1981). Cognitive and ethical growth: The making of meaning. In A. Chickering (Ed.), *The modern American college* (p. 76-116). San Francisco: Jossey-Bass.

Popper, K. R. (1992). *The logic of scientific discovery (reprint edition).* New York: Routledge. (First published 1959 by Hutchinson Education, first appeared 1934)

Quine, W. V. (1951). Two dogmas of empiricism. *Philosophical review, 60,* 20-43.

Rudner, R. (1998). The scientist *qua* scientist makes value judgments. In E. D. Klemke, R. Hollinger, D. W. Rudge, & D. Kline (Eds.), *Introductory readings in the philosophy of science (3rd ed.)* (p. 492-498). Amherst, NY: Prometheus

Ryan, A. G., & Aikenhead, G. S. (1992). Students' preconceptions about the epistemology of science. *Science Education, 76*(6), 559-580.

Sternberg, R. (1989). Domain-generality versus domain-specificity: The life and impending death of a false dichotomy. *Merrill-Palmer Quarterly, 35*(1), 115-130.

Zeidler, D. L., & Keefer, M. (2003). The role of moral reasoning and the status of socioscientific issues in science education: Philosophical, psychological and pedagogical considerations. In D. L. Zeidler (Ed.), *The role of moral reasoning on socioscientific issues and discourse in science education* (Chapter 1). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Zeidler, D. L., Walker, K. A., Ackett, W. A., & Simmons, M. L. (2002). Tangled up in views: Beliefs in the nature of science and responses to socioscientific dilemmas. *Science Education, 86, 343-367.*

Chapter 3

EXPLORING THE ROLE OF NATURE OF SCIENCE UNDERSTANDINGS IN DECISION-MAKING

PIPE DREAM OR POSSIBILITY?

Randy L. Bell

INTRODUCTION

> *Were I a traffic cop on the highway of life, I've got to tell you that I'd be very much inclined right now to turn on my flashing red lights, hit the siren, and pull the American Medical Association over for swerving. Now, let's recap just some of the things we've heard from these guys over the last few years: Coffee's bad for you—noooo, coffee's not bad for you. Okay then, alcohol's bad for you—no, alcohol's good for you. As long as its red wine, because the French drink it and they live to be old and problematic despite smoking like chimneys. But wait a minute, check that. It's not just red wine, but any kind of alcohol lessons your chance of stroke, so bottoms up. Unless of course, it's milk. Now that's bad for you. It's got all that fat and stuff in it. But, wait a minute. Everybody's going to get osteoporosis, because they don't get enough calcium. Hmmm… Then, of course Thursday, this story comes out saying the AMA is not so sure all that talk about eating lots of fiber to avoid colon cancer is altogether, well... true. Sorry. Never mind. Somehow, I suspect I'm not the only one who has thoughts of the boy who cried wolf here… After a while, you just stop listening.* (Mike Renfrow, *Morning Edition*. National Public Radio. January 24, 1999.)

Renfrow's dietary dilemma is only one of the many science and technology related issues facing 21st-century citizens. In a world increasingly impacted by the processes and products of science, citizens are asked to make decisions on everything from personal health to public policy. Educators have come to realize that traditional science curriculum with its absolute views does not produce citizens prepared to deal with real-world science, which is more often than not equivocal,

D.L. Zeidler (ed.),
The Role of Moral Reasoning on Socioscientific Issues and Discourse in Science Education, 63-79.

revisionary, and conflicting. How then do we prepare citizens to make reasoned decisions about scientific issues that are complex and ever changing?

Science education reform documents promote scientific literacy as the answer, of which nature of science is a principle component (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996). In fact, recent commentary has specifically linked nature of science instruction to decision-making on science and technology based issues (Carey & Smith, 1993; Collins & Shapin, 1986; Cotham & Smith, 1981; Driver, Leach, Millar & Scott, 1996; Kuhn, Amsel & O'Loughlin, 1989; Lederman, 1983; Lederman, 1999; Millar & Wynne, 1988; Shamos, 1995). By knowing the characteristics of scientific knowledge and the way it is constructed, the argument proceeds, citizens will be better prepared to recognize pseudoscientific claims, distinguish good science from bad, and apply scientific knowledge to their everyday lives.

Given these lofty aspirations for nature of science instruction, it is reasonable to ask what evidence exists to support them. Or, as in so many other instances in science education, are these aspirations based on unfounded assumptions? Are we certain that better understandings of the nature of science would help Renfrow decide how much fiber to include in his diet? Or when it comes to everyday decision-making, does the influence of values, morals, and personal experience wield the greater influence?

In this chapter, I explore the influence of nature of science understandings on decision-making regarding science and technology based issues by summarizing the findings of relevant empirical research and discussing implications of these findings for the classroom. In so doing, I argue for the necessity of explicit instruction on decision-making that emphasizes roles for moral reasoning and understandings of the nature of science.

WHAT IS THE NATURE OF SCIENCE?

A working definition might refer to the nature of science as science epistemology, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development (Lederman, 1992). These characterizations are fairly general, however. When exploring the nature of science construct in more detail, one quickly realizes that those who study the scientific enterprise disagree on some specifics of the nature of science. While this should hardly be surprising given the multifaceted and complex nature of the scientific enterprise, it can be disconcerting to those looking for a quick and easy definition.

Fortunately, the vast majority of disagreements among philosophers, historians, sociologists, and science educators are irrelevant to K-16 instruction (the existence of a reality independent of the observer being a case in point). Furthermore, scholars of the scientific enterprise do agree on many nature of science concepts, and it is these concepts that are most relevant to K-16 science students. For instance, few philosophers, science educators, etc., would reject the idea that scientific observations and investigations are theory-laden, nor would they defend an absolutist view of scientific knowledge. At this level of generality, many critical aspects of the nature of science are noncontroversial. Moreover, these nature of science aspects have been emphasized in recent science education reform documents as being relevant to the development of a citizenry capable of informed decision-making (e.g., AAAS, 1989, 1993; NRC, 1996).

Such concepts include the ideas that scientific knowledge is tentative, empirically based, subjective (theory-laden), partly the product of human inference, imagination, and creativity, and socially and culturally embedded. Other critical aspects of the nature of science relevant to K-16 science instruction include the distinction between observation and inference, the lack of a universal scientific method, and the relationship between scientific theories and laws. For a more detailed description of these aspects and the issue of consensus on a definition for the nature of science, see Bell, (in press) Lederman, Abd-El-Khalick, Bell and Schwartz (2002), and Smith, Lederman, Bell, McComas and Clough (1997).

NATURE OF SCIENCE AND DECISION-MAKING

Considering the importance ascribed to the nature of science in decision-making, it is surprising how little empirical work has been published on it. Besides the work reported in Chapter 3 of this volume, my search produced only three research projects that have explored the nature of science in decision-making, and only one of these has addressed the issue directly. Certainly, more work can and should be done, but even so, these three studies allow for some initial conclusions and implications.

Fleming (1986a) explored the nature of the interaction between high school students' knowledge of the physical and social worlds when making decisions on science and technology based issues. His goals were to identify the domains of reasoning that adolescents use when making decisions and to explore any relationships between the domains.

Fleming chose 38 adolescents who had completed introductory courses in high school chemistry and biology to participate in the study. The students' mean age was 17.3 years. To provide a context for students to discuss their reasoning, Fleming developed two scenarios dealing with nuclear power plants and genetic engineering. These scenarios provided a backdrop for semi-structured interviews that explored each student's decisions, reasoning, and justifications. Fleming subsequently analyzed the interview transcriptions by organizing the justification statements of the participants into categories. Some of these categories were provided by a scoring manual (Davidson, Turiel & Black, 1983), while others were created by Fleming directly from the participants' responses.

The results of this analysis indicated that the primary domain of reasoning for these adolescents lay within the area of social cognition. The two social cognitive domains used by the participants were (a) the moral domain, which emphasizes concepts regarding the welfare and rights of others and justice, and (b) the personal domain, which emphasizes self-preservation, respect for individuality, and control over one's physical state.

Fleming classified 70% of the participants as moral reasoners, with concern for the potential for harm to others as the central reason for the classification. Interestingly, these individuals tended to view uncertainties in scientific data as increasing the risk of harm to others. Therefore, once they perceived potential harm to others in an issue, additional scientific data offered by the researcher were considered irrelevant. The remaining 30% of the participants were classified as personal reasoners. For these individuals, there was a strong belief that individuals should make their own decisions about risk. Harm to others was not a major concern. Rather, the issues of personal benefits dominated, especially in regard to economic gain.

In conclusion, Fleming asserted that because students approach science and technology based issues primarily from the domain of social cognition, social cognition should be the starting point for their instruction. It is counterproductive to ask students to withhold social judgments until they “know more,” since they are already dealing with the issue from a social cognitive domain. Thus, he recommended future research should reexamine the traditional emphasis on content knowledge in science education.

In a second part of the investigation into reasoning in science and technology based issues, Fleming (1986b) explored how this same group of students used nonsocial cognition when analyzing science and technology based issues. From the set of interview transcripts from his previous investigation, Fleming generated three categories of statements within the nonsocial domain. These included statements about (a) the physical world (science content), (b) science terminology, and (c) scientists and the nature of science. It should be noted that the “nature of science” statements in the third category were more aligned with the characteristics and motivation of scientists than with the nature of science as defined at the beginning of this chapter. So few participants made statements about the physical world that Fleming considered these responses insignificant. To compensate for the possibility that lack of science content knowledge limited students' responses about the physical world, Fleming provided information packets for the participants' use during the interviews. However, none of the students chose to use these packets.

Fleming categorized student arguments that involved scientific terminology as a major component as “science terminology statements.” These arguments focused on such terms as “chemical” or “bacteria,” and tended to reference the scientific concepts in a cursory manner. A large majority of students (91%) used these types of arguments. When questioned, every student identified school as the source of the terms they used in their arguments. However, every student qualified his or her response by further indicating that none of the information they learned in school was useful in making decisions about the socio-scientific issues.

Fleming further probed students' perceptions of the accuracy and completeness of scientific data. Ninety-four percent of the students believed that they had complete data (i.e., they declined to use information packets related to the two issues offered by Fleming). However, in apparent contradiction, 96% said they needed more information when asked what they would need to make better decisions. Fleming believed that students rejected the information packet while expressing the desire for more information because they viewed the current data as incomplete and inaccurate. More information would result in more accuracy, but the factual knowledge must be completely true. In other words, students were only willing to alter their decisions if the added data were “totally true.”

In defending their positions on the science and technology based issues during the interviews, large percentages of participants (96%) also used statements about science and scientists. In general, the students appeared to view scientists as the finders and keepers of true (i.e., useful) facts. When Fleming asked the students what they thought scientists would say about the two issues, they were fairly evenly split in saying that the scientists would favor or oppose them. The scientists were viewed as being in favor of the nuclear power and genetic engineering plants for two reasons: career (67%) and the advancement of science and technology (33%). Students viewed scientists who opposed the two plants as having an understanding of the potential harm they could cause. When asked what professionals in non-scientific fields would say, the students unanimously replied that they would oppose both issues, because these professionals are more concerned with human effects than scientists are.

Based on these responses, Fleming concluded that students rarely, if ever, use knowledge of the physical world when analyzing and discussing science and technology based issues. It follows that school science, which emphasizes knowledge about the physical world, is not a source of useful information for student decision-making. The implication of these results is that to be useful to students, curricula dealing with science and technology based issues must emphasize the nature, strategies, and limitations of science. Further, Fleming said that the human qualities of science should be emphasized so students can better understand science as a human endeavor.

Four years after the publication of Fleming's investigations, Lederman and O'Malley (1990) explored secondary students' beliefs about the tentative nature of scientific knowledge, the sources of these beliefs, and the impact of these beliefs on their personal and societal decisions. The students of one class from each of the four science courses offered in a small, rural Oregon high school were selected to participate in the study. A total of 69 participants spanning grades 9-12 were selected; however, complete data were available for only 55 of these participants.

Students in the selected classes were asked to complete an open-ended questionnaire during the second week of the school year. The seven-item, open-ended questionnaire was designed to assess beliefs about the tentative nature of scientific knowledge with respect to each of the four "dichotomies" previously documented by Cotham and Smith (1981). The researchers analyzed the questionnaire responses by categorizing them with respect to their relation to tentative or absolutist views of science. Only four of the seven items elicited useful responses, so the researchers limited data analysis to the students' responses to these four questions. In order to identify any changes in the students' beliefs, participating students were asked to complete a posttest of the same questionnaire during the last month of the school year. Interestingly, the researchers did not ask the science teachers to specifically address the tentative nature of scientific knowledge or to purposively alter their normal instruction in the four science classes. The posttests were simply used to identify students whose views might have changed, regardless of the specific teachers and/or instructional approach.

Next, the researchers reviewed the completed questionnaires and, with the help of teachers, selected a sample of 20 students who matched the criteria of being highly verbal, representative of each grade/subject level, holding the tentative/absolutist views of science, and whose beliefs had/had not changed toward a more tentative view. This stratified sample was then interviewed in order to (a) validate the questionnaire, (b) identify the source(s) of each student's beliefs about science,

(c) elicit descriptions of any experiences which may have changed each students' beliefs, and (d) assess how students' views of the tentative nature of scientific knowledge affect their personal and societal decisions. While the inter-views were flexible, a common set of questions was asked regarding each of the specific items on the questionnaire. These questions focused on when the participants learned the answers they wrote, whether their views had changed, and what caused the change. Finally, students who had expressed a tentative view were presented with a list of scientific claims that have recently changed and asked whether such scientific claims ever caused them to change what they eat, drink, or do.

Comparison of the students' pre- and posttest questionnaire and interview responses indicated a general shift to a more tentative view of scientific knowledge over the course of the school year, especially in regard to question #2, regarding how scientists "know" what an atom looks like (Table 1). Most students were unable to provide specific sources when asked about pre- to posttest changes in their views of the tentative nature of scientific knowledge. What sources were listed included reflection on subject matter, outside reading, examples presented in class, and completing the questionnaire. Interestingly, several students indicated that they were unable to comprehend the tentative nature of scientific knowledge until they had the opportunity to learn specific examples in high school. Thus, students believed that they needed a substantial knowledge base about science before they would be able to consider questions about the nature of science.

Table 1.Percentages of Responses to Selected Pretest (N = 55) and Posttest (N = 69) Questionnaire Items

		Tentative	
	Question	Pre%	Post%
1.	After a scientist develops a theory (e.g., atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to learn about theories. Defend your answer with examples.	74.5	92.8
2.	What does an atom look like? How do scientists know that an atom looks like what you have described or drawn?	18.2	47.8
3.	Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.	5.5	8.7
4.	Some astrophysicists believe that the universe is expanding while others believe that it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?	50.9	58.0

Modified from a table originally presented in Lederman and O'Malley, 1990.

When asked how they responded to scientific claims, given their understanding of the tentative nature of scientific knowledge, each of the interviewed students indicated that they would need more proof or certainty before they would change their eating habits or lifestyles. As one student put it, “I won't go out and play with nuclear waste, but I will still eat my Twinkies.” Thus, students were apparently unable or unwilling to use their understandings of the tentative nature of science when deciding how to conduct their daily lives.

Piaget (1972) and Iozzi (1978) theorized that individuals tend to reason at more sophisticated levels in areas in which they have more knowledge. If the nature of science is related to decision-making on science and technology based issues, as is commonly assumed, then it follows that those with sophisticated understandings of the nature of science should reason differently on these issues than do those whose understandings are less developed. Thus, while the previous studies focused on the decision-making of high school students, Bell (1999) explored the decision-making of adults, both nature of science experts and non-experts. Specifically, the investigation sought to assess the influence of adults’ understandings of the nature of science on their decision-making regarding science and technology based issues and to delineate the factors and reasoning people use when making these types of decisions.

In order to assess the impact of divergent views of the nature of science on decision-making, Bell purposively selected 21 university professors to create two groups of adults most likely to possess disparate conceptions of the nature of science. In the first group were 10 university professors and scientists whose education and research pursuits provided ample opportunities for reflection on the nature of science (i.e., science educators, science philosophers, and research scientists). The second group consisted of 11 university professors of history, English, business, and education. To formally assess their views, participants completed the Views of Nature of Science Questionnaire, Form B, in conjunction with follow-up interviews (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). The 9 participants whose understandings were most consistent with current conceptions (as delineated in philosophy of science literature and science education reform documents) were assigned to Group A. The 9 participants whose undertandings were largely inconsistent with current conceptions were assigned to Group B. Three participants whose views did not clearly fall within either category were dropped from consideration to create a greater distinction between the two groups.

Participants also completed a second instrument, the Decision-making Questionnaire (DMQ), which included scenarios and accompanying questions based on a variety of print and web-based materials (e.g., Brinckerhoff, 1992; Campbell, Lofstrom & Jerome, 1997). The scenarios referred to real-world issues related to four science and technology topics on which a citizen might be expected to vote and/or make personal decisions: (a) fetal tissue implantation, (b) global warming, (c) the relationship between diet and cancer, and (d) the relationship between cigarette smoking and cancer. All four scenarios presented controversy (usually in terms of how scientists and/or individuals might interpret the complex range of relevant evidence) and were designed to evoke the kind of complex decision-making that is the goal of current science education reforms. Each scenario was followed by three to five questions designed both to elicit “yes” or “no” decisions and to encourage respondents to describe the factors and reasoning patterns influencing their decisions.

Once the final group assignments were made, participants' "yes" and "no" responses to the 15 DMQ items were tallied for each group and summed separately for each individual DMQ item and the total DMQ (Bell, 1999). A few DMQ responses were unclear or the respondents were unwilling to commit to a decision for a particular question. These responses were categorized as "undecided."

Despite their disparate views of the nature of science, the participants' responses to individual questions (whether "yes," "no," or "undecided") differed very little between Group A and Group B (Table 2). For example, the difference between "yes" decisions on the DMQ items was only 3% and the "no" decisions differed by only 1%. Bell concluded that these differences were not substantial enough to warrant the conclusion that the two groups' decisions differed in any practical sense of the word.

Table 2.Comparison of NOS Expert and Non-Expert Decisions

No. of Questions/	Response to DMQ Items		
	Yes	**No**	**Undecided**
Group A (n=9)	70%	27%	3%
Group B (n=9)	73%	26%	1%

Percentages are based on the sum total of each group's responses to the 15 DMQ items

The questions following each of the four scenarios on the DMQ instructed respondents to justify their decisions. These justifications were used to generate a list of the factors that influenced their decision-making. (In most cases, participants listed multiple factors.) The lists of factors generated for the two groups were used to determine (a) the relative influence of the nature of science in reaching these decisions, and (b) whether there were any differences in the kinds of factors listed between the two groups.

Factors were listed separately for each group per scenario and then categorized. Although the frequency of factors mentioned differed from scenario to scenario, the frequency between Groups A and B was consistent in every scenario. Overall, few differences were found in the factors influencing the two groups' decisions on the science and technology based issues of the DMQ. Factors associated with the nature of science played an insignificant role for a minority of the respondents and no clear role for the majority. Other factors, including social/political issues, ethical considerations, and personal values, appeared to dominate the participants' decision-making. These factors were in line with the results of Fleming's earlier studies (Fleming, 1986a, 1986b).

Both the DMQ and the follow-up interviews provided opportunities for participants to describe and elaborate on their reasoning on science and technology based issues. Participants were asked several questions emphasizing the equivocal nature of the science related to one or more of the scenarios. For example, in Scenario 1, participants were asked how the experimental nature of the fetal tissue treatment affected their decisions. In Scenario 3, the researcher asked participants how they made dietary decisions when nutritionists have repeatedly altered their recommendations, as in the case of the inclusion of Omega-3 fatty acid supplements in the diet.

Not all participants clearly elucidated their reasoning, but most provided multiple decision-making strategies that could be classified. A total of six different reasoning patterns were identified and were remarkably similar between the two groups. "Considering the evidence" was a strategy mentioned by all 9 participants in both groups. Four Group A and 5 Group B participants expressed a personal philosophy related to conservatism; i.e., if the evidence did not provide a clear cut answer, they decided the issue by maintaining the *status quo*, deciding in favor of safety, or using moderation. Additional strategies cited included risk analysis, cost-benefit analysis, and tempering scientific evidence with personal values and emotions.

The processes the two groups used to reach their decisions were generally similar, and as in the Lederman and O'Malley (1990) study, not always consistent with their views of the nature of science. However, in both groups an understanding of the nature of science regarding evidence emerged as only one of several reasoning patterns, which tended to emphasize personal philosophy and commitments over reasoning based on scientific evidence. Once again, the nature of science appeared to play a minor role at best in influencing their decisions.

DISCUSSION

What role, if any, do understandings of the nature of science play in decision-making on science and technology based issues? Although this area of inquiry is in its infancy, the results of these four studies allow for some tentative conclusions and implications that may provide a guide for future investigations.

That being said, the preliminary news is not good for those who have assumed that improving understandings of the nature of science will lead to better decision-making. The students in the two Fleming studies clearly emphasized the social aspects of the issues in their reasoning and decision-making. In the relatively few instances when students did speak of evidence, they typically did so in a cursory manner and rejected the offers of additional, potentially useful information. When describing the work of scientists, they spoke in terms of absolute knowledge and emphasized that for knowledge to be useful in decision-making, it had to be true in the absolute sense. In the Lederman and O'Malley investigation, students' reasoning and decision-making did not clearly match their views of the nature of science. As in the Fleming studies, the students wanted absolute knowledge before they were willing to use scientific knowledge in their decision-making. If scientists were equivocal on an issue, the students did not see scientific knowledge as an asset. The Bell investigation found little role for the nature of science in decision-making, even though the participants in this case included adults who were nature of science experts. Rather, like the high school students in the Fleming and Lederman and O'Malley studies, the adults emphasized the social and moral aspects of the issues in their decision-making and ultimately reached the same conclusions, whether they adhered to tentative or absolute views of scientific knowledge.

Decision-making as explored in these four studies was primarily impacted by factors other than the nature of science, including values and ethics. For example, as the Bell study demonstrated, participants in both the nature of science expert and non-expert groups commonly spoke of using values to help in their decision-making. For the nature of science experts, values were used in conjunction with their understandings of the relevant science:

> So, I think that as a citizen, you take the scientific information, but then you also have to make decisions based on values and societal, cultural, and personal goals. And that's true of any sort of everyday decision that relates to science and technology. I don't think anybody takes scientific information, whether it's equivocal or unequivocal and incorporates it whole clause into their everyday experience.

For the non-expert participants, values and personal experience were used *in place of* knowledge about science:

> Researcher: What would it take from science for you to make changes in your diet?
>
> Participant: I don’t know if science could do anymore at this point. I think it’s a matter of saying OK, this is something that needs incorporated in my own personal lifestyle. I need to be exercising and eating right. It has to be more of a personal concern, like a family thing. You know, “We’re worried about you and your cholesterol. We want you around for a while.” It has to be a more personal level to lead to that kind of motivation.

Either way, personal values appeared much more influential to the participants’ decision-making than did their understandings of the nature of science. Thus, the picture emerging from the Bell investigation, as well as the others reported here, indicates a role for explicit instruction on values and moral reasoning.

However, explicit instruction on values and moral reasoning would need to be pursued carefully. Certainly, it would be a mistake for teachers to merely indoctrinate students with their own particular values. Rather, this instruction could strive to make students aware of how values and moral reasoning are used in decision-making. For example, a skilled teacher might help students realize that when it comes to science and technology, there are no value-free issues. Whether the topic is nuclear power, space exploration, evolution, or saving the condors, public decisions on scientific matters always involve social implications. Making students aware of this fact, as well as the influence of their own values when considering scientific issues, would be a good start toward helping them think critically about decision-making.

Awareness of the role of values in decision-making plays a central role in the curricular framework suggested by Hodson (1994) and Pedretti and Hodson (1995). This framework for Science-Technology-Society (STS) education addresses the role of values in decision-making at four increasing levels of sophistication. The outline of this framework is presented in Table 3. At the first level, students are made aware of the intended and unintended impacts of scientific and technological change. At the second level, students begin to understand that advances in science and technology reflect particular socio-political interests and that what benefits the interests of one group may serve to harm the interests of another. The third level focuses on establishing students' own values concerning science, technology, and the environment. Finally, the fourth level provides opportunities for students to address the ways their values can be put into action in order to participate effect-tively in decision-making processes and to value and encourage the participation of those with alternative interests.

Table 3. A Framework for an Issues-Based Curriculum.

Level 1:	Appreciating the societal impact of scientific and technological change, and recognizing that science and technology are, to some extent, culturally determined.
Level 2:	Recognizing that decisions about scientific and technological development are taken in pursuit of particular interests, and that benefits accruing to some may be at the expense of others. Recognizing that scientific and technological development is inextricably linked with distribution of wealth and power.
Level 3:	Developing one's own views and establishing one's own underlying value positions.
Level 4:	Preparing for, and taking action.

(From Pedretti & Hodson, 1995)

A number of guides are currently available to teachers who wish to teach the role of values in decision-making. For example, the National Science Teachers Association has recently published the curriculum guide, *Decisions Based on Science* (Campbell, Lofstrom & Jerome, 1997). This student-centered curriculum provides a model for teaching decision-making that focuses on defining the problem, using available information to predict possible outcomes, identifying stakeholders and values, and reaching informed decisions (Figure 1). The curriculum emphasizes identification of personal values and the role they play in decision-making. The second part of the book provides a variety of issues that students can explore either independently or as a class in order to develop and hone their decision-making skills.

Figure 1. A Model for Informed Decision-making

Step One: What's the Decision?

Step Two: What Should Happen?

Step Three: What Do We Know?

Step Four: What's the Answer?

From (Campbell, Lofstrom, & Jerome, 1977)

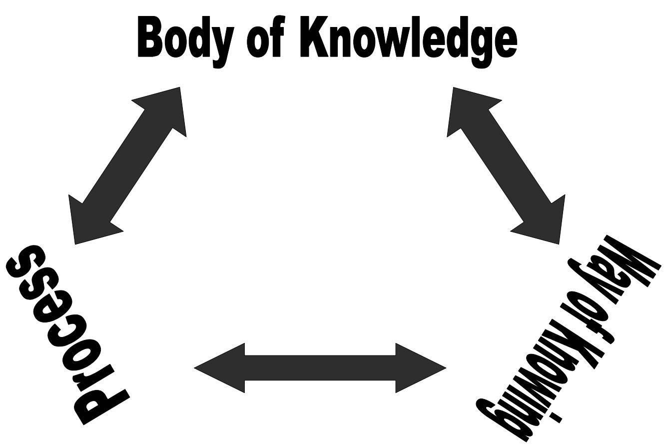
In all, 24 issues ranging from the hazards of meteors and ozone depletion to dietary decisions and smoking are included in the guide. Additionally, *Society* presents 74 issues in the form of short readings followed by provocative questions covering biology, chemistry, physics, earth science, and social science.

As students work through these decision-making exercises, they should begin to realize that there may be more than one “right” answer (or, conversely, no right answer) to some science and technology based dilemmas. By definition, real-world science and technology based issues do not involve simple solutions with single right answers. Rather, there are always multiple benefits to weigh against multiple costs. Add to this mix the problem of unintended consequences and the promotion of contradictory viewpoints by groups with opposing interests and you have the mess we know as “the real world.”

Unfortunately, current science instruction does little to provide citizens with the necessary tools to deal with real-world issues. Instead, by emphasizing breadth at the expense of depth, science instruction has tended to foster an over-simplistic and unproblematic view of science and scientific knowledge. Instruction focusing on abstract, theoretical knowledge, encyclopedic presentation of scientific knowledge in textbooks, and conformational, cookbook-style laboratory experiences conspire to paint a picture of the scientific knowledge as progressing by the result of steady and unproblematic accumulation of confirmed hypotheses (Carey & Smith, 1993).

However, in its actual practice, science is seldom so simple. This is especially true in the case of science issues and controversies, which are almost never decided by data alone – personal and social issues are always involved (Collins & Pinch, 1998; Kuhn, 1996; Popper, 1988). Exposing students to the “messiness” of science-in-the-making has the potential, to help them realize that answers in the real world are often not as clear-cut as we might like. This, in turn, should help students accept the inevitable situations in which scientists and other experts fall out on opposing sides of science and technology based issues. The goal, then, should be to help students realize that even imperfect information can be useful in decision-making.

Figure 2. Three Domains of the Scientific Enterprise



To achieve this goal, educators must provide students with a more complete picture of science. Such a picture would necessarily include several key components of science, including its products (accumulated body of knowledge), processes (methodologies), and epistemologies (nature of science). Figure 2 (above) provides one example of a useful heuristic for describing science. In this view, science is depicted as a body of knowledge, a process, and a way of knowing. While this picture of science is useful as a heuristic to facilitate students' comprehension of the multifaceted nature of the scientific enterprise, it also can serve as a guide for science instruction. It reminds science educators that, in order to accurately portray the scientific enterprise, science instruction should reflect its multifaceted nature. Focusing exclusively on the body of knowledge, as it is so easy to do, presents but a caricature of science, and, as seen in the reviewed studies, does not provide students with the kind of knowledge they need for decision-making.

Yet, addressing content, process, and nature of science in a single lesson or even a unit may seem like an impossible task. Collins and Pinch (1998) described one way this might be done. In their example, students learn science content (the boiling point of water is 100 ^{o}C), while experiencing all of the difficulties that go along with producing that knowledge. Few, if any, students get the “right answer.”

> Every classroom in which children are conducting the same experiment in unison is a microcosm of frontier science. Each such multiple encounter with the natural world is a self-contained sociological experiment in its own right. Think about what happens: the teacher asks the class to discover the boiling point of water by inserting a thermometer into a beaker and taking a reading when the water is steadily boiling. One thing is certain: almost no one will get 100 °C unless they already know the answer, and they are trying to please the teacher. Skip will get 102 °C, Tania will get 105 °C, Johnny will get 99.5 °C, Mary will get 100.2 °C, Zonker will get 54 °C, while Brian will not quite manage to get a result; Smudger will boil the beaker dry and burst the thermometer. Ten minutes before the end of the experiment the teacher will gather these scientific results and start the social engineering. Skip had his thermometer in a bubble of superheated steam when he took his reading, Tania had some impurities in her water, Johnny did not allow the beaker to come fully to the boil, Mary's result showed the effect of slightly increased atmospheric pressure above sea-level, Zonker, Brian and Smudger have not yet achieved the status of fully competent research scientists. At the end of the lesson, each child will be under the impression that their experiment has proved that water boils at exactly 100°C, or would have done were it not for a few local difficulties that do not affect the grown-up world of science and technology, with its fully trained personnel and perfected apparatus.
>
> That ten minutes’ renegotiation of what really happened is the important thing. If only, now and again, teachers and their classes would pause to reflect on that ten minutes they could learn most of what there is to know about the sociology of science. For that ten minutes illustrates better the tricks of professional frontier science than any university or commercial laboratory with its well-ordered predictable results. Eddington, Michelson, Morley, Weber, Davis, Fleischmann, Pons, Jones, McConnell, Ungar, Crews, Pasteur and Pouchet are Skips, Tanlas, Johnnys, Marys, Zonkers, Brians, and Smudgers with clean white coats and 'PhD' after their names. They all come up with wildly varying results. There are theorists hovering around, like the schoolteacher, to explain and try to reconcile. In the end, however, it is the scientific community (the head teacher?) who brings order to this chaos, transmuting the clumsy antics of the collective Golem Science into a neat and tidy methodological myth. There is nothing wrong with this; the only sin is not knowing that it is always thus. (Collins & Pinch, 1998)

Furthermore, by emphasizing the negotiated nature of the knowledge produced at the end of the lesson, the teacher can facilitate students' understandings of the sociology of science, as well as its limitations and strengths. Thus, learning about the nature of science may be seen as a metacognitive process in which students think about their thinking as they do science and science-related activities.

Interestingly, metacognition appears to be central to teaching both about the nature of science and decision-making. Nature of science instruction can be thought of as the process of teaching students to think about science. Similarly, moral reasoning instruction involves teaching students to think about reasoning. Both types of instruction involve metacognition, which involves a set of high-level thinking skills that must be explicitly taught. Teaching students to think about how they think could segue nicely into the topics of science and reasoning.

The four investigations reviewed earlier in this chapter all indicate that the nature of science played a limited role at best in participants' decision-making. At first glance, this could be bad news for those who have supposed it should play a more central role, as well as for those who have used the potential for enhanced decision-making as a justification for K-12 nature of science instruction. Perhaps the picture is not as bleak as it first appears. There are many other justifications for teaching the nature of science, including the potential for enhanced learning of science content and increased student interest (Driver, et al., 1996; McComas, Clough & Almazroa, 1998). Perhaps the most poignant justification for teaching the nature of science is so we science educators can sleep at night. Certainly, science instruction that includes the nature of science and science processes in addition to the more traditional content can be argued on moral grounds alone. It is definitely a better representation of the scientific enterprise.

In view of the seemingly tenuous relationship between understandings of the nature of science and decision-making, perhaps another lesson can be learned. Educators have long been susceptible to the notion that goals related to the nature of science may be achieved through implicit instruction. Consider the assumption that teachers' understandings of the nature of science will necessarily impact their classroom instruction (Lederman, 1992). Despite earlier widespread support for this notion, recent studies have shown that the relationship between beliefs and practice is tenuous at best (Abd-El-Khalick, Bell & Lederman, 1998; Bell, Lederman, Abd-El-Khalick, 2000; Dibbs, 1982; Lederman, 1999; Lederman & Zeidler, 1987; Mellado, 1997). Many now conclude that better understandings of the nature of science are necessary but not sufficient to enable teachers to address the topic more appropriately in their own instruction. These educators call for more explicit treatment of effective ways to teach nature of science goals and objectives in teacher preparation and professional development programs.

The assumption that improved understandings of the nature of science will lead to better decision-makers has followed a parallel course. It is tempting to assume that explicit instruction about the nature of science in itself will lead to more reasoned decision-making. However, this amounts to teaching the complex skills of decision-making implicitly. Just as teachers are unlikely to translate their understandings of the nature of science into instructional practice without explicit instruction on how to do so, citizens (including nature of science experts) are unlikely to translate their nature of science understandings into decision-making in the absence of specific instruction on how to do so.

It is important to remember that, in most cases, students learn only what they are taught. That is not to say that implicit learning does not occur; however, it seldom results in the achievement of desired goals. Besides, why leave the learning of critical goals and objectives to chance? If our goal is to produce better decision-makers, and we have reason to believe that more adequate understandings of the nature of science can facilitate decision-making, then perhaps we need to provide more explicit instruction on how to use understandings of the nature of science when making decisions on science and technology based issues. Rather than assuming that students will put their new-found understandings of the tentative nature of science to good use, we should encourage them to apply their under-standings to issues on which experts do not agree and science does not provide a single clear answer. For example, instead of students' relying solely on their own values and experiences, they could be encouraged to apply their understandings of scientific theories to the issue of whether evolution should be taught in public schools and whether creationism is viable as a scientific theory. Rather than viewing reverses in dietary recommendations as "flip-flopping" and giving up on science as "the boy who cries wolf" (as Mike Renfrow suggested in his National Public Radio commentary), students could be encouraged to apply their views of the revisionary nature of science.

Thus, we can view the somewhat discouraging initial results of the empirical studies reviewed in this chapter both as a challenge and as a reminder that "there is no free lunch" in education. Without explicit, purposive instruction, the possibility of improving decision-making is likely to remain a pipe dream.

REFERENCES

Abd-El-Khalick, F., Bell, R. L., & Lederman, N.G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education, 82,* 417-436.

American Association for the Advancement of Science. (1989). *Project 2061: Science for all Americans.* Washington, DC: Author.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy: A Project 2061 report.* New York: Oxford University Press.

Bell, R. L. (1999). Understandings of the nature of science and decision making on science and technology based issues (Doctoral dissertation, Oregon State University, 1999). *Dissertation Abstract International, 60*, 3310.

Bell, R. L. (in press). Perusing Pandora's Box: Exploring the what, when, and how of nature of science instruction. In L. Flick & N. Lederman (Eds.), *Scientific inquiry and nature of science: Implications for teaching, learning, and teacher education.* The Netherlands: Kluwer Academic Publishers.

Bell, R. L., Lederman, N. G., & Abd-El-Khalick, F. (2000). Developing and acting upon one's conception of the nature of science: A follow-up study. *Journal of Research in Science Teaching, 37,* 563-581.

Brinckerhoff, R. F. (1992). *One-minute readings: Issues in science, technology, and society*. New York, NY: Addison-Wesley.

Campbell, V., Lofstrom, J., & Jerome, B. (1997). *Decisions based on science*. Arlington, VA: National Science Teachers Association.

Carey, S., & Smith, C. (1993). On understanding the nature of scientific knowledge. *Educational Psychologist, 28*, 235-251.

Collins, H. M. & Pinch, T. (1998) *The golem: What you should know about science*. (2nd ed.). Cambridge, MA: Cambridge University Press.

Collins, H. M., & Shapin, S. (1986, June 27). Uncovering the nature of science. *Times Higher Educational Supplement.* Reprinted in J. Brown, A. Cooper, T. Horton, F. Toates, & D. Zeldin (Eds.) (1986) *Science in schools,* (p. 71-77). Milton Keynes: Open University Press.

Cotham, J., & Smith, E. (1981). Development and validation of the conceptions of scientific theories test. *Journal of Research in Science Teaching, 18*(5), 387-396.

Davidson, P., Turiel, E., & Black, A. (1983). The effect of stimulus familiarity on the use of criteria and justification in children's social reasoning. *British Journal of Developmental Psychology, 1*, 49-65.

Dibbs, D. R. (1982). *An investigation into the nature and consequences of teacher's implicit philosophies of science*. Unpublished dissertation. University of Aston, England.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science.* Philadelphia: Open University Press.

Fleming, R. (1986a). Adolescent reasoning in socio-scientific issues, Part I: Social cognition. *Journal of Research in Science Teaching, 23,* 677-687.

Fleming, R. (1986b). Adolescent reasoning in socio-scientific issues, Part II: Nonsocial cognition. *Journal of Research in Science Teaching, 23,* 689-698.

Hodson, D. (1994). Seeking directions for change: The personalisation and politicisation of science education. *Curriculum Studies, 2*, 71-98.

Iozzi, L. (1978). The environmental issues test (EIT): A new assessment instrument for environmental education. In C. Davis and A. Sacks (Eds.), *Current issues in environmental education-IV.* Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education, 1978, 200-206.

Kuhn, D., Amsel, E., & O'Loughlin, M. (1989). *The development of scientific thinking skills.* New York: Academic Press.

Kuhn, T. S. (1996). *The structure of scientific revolutions*. 3rd Edition. Chicago: The University of Chicago Press.

Lederman, N. G. (1983). *Delineating classroom variables related to students' conceptions of the nature of science.* (Doctoral dissertation, Syracuse University, 1983). *Dissertation Abstracts International, 5-02A,* 0483.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*, 331-359.

Lederman, N. G. (1999). Teachers' understandings of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching, 36*, 916-929.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire (VNOS): Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*, 497-521.

Lederman, N., & O'Malley, M. (1990). Students' perception of tentativeness in science: Development, use, and sources of change. *Science Education, 74*(2), 225-239.

Lederman, N. G., & Zeidler, D. L. (1987). Science teachers' conceptions of the nature of science: Do they really influence teaching behavior? *Science Education, 71,* 721-734.

McComas, W. F., Clough, M.P., & Almazroa, H. (1998). The role and character of the nature of science in science education. In W. McComas (Ed.), *The nature of science in science education: Rationales and strategies* (p. 3-39). The Netherlands: Kluwer Academic Publishers.

Mellado,V. (1997). Preservice teachers' classroom practice and their conceptions of the nature of science. *Science & Education, 6*, 331-354.

Millar, R. & Wynne, B. (1988). Public understanding of science: From contents to processes. *International Journal of Science Education, 10*(4), 388-98.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academic Press.

Pedretti, E. & Hodson, D. (1995). From rhetoric to action: Implementing STS education through action research. *Journal of Research in Science Teaching, 32*, 463-485.

Piaget, J. (1972). Intellectual evolution from adolescence to adulthood. *Human Development, 15*, 1-12.

Popper, K. R. (1988). *The open universe: An argument for indeterminism*. London: Routledge.

Shamos, M. (1995). *The myth of scientific literacy*. New Brunswick, NJ, Rutgers university Press.

Smith, M.U., Lederman, N.G., Bell, R.L., McComas, W.F., & Clough, M.P. (1997). How great is the disagreement about the nature of science? A response to Alters. *Journal of Research in Science Teaching, 34,*1101-1103.

CHAPTER 4

BELIEFS IN THE NATURE OF SCIENCE AND RESPONSES TO SOCIOSCIENTIFIC ISSUES

Michael L. Simmons & Dana L. Zeidler

INTRODUCTION

It has been said that if educators wish to stimulate thinking and reasoning skills, then students must be given something to think about (Brown, 1997). Certainly, one of the most powerful stimuli to thinking is the consideration of moral and ethical issues. As virtually anyone who has become involved in heated discussions regarding sex, politics, or religion can attest, people often tend to react eagerly when their existing conceptions of the morality of such issues are challenged. For a number of reasons, many science educators are reluctant to present curriculum that evokes strong emotions, unintentionally rejecting an effective pedagogical strategy. In this chapter, we present our case that science educators should include controversial socioscientific issues in their curricula. By engaging in carefully selected moral problems in the domain of science, we believe that students can and will develop logical and moral reasoning skills while they gain a deeper understanding about important aspects of the nature of science.

The purpose of this chapter is to describe rationale and methods useful to science educators who strive to include moral development in science curricula while simultaneously addressing the nature of science. To that end, this chapter is arranged into two parts: first, an overview of the theory and practice of using controversial scientific dilemmas and anomalous data in the classroom to address the nature of science; and second, a synopsis of a recent research study investigating the reactions of students to contentious socioscientific issues, dialogic interaction, and contradictory evidence, and the relationships between these instructional strategies and students' conceptions of the nature of science. By providing a theoretical framework combined with real world examples of using socioscientific issues in the classroom,

D.L. Zeidler (ed.),
The Role of Moral Reasoning on Socioscientific Issues and Discourse in Science Education, 81-94.

we hope that this chapter serves as a guide for educators and researchers seeking methods that can be used to both reveal and teach critical thinking skills, moral and ethical reasoning, and the nature of science.

PART ONE: OVERVIEW OF SOCIOSCIENTIFIC ISSUES AND REASONING WITH ANOMALOUS DATA

Critical Thinking and Moral Reasoning

The development of critical thinking skills has been and continues to be among the central goals of science literacy (AAAS, 1993). While no universally accepted definition of critical thinking exists, even a cursory review of seminal and recent literature reveals a core of key attributes. For example, Ennis (1962) provides a general and concise definition of critical thinking as an assessment of the correctness of statements. Dick's (1991) review of critical thinking literature from 1946 to 1987 resulted in a detailed taxonomy comprising fifteen types of critical thinking divided into five categories: identifying arguments, analysing arguments, external forces, scientific analytic reasoning, and reasoning and logic. Paul (1990) described "thinking about your thinking" (p. 32) as an important factor in critical thinking, although Lipman (1991) refined that definition by including the necessity of self-regulation of metacognition as a prerequisite for metacognition to be considered a critical thinking component. For the purposes of this paper, Ennis's more recent (1991) description of critical thinking as the "reasonable reflective thinking that is focused on deciding what to believe or do" (p. 5) will be used here because of its applicability to moral and ethical decision-making. We should also note, however, that this view is also consistent with Dewey's (1910) conceptualization of critical thinking which was evaluative in nature in terms of assessing claims, suppositions, procedures and influences arguments at-hand.

Critical thinking and moral reasoning are intimately entwined in both theory and practice. Autonomous moral and ethical judgments necessarily require skilled dialectical thinking (Allegretti & Frederick, 1995; Paul, 1984), and these types of thinking skills may be developed by using appropriate curricula (Allegretti & Frederick, 1995; Kohlberg, 1972; Kuhn, 1999). While the literature is replete with methods for developing critical thinking (Chapman, 2001; Zimmerman, 2000; Zohar, Weinberger & Tamir, 1994), and much has been written about moral and ethical development (Berkowitz, 1997; Kohlberg, 1987; Nucci, 2001), the precise nature of interaction between these two constructs remains open for further investigation.

Briefly, ethics may be defined as the theory of what is right while morality is the practice of conduct that is right (Sahakian & Sahakian, 1966). In order to make moral decisions, a person must think critically about available and relevant information. It may be argued that developing a mature epistemology about socioscientific issues in science requires the evaluation and analysis of claims and influences. For example, to appreciate the empirical nature of science, one must understand what constitutes data, and it seems likely that critical thinking skills are involved in the evaluation of information in order to identify data. Moral judgments about what how one should act having knowledge of those data then entail ethical dimensions of science. This is akin to policymaking, which also plays a central role when discussing moral and ethical issues in science classrooms that are not detached from social concerns (Zeidler, 1984). Critical thinking and ethics now become conjoined in that policymaking involves deliberation, negotiation, and collectively derived decisions and the only way for conflicting parties in a controversial situation to achieve some degree of optimal resolution is to evoke critical reasoning. Consider the following scenario entailing ethical discourse:

> By optimality I mean to refer to the best composition of conflicting goals so that optimization of the whole set may require something less than the maximization of each in order to get the greatest amount of them all combination. The concept of 'optimality' understood in this way is an interesting notion. There is a kind of duality in its logic that may well mark it off as unique. On the one hand it has to do always with what can be chosen. Therefore, it is always related to the possible. "Optimal' means 'feasible'. But on the other hand, even etymologically, 'optimality' relates to what is best. There is always that normative aspect to its logic. On the one hand, the concept of optimality deals always with what is possible, but on the other hand, it touches on what is ideal, which is best (Green, 1975, p.76).

Making rational and informed decisions about socioscientific topics therefore requires arriving at optimal resolutions which in turn demand making critical moral judgments about information relevant to the conflicting goals.

Socioscientific Issues and Moral Reasoning

If we hope to stimulate and develop students' moral reasoning abilities, then we must provide students with rich and varied opportunities to gain and hone such skills. Our present argument rests on the assumption that using controversial socioscientific issues as a foundation for individual consideration and group interaction provides an environment where students can and will develop their critical thinking and moral reasoning skills. As discussed in the introduction to this book, socioscientific issues are equated with the consideration of ethical issues and construction of moral judgments about scientific topics via social interaction and discourse. Accordingly, students will be confronted with multiple perspectives to moral problems that inherently involve discrepant viewpoints and information – sometimes at odds with their own viewpoints. The joint construction of scientific knowledge that is at once personally relevant and socially shared therefore relies on exposure to, and careful consideration of data that may be in conflict with one's existing conceptions. We believe that educators can foster and enhance both critical thinking and moral reasoning by carefully providing data that does indeed conflict with the students' beliefs. We will use the term "anomalous data" to indicate empirical data, dialogic interaction, and logically supported position statements that conflict with a person's pre-existing beliefs regarding scientific concepts or issues.

Why Use Anomalous Data?

Piaget's classic work asserting that cognitive development occurs when individuals experience cognitive dissonance as a result of exposure to information that does not easily fit into a person's existing schema (Inhelder & Piaget, 1958; Piaget, 1965) serves as the foundation for our present discussion. If educators wish to stimulate thinking in this way, then we must develop methods that create cognitive dissonance. Since Piaget's pioneering work, a number of researchers have employed and evaluated the effects of using anomalous data to foster conceptual change. One early theory of conceptual change in science education delineated the following four important factors necessary for accommodation to occur: 1) There must be dissatisfaction with existing conceptions; 2) A new conception must be intelligible; 3) A new conception must appear initially plausible, and 4) A new concept should suggest the possibility of a fruitful research program. (Posner, Strike, Hewson & Gertzog, 1982). More recently, Driver, Leach, Millar and Scott (1996) have extended the idea of examining how students handle conflicting evidence related to socioscientific issues. It seems clear that students can draw upon past experiences and combine them with new information to help explain actions in a scientific context through carefully planned science pedagogy.

Chinn and Brewer (1998) concisely describe the elemental assumption regarding the use of anomalous data in science education as follows: "The instructional use of anomalous data assumes that anomalous data produce conflict or cognitive dissonance and that students will resolve the cognitive conflict by bringing their personal conceptions closer in line with scientists' conceptions" (p. 624). Researchers have presented models of epistemological change related to the use of anomalous data and have found that students' patterns of reasoning can be revealed through the use of anomalous data during discussions about scientific and socioscientific information (Chinn & Brewer, 1993, 1998; Zeidler, 1997). While the use of anomalous data (e.g. conflicting data, differing positions, counter arguments and the like during "debate" formats) does reveal students' patterns of thought, it does not ensure that students will alter their beliefs. The teacher remains central as a facilitator to ensure that students will have practice and experience in cultivating habits of mind consistent with mature understandings of how scientific knowledge may be used in the process of decision-making. In short, teachers need to present a vision of scientific literacy that incorporates the social dimensions of the nature of science.

Socioscientific Issues and the Nature of Science

For over ten years, the nature of science has received considerable attention from scholars in the field. Although different authors include or exclude varying aspects of the nature of science in descriptions of what science is, several characteristics appear repeatedly in the literature. Many philosophers of science and science education researchers agree that science is tentative, socially and culturally influenced, subjective, and while empirically based, is also a product of human creativity (see, for example, Lederman, 1992; McComas, Clough & Almazroa, 2000). These particular aspects of the nature of science (NOS) are especially prominent when evaluating controversial socioscientific issues.

Currently, several instruments are available that can assist researchers and educators who wish to ascertain the NOS understandings of students at all grade levels (see, for example, Abd-El-Khalick & Lederman, 2000). We contend that using socioscientific issues in the daily curriculum is another means of eliciting NOS beliefs in students in a manner that serves as a basis for continued dialogue, student interaction, and in-depth research into familiar real-world issues. Once these beliefs are revealed, the researcher or educator may design continuing curriculum aimed at facilitating deeper understanding of NOS as well as developing critical thinking skills related to socioscientific issues. Furthermore, by examining the tacit beliefs that students hold about scientific research and how those beliefs interact with the nature of a socioscientific topic, we can add to our understanding of the social construction of knowledge. It may be the case, for example, that students conflate the role of selecting evidence in making scientific judgments with personal opinions. Awareness of how personal beliefs affect decisions concerning scientific information is certainly important in terms of achieving functional knowledge of scientific literacy.

With these foundations in mind, we now turn to a recent study where this approach to eliciting student beliefs about socioscientific issues revealed the complex and varied nature of students' thinking regarding NOS and the role of science in their lives. This research review is intended to serve as an example of how educators may use socioscientific issues and anomalous data in order to reveal how students view the relationships between science and moral decision-making. With this knowledge, teachers may create an environment where students concurrently develop their understandings and knowledge in the domains of science content, the nature of science, logic, and moral decision-making.

PART TWO: USING DATA TO EVOKE REFLECTION ON NATURE OF SCIENCE AND SOCIOSCIENTIFIC ISSUES

The second portion of this chapter consists of an extended synopsis of a recent study aimed at exploring the relationships between students' views of the nature of science and their reactions to anomalous data pertaining to socioscientific dilemmas [see Zeidler, Walker, Ackett & Simmons (2002) for a thorough description of the study]. Research findings in this study provide insight into how students respond to and interpret data in the context of their pre-existing beliefs regarding science concepts, nature of science understandings, and thought processes resulting in the students' decision-making. We present this overview as an example of the classroom application of socioscientific dilemmas, the pedagogical value of these strategies, and the teacher's role in presenting controversial issues in the classroom. Additionally, directions for future research may be elucidated by the description and findings of this study.

The pivotal research question in the study was: "In what ways are students' views of the nature of science reflected in their reactions to socioscientific issues when confronted with information that challenges their initial beliefs?" In order to gain insight towards answering this question, the researchers conducted a study focusing on 82 participants identified as "critical cases" selected from a sample of 248 students including 28 students in 9th and 10th grade at an alternative high school program, 119 11th and 12th grade honors biology, biology, and physics students from an urban high school, and 101 students in preservice elementary science methods classes at a large south eastern state university. Of the 82 "critical case" students, 54 were from the high school level while 28 were college students.

During the first of three stages of the study, the 248 initial participants were asked to respond to four questions regarding four aspects of the nature of science (NOS). Specifically, the questions were intended to address the tentative, empirical, socially and culturally influenced, and creative aspects of the nature of science. The questions were previously used in other studies of student perceptions of the NOS (Bell, Lederman & Abd-El-Khalick, 2000; Lederman and Abd-El-Khalick, 1998; Lederman & O'Malley, 1990), and were open ended in design. The questions were:

1. After scientists have developed a theory, does the theory ever change? If you believe that theories do change, explain why we bother to teach scientific theories.
2. Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer.
3. Some astronomers believe that the universe is expanding while others believe that it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?
4. How are science and art similar? How are they different?

These four questions address the characteristics of science as being tentative, empirically-based, theory-laden, socially and culturally embedded, and creative, respectively.

The second stage of the study occurred approximately 1 week after the first stage. All 248 student participants were presented with a controversial socio-scientific dilemma regarding the use of animals in medical research. The dilemma was derived from Brinckerhoff and Zeidler (1992), and required the students to rate their beliefs on an ordinal scale followed by open-ended justification of their positions, given more specific details regarding the dilemma. From this survey, 41 pairs of students were selected based upon the strength of conviction reported in their responses. These 82 students were selected to purposefully obtain pairs with opposing viewpoints, and each student was assigned a counterpart who had expressed similar (although diametrically opposing) belief conviction strengths. Within two weeks of the original survey, each pair of students was interviewed by an investigator who was not the students' teacher. The interviewer, following a semi-structured protocol, supervised a dialogue between each pair of students and provided anomalous data conflicting with the each student's previously determined belief convictions regarding animal testing in scientific research. The interviewer began by giving the students copies of their original responses to the animal rights survey, then asking them to restate their position and their reasons for their beliefs for the benefit of their companion in the interview. The interviewer followed by asking scripted questions intended to elicit and reveal the participants' beliefs and reasoning processes resulting in those beliefs, as well as to provide a foundation for dialogic interaction in the subsequent portion of the interview. The four probing questions were:

1. If you had to convince (the other person) that your view is right, what evidence of proof would you say or show to persuade him/her?
2. Could (the other person) prove that you were wrong? Why? Why not?
3. Could more than one point of view on this matter be right? Please explain.
4. How does either scientific knowledge or opinion play a role in each of your positions? (Zeidler et al., 2002)

The questions were interjected sequentially at various points during the interview as the students interacted and responded to the probes. After the student dialogue had reached completion (as judged by repetition or diminished responses), each student was given one of two fictitious, yet "official-looking" press releases promoting the point of view opposite that which each student had previously expressed. After reading the fictitious reports, the students were given a written instrument asking them to rate their confidence in the report and its effects on their opinion regarding animal testing.

The interviews were tape-recorded and the interviewer also took notes during the dialogues. After transcription, the researchers developed a taxonomy of responses representing the students' beliefs regarding several characteristics of the nature of science. The following discussion illustrates how students' reactions and comments reveal their patterns of beliefs and reasoning regarding NOS.

Key Findings

In the study, the focal socioscientific issue was animal testing, a topic that serves as an example of a controversial issue certain to stimulate discussion in science classrooms. Most students in the study expressed strong opinions on the subject, and statements made during the interviews reflected the complex nature of the interplay between students' understandings of the nature of science and their thought processes leading to the development of their positions. The issue was chosen based on its potential for provoking student interest, eliciting emotional responses, and providing a rich context of science content for consideration. The reactions to such an issue serve as an outstanding example of the utility of using socioscientific dilemmas in the science classroom.

A popular topic in the study of student perceptions of the nature of science is the role of theories in science. Participant opinions in this study were divided between individuals who believe that scientific theories are static and those who understand the tentative nature of theories. For example, one student stated that "once a theory has been proved enough it does not change" while another responded that "Theories change when more information is discovered that may shed doubt on previous ideas." Another student wrote "We teach theories to students to explain phenomena. However, theories are meant to be tested and challenged." These examples demonstrate how assessing students' views of NOS can provide a starting point for teachers to facilitate development of students' understanding.

Opinions, Data, and Scientific Knowledge

One of the most remarkable phenomena emerging from this study was the tendency for students to bestow empirical validity on socio-cultural beliefs and personal opinion. As stated previously, two of the most universally-recognized characteristics of the nature of science are its empirical base and its social and cultural aspects. When confronted with the question aimed at soliciting students' views of the role of opinions versus data in science, the participants expressed a diverse variety of beliefs ranging from the importance of empirical data in science to the personal independence and unassailable nature of opinion. Time and again, students conflated the roles of scientific knowledge, opinion and empirical data, sometimes even asserting that knowledge and opinion were virtually equivalent. To illustrate, the following student statements were recorded in response to the question regarding the difference between scientific knowledge and opinion:

> If we make a statement about a theory then it can be assumed as an opinion because theories have not been proven for sure.
>
> An opinion requires little qualifying other than a person's own knowledge and feeling about an issue.
>
> Scientific knowledge can always be an opinion but has facts or proof behind it to back it up.
>
> One man's knowledge is always another man's opinion and vice versa.

It is clear that many students have a nebulous understanding about the need for data in making scientific decisions. Indeed, the meaning of the term "data" is often misused or confused by both high school and college students. The following concept map (see Figure 1) provides a schematic representation of how high school and college students perceive the relationships between scientific knowledge and opinion.

A powerful testament to the importance placed on opinion as a valid source of motivation for decision-making emerged as some students described the role of their religious beliefs on their viewpoint regarding animal testing. Several students attempted to combine religious views with scientific theories in order to defend their stance. For example, one student in favor of animal testing stated that God put the animals on Earth [religious belief] so that they would be part of the food chain [scientific belief]. Another claimed that God's intent was that animals would be part of a life cycle where the stronger predator would win, thereby commingling religious beliefs about creation with Darwin's theory of natural selection. Other students opposed to animal testing also invoked the will of God as reason to prohibit testing, granting animals and humans equally sacred status because "God [created] humans as He did animals." Even more interesting was the tendency for a few students to deplore animal testing, yet to suggest the alternative of using death row inmates instead, thereby assigning them lower moral status than animals!

Is there a difference between scientific knowledge and opinion?

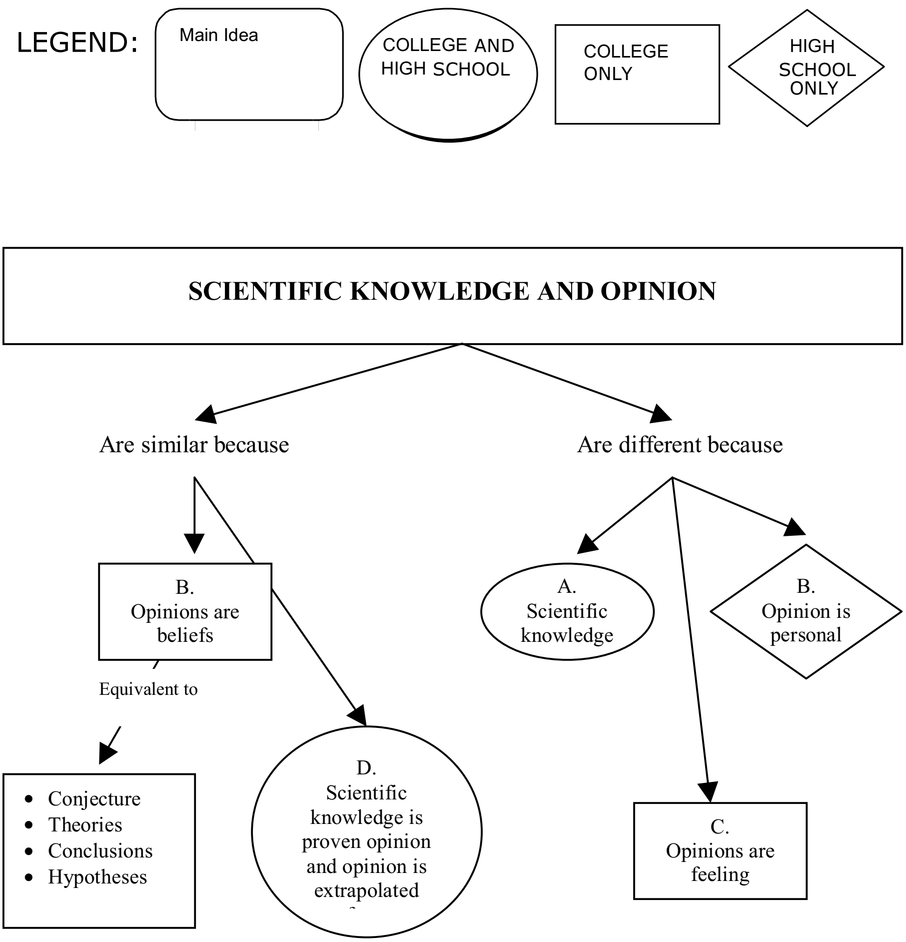


Figure 1 NOS: Subjectiveness in Science

Responses to Anomalous Data: Reasoning, Fallacious Reasoning, and Other Responses

As stated earlier, one of the goals of this chapter is to help elucidate the critical thinking processes of students when confronted with anomalous data. The investigators repeatedly observed cases of fallacious reasoning in the interviews of the students. Many examples of formal and informal fallacies have previously been reported (Zeidler, Lederman, and Taylor, 1992; Zeidler, 1997), and fallacious reasoning has been shown to be central to critical thinking processes (Zeidler, 1997). The unique focus of this investigation was to examine the nature of more common informal fallacies as they occur through dialogic interaction about socio-scientific issues. Four common fallacies are discussed to demonstrate how students responded to anomalous information from other students. The nature of the fallacy is discussed in each of the following examples.

Confirmation Bias

One student who strongly disagreed with the use of animals for medical research demonstrated a striking example of confirmation bias in her reasoning. The connection between her belief persistence regarding the abuse of animals and her evaluation of new evidence that runs counter to her viewpoint is evident in the student's response in how she would account for that discrepant evidence:

> I don't know… again I would have to listen to both of them how is this doctor or scientist able to use no animals and find cures and what are you doing wrong that you have to use animals. ...if someone came to me with all the information, here is all the people that were saved and you saw the people or you saw the statistics who was saved and what they did. My concern would be the animals, how did it hurt the animals. Did they inject Chemo and see how long they suffered? ...I would want to see the statistics more on the animals.

Note that the implicit assumption in the student's explanation for the alternative point of view is that it stems from a priori assumption of faulty methodology. This reasoning strategy has the effect of serving as a self-selecting filter to evaluate only confirming evidence in support of one's ethical position on a socio-scientific issue.

Validity Concerns

In the following selection, the student may be able to accept data or arguments contrary to his/her own beliefs, but remains "agnostic" or rejects the validity of a claim because of the mediating effect that emotive considerations bring to bear on a problem, which may conflate the validity of alternative data or information:

> the pictures are more powerful because that hits your emotional side so that you know what the facts are they help you make up your mind if you are looking at it logically and rational. But, it you see a picture then your emotions are going to come into play no matter what you do… If you are shown a picture of a war where 10,000 men are being bombed and one little dog walks through the thing and gets bombed and everyone starts crying. But, it's seeing the innocence of it, it's like a baby that cries and you feel for the baby because of the innocence of the child and, it's like that for the animal. You know

> the facts are good and the facts are the best way if you are going to look at it logically – (we are) going to think with our emotions.

Normative Reasoning

A fairly regular occurrence was that students frequently referred to previous personal experience and used those experiences to argue their point of view. This tended to occur with such regularity that their subjective and highly personal experiences played a constant role in mediating ethical judgments on socio-scientific issues. The following is typical of the extent to which normative social factors influenced students' reasoning:

> See, I have been through an experience like that. My aunt had MS. She passed away about two years ago. With something like that it is completely awful to see somebody go through and if it came down to that, I would say, primate or not, let's find what works. Just because seeing the deterioration and all – and I would feel bad for the animals – but of course you're talking about a family member. But just nobody, no person should have to go through those kind of things. Any method that we could find to reach a cure for that even if it doesn't work, we know that that doesn't work now.

Science teachers must be aware of the strong tendency of students to relate socioscientific issues to their own experiences. It is essential that students be informed of their own personal prejudices in order to progress in their understanding of the "big picture" regarding controversial socioscientific dilemmas.

Altering Representation of Argument and Evidence

Consistent with prior research (Kuhn, 1991; Zeidler and Schafer, 1984), students discussing socioscientific problems often exceed the "boundaries of evidence" provided in a fictitious scenario. Students, at times, add pragmatic inferences to the arguments under consideration by allowing their personal beliefs to mediate the argument at hand. In the following example, a student uses anthropomorphic reasoning to endow a sense of utilitarianism and purposeful means-to-ends decisions for primates:

> My grandmother has arthritis. She is in another country but they are doing testing on her to see if it could help her and possibly other people. I mean, sure the animal has no say in it, but I am sure that if they did, they would agree to it.

The partner's response takes on the same anthropomorphic reasoning and exceeds the boundaries of evidence when she adds the following pragmatic inference during their discussion:

> One (issue) that comes to my mind is the chimpanzees in the Air Force. They were exposed to radiation. They taught these chimpanzees to fly planes. Then, you know, they dropped the bombs and the fallout. Chimpanzees were actually exposed to radiation.

Chimpanzees that fly planes, drop atomic bombs, and become exposed to radiation as a result? If nothing else, using socioscientific dilemmas in the classroom can result in startling revelations for the classroom teacher! While this may be an extreme example of the types of reasoning that students might employ during classroom discourse, the teacher should be prepared for remarkably unique statements and arguments.

Teacher Preparation

The above selections represent but a few of the responses to a controversial socioscientific issue that could provide the classroom teacher with a powerful and engaging foundation for discussion of the nature of science as well as fostering the development of critical thinking skills. It must be noted, however, that in order for a teacher to use a controversial socioscientific issue in the classroom, the teacher should be knowledgeable regarding the issue, skillful in guiding class discussions, and familiar with logic necessary for critical thinking. Furthermore, if the teacher wishes to address characteristics of the nature of science, then a strong working knowledge of NOS is also necessary. If these requirements are met, the teacher can develop curriculum that is at once content-based, relevant to students' real-world knowledge and experience, and useful in developing the students' understanding of the nature of science and logical reasoning skills. We expect, however, that many teachers would be hesitant to implement these strategies at least in part due to uncertainty regarding how students might react to such controversial issues, and we therefore suggest that in-service as well as preservice teachers become familiar with the theoretical background and practical application of using socioscientific issues through science teaching methods courses and in-service training.

Because this chapter is meant to serve as a guide to pedagogy, we offer the following brief general curriculum plan as but one example of how a teacher may develop lessons using socioscientific issues. First, the teacher should choose an issue that is relevant and developmentally appropriate for the student population involved. For example, discussions of genetic engineering require more detailed scientific knowledge than most middle-school students have mastered, but animal testing may be a topic these students can consider. Once the topic is chosen, the teacher can assess the students' opinions regarding the topic using a simple instrument such as the one described above. A lively classroom discussion can follow, with the teacher guiding the discussion, assisting the students in clarifying their positions, interjecting both content and logical considerations, and facilitating student exploration of the issue. Next, students could write position statements using data and evidence to support their stance. A mock "science conference" could be held, with a vote taken determining the "official" class opinion. In order to explicitly teach about the nature of science, the teacher should inform the students how such an activity mimics the reality of the scientific community. Certainly, this type of lesson could be expanded to include guest speakers, independent research projects, and exercises in formal logic skills. It is inherently obvious, however, that the possibilities of using socioscientific dilemmas for a vast array of pedagogical goals are virtually inexhaustible.

Recommendations for Future Research, Policy, and Practice

The growing interest in socioscientific issues as a valuable pedagogical approach in science education dictates intensified research regarding the theoretical basis and classroom application of these strategies. One of the more obvious areas that must be explored is the stage-appropriateness of the possible moral and ethical issues considered. What types of dilemmas are suitable for 4th graders? Can high school juniors and seniors be expected to consider the merits and dangers of human cloning? How should a middle school teacher react when a student announces that he or she objects to discussions regarding stem cell research? These and many other questions must be answered through research into developmentally appropriate issues and pedagogical techniques if socioscientific issues are to become mainstream in science education. We hope that this book inspires interested science educators and researchers to explore the fertile possibilities of using socioscientific issues as a regular part of science instruction.

The ways in which a teacher can use controversial socioscientific issues in the classroom are limited only by the teacher's interest, skills, and commitment. We believe that the current surge in interest in socioscientific issues as a valuable tool to simultaneously address data interpretation, critical thinking processes, and nature of science understanding will undoubtedly continue, and further research into the theoretical base and practical application of this pedagogical approach will provide both researchers and practitioners with an intellectually stimulating and emotionally appealing approach to the development of scientific reasoning skills as well as increased understanding of science content and the nature of science. By using socioscientific issues, the science educator can provide a rich environment leading to a deeper understanding of and greater appreciation for the relationships between science, morals, ethics, and society.

REFERENCES

Abd-El-Khalick, F., & Lederman, N. G. (2000). The influence of history of science courses on students' views of the nature of science. *Journal of Research in Science Education, 37*(10), 1057-1095.

Allegretti, C. L. & Frederick, J. N. (1995). A model for thinking critically about ethical issues. *Teaching of Psychology, 22*(1), 46-48.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

Bell, R.L., Lederman, N. G., & Abd-El-Khalick, F. (2000). Developing and acting upon one's conception of the nature of science: A follow up study. *Journal of Research in Science Teaching, 37*(6), 563-581.

Berkowitz, M. W. (1997). The complete moral person: Anatomy and formation. In J. M. DuBois, ed., *Moral issues in psychology: Personalist contributions to selected problems*. Lanham, MD: University Press.

Brinckerhoff, R. F., & Zeidler, D. L. (1992). *Values in school science: A teacher's handbook*. Reading, MA: Addison-Wesley.

Brown, A. (1997). Transforming schools into communities of thinking and learning about serious matters. *American Psychologist, 52*, 399-413.

Chapman, B. S. (2001). Emphasizing concepts and reasoning skills in introductory college molecular cell biology. *International Journal of Science Education, 23*, 1157-1176.

Chinn, C. A., & Brewer, W. F. (1993). The role of anomalous data in knowledge acquisition: A theoretical framework and implications for science instruction. *Review of Educational Research, 63*(1), 1-49.

Chinn, C. A., & Brewer, W. F. (1998). An empirical test of a taxonomy of responses to anomalous data in science. *Journal of Research in Science Teaching, 35*(6), 623-54.

Dewey, J. (1910). *How we think.* Boston: D.C. Heath.

Dick, R. D. (1991). An empirical taxonomy of critical thinking. *Journal of Instructional Psychology, 18,* 79-92.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science*. Bristol, PA: Open University Press.

Ennis, R. H. (1962). A concept of critical thinking. *Harvard Educational Review, 32*, 81-111.

Ennis, R. H. (1991). Critical thinking: A streamlined conception. *Teaching Philosophy, 14*, 5-24.

Green, T.F. (1975). *Perspective on thinking about change*. Report for: Exploration Fund of the Kettering Foundation.

Inhelder, B. & Piaget, J. (1958). *The growth of logical thinking: From childhood to adolescence*. New York: Basic Books, Inc. Publishers.

Kohlberg, L. (1972). Development as the aim of education. *Harvard Educational Review, 42*(4), 449-496.

Kohlberg, L. (1987). The cognitive-developmental approach to moral development. in P. F. Jr. Carbone (Ed.), *Value theory and education* (p. 226-243). Malabar, Florida: Robert E. Krieger Publishing Company.

Kuhn, D. (1991). *The skills of argument*. Cambridge: Cambridge University Press.

Kuhn, D. (1999). A developmental model of critical thinking. *Educational Researcher, 28*(2), 16-25.

Lederman, N.G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*(4), 331-359.

Lederman, N. G. & Abd-El-Khalick, F. (1998). *Avoiding de-natured science: Activities that promote understandings of the nature of science*. Paper presented at the annual meeting of the Association for the Education of Teachers in Science, Minneapolis, Minnesota.

Lederman, N. G. & O'Malley, M. (1990). Students' perceptions of tentativeness in science: Development, use, and sources of change. *Science Education, 74*, 225-239.

Lipman, M. (1991). *Thinking in Education*. New York: Cambridge University Press.

McComas, W. F., Clough, M. P. & Almazroa, H. (2000). The role and character of the nature of science in science education. In W. F. McComas (Ed.), *The nature of science in science education: Rationales and strategies*. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Nucci, L. P. (2001). *Education in the Moral Domain.* Cambridge: Cambridge University Press.

Paul, R. W. (1984). Critical thinking: Fundamental to education for a free society. *Educational Leadership, 42*, 4-14.

Paul, R. W. (1990). *Critical thinking*. Rohnert Park, CA: Center for Critical Thinking and Moral Critique, Sonoma State University.

Piaget J. (1965). *The moral judgment of the child* (M. Gabain, Trans.). New York: The Free Press.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education 66*(2): 211-227.

Sahakian, W. S. & Sahakian, M. L. (1966). *Ideas of the great philosophers*. New York: Barnes & Noble, Inc.

Zeidler, D. L. (1997). The central role of fallacious thinking in science education. *Science Education, 81*(1), 483-495.

Zeidler, D. L., Lederman, N. G., & Taylor, S. C. (1992). Fallacies and student discourse: Conceptualizing the role of critical thinking in science education. *Science Education, 76*(4), 437- 450.

Zeidler, D. L. & Schafer, L. E. (1984). Identifying mediating factors of moral reasoning in science education. *Journal of Research in Science Teaching, 21*(1), 1-15.

Zeidler, D. L., Walker, K. A., Ackett, W. A., & Simmons, M. L. (2002). Tangled up in views: Beliefs in the nature of science and responses to socioscientific dilemmas. *Science Education*, *86*(3), 343-367.

Zimmerman, C. (2000). The development of scientific reasoning skills. *Developmental Review, 20*, 99-149.

Zohar, A., Weinberger, Y., & Tamir, P. (1994). The effect of the biology critical thinking project on the development of critical thinking. *Journal of Research in Science Teaching, 31*, 183-19

SECTION III: CLASSROOM DISCOURSE ISSUES

CHAPTER 5

THE ROLE OF ARGUMENT DURING DISCOURSE ABOUT SOCIOSCIENTIFIC ISSUES

Dana L. Zeidler, Jonathan Osborne, Sibel Erduran, Shirley Simon & Martin Monk

INTRODUCTION

This chapter synthesizes research on the role of argument and the pitfalls of fallacious reasoning in student classroom discussions of socioscientific topics and issues. Its specific focus is on the nature of the argument that emerges in such context and its evaluation. For while there is a growing imperative that students should have the opportunity to 'consider the power and limitations of science in addressing industrial, social and environmental questions' (DfEE, 1999), asking teachers to engage in such practice and its discourse confronts them with a number of dilemmas. Foremost is the requirement that such activity requires some kind of formative evaluation of the activity itself. For only then can teachers provide the kind of essential feedback required to aid students identify the weaknesses in their own argument and improve their critical reasoning. Yet how, for instance, does the science teacher identify weaknesses in students' argument? What perspective should they use to evaluate their discourse – to decide that some contributions are better than others? And what, for instance, constitute exemplars of good practice – that makes one student's contribution more effective than another? For without such frameworks, it is difficult for the teacher to engage in the process of scaffolding discourse and to make the activity a learning experience from which the student might emerge more able to engage in similar experiences.

The chapter seeks, therefore, to explore a number of perspectives on analyzing the discourse that emerges in such contexts and evaluating the quality of argument. To that end, common examples of argumentation and examining moral and ethical

D.L. Zeidler (ed.),
The Role of Moral Reasoning on Socioscientific Issues and Discourse in Science Education, 97-116.

issues will be presented. These have been chosen to illustrate the nature of the argument and instances of fallacious argumentation in a context of socioscientific reasoning. Finally, the implications for the teaching of science are also considered.

SCIENTIFIC LITERACY, ARGUMENTATION AND SOCIOSCIENTIFIC ISSUES

The introduction of this book introduces and argues for the idea of conceptualizing science education as a form of education for citizenship. Some have argued that the humanistic face of science – decisions about moral and ethical issues, arguments and evidence used to arrive at those decisions – are necessary prerequisites for the cultivation of scientifically literate citizens engaged in thoughtful decision-making (Aikenhead, 1985 & 2000; Driver, Newton & Osborne, 2000; Driver, Leach, Millar & Scott, 1996; Millar & Osborne, 1998; Zeidler, 1984, 1997 & 1999). In short, the substance of their argument is that separating the learning of the content of science from any consideration of its application and its implications is an artificial divorce that makes school science seem irrelevant (Osborne & Collins, 2000) and, moreover, fails to develop the skills and expertise likely to be needed for citizenship. In a context, where ethical questions increasingly form the political and moral dilemmas confronting society i.e. reproductive and therapeutic cloning, any notion of scientific literacy that seeks to develop an understanding of science and its practices can, therefore, not escape consideration of contemporary issues as well as the epistemological considerations raised in the formulation of scientific knowledge. For Zeidler (2001) such a view is commensurate with a broad-based view of scientific literacy when he suggests that science faculty should strive to:

> Foster a vision of scientific literacy that encourages practical knowledge of the nature of science, developing habits of mind consistent with positive scientific perspectives and attitudes, stressing skepticism and critical thinking, teaching for conceptual understanding of seminal linking themes and theories among the sciences, embedding science in cultural and historical contexts, and providing opportunities for students to generate their own meaningful questions and design approaches to investigate real world issues (p. 18-19).
>
> Of necessity, such a view of science education would require students to engage in a greater range of discursive activity, which addressed not only the central epistemological question of 'how do we know?' but also the technological imperative of 'what can we do?'. The latter question, in particular, helps to dissolve the boundary that separates the school science classroom from the real world forcing the consideration of socioscientific issues.
>
> Drawing on a range of contemporary research on the topic and illustrating our point with short case studies of student discourse, the aim of this chapter, therefore, is to help elaborate an argument for a range of frameworks for analyzing argument in the context of students engaging in socioscientific discourse.

The Role and Value of Argument

Most teachers would be inclined to support the notion that scientific literacy entails, at least in part, the ability for students to engage in active dialogue as they ponder evidence, apply critical thinking skills, and formulate positions on various topics. To this end, informal discussions and formal debates play an important part in preparing students to utilize "argumentative thinking" as a vehicle by which they may come to terms with socioscientific issues. If science teachers recognise the development of concepts as the product of the co-construction of shared social knowledge, then the opportunity to engage in deliberative dialogue becomes central to the teaching of science. Moreover, the ability to structure, support and enable such dialogue becomes central to science teacher education. Wickman and Ostman (2002) emphasize the importance of acknowledging the attention discourse should receive in science education when they state the need to further understand "how esthetical and moral relations are construed as a part of the scientific discourse, and how questions of power influence meaning making" (p. 621). A core feature of deliberative dialogic is the opportunity to reason, to criticize and to justify – in short to argue. Thus ability to argue in an effective manner becomes central to the learning of science and a central component of scientific literacy (Kuhn, 1992; Zeidler et al., 1992).

Unfortunately, with many demands already placed on the classroom teacher, practicing teachers may find it difficult to devote valuable classroom time to providing students with the opportunity to engage in argumentation and practice such skills. For instance, in a small survey of 34 science lessons in England, Newton, Driver and Osborne (1999) found almost no substantive argumentation or classroom discussions present. Similar findings were noted by Watson, Swain and McRobbie (2001) who reported that the quantity and quality of discussion in science lessons were low. These researchers suggested that the main explanatory factor was that students and teachers viewed scientific inquiry as: "a set of fixed procedures, which could be used over and over again in the same ways in different inquiries – reflection and argument were absent" (p. 13). Science teachers will also question the degree of conceptual understanding developed and the perceived relevance of the information to the lives of students.

Yet it is Howe (1996) who reminds us of the important contribution of Vygotsky's work for establishing the case for the role and value of argumentation. For Vygotsky maintained that the development of scientific concepts could *not* occur without social interaction. And out of social interaction emerges difference and argument from which understanding emerges. Billig (1996) takes this case further arguing that learning to argue is an essential process of learning to think. If so, then argument is not a peripheral or marginal activity of science education but one, which deserves to be at its core. As a consequence, Driver, Newton and Osborne (2000) have also called for more research to help inform our understanding of the central role argumentation in science plays in the learning of science.

Developing students' knowledge of science through argumentation means that we should no longer constrain our investigations to how an individual "acts on" a problem, focusing their cognitive structures on some task-specific goal. Rather, when investigating socioscientific issues we are concerned with the construction of shared social knowledge; hence our attention turns to what the literature has termed "transactive discussions" (Berkowitz, 1985) and "dialogic argument" (Kuhn, 1992). Whereas, in problem-solving, in the usual sense of the word, compels an individual to coordinate internal reasoning structures with some aspect of the physical world, dialogic reasoning (argument), in contrast, compels one individual to coordinate his or her reasoning structures with those of another individual. The result is an exchange in which a "mutual bootstrapping" occurs (a phrase credited to Kohlberg (1981) in scoring moral discussions). When counter positions or arguments ensue, mutual dissonance is created between or among students. Each student is cognitively challenged during discourse to reflect upon his or her own beliefs, assertions and premises, and those of other individuals. The resulting discourse leads to a joint construction of shared social knowledge (though not necessarily shared beliefs). Each person's reasoning is thereby "elevated" or better developed as a result of challenges to their argument discourse. Yet how and where might argument be generated in the science classroom?

Kolstø (2001) provides a general framework of eight "content transcending" topics for examining the science dimension of the role of socioscientific issues in science education. All of these provide an opportunity for exploring the role of argument in science. The topics are not mutually exclusive and may occur singularly or in conjunction with one another. These topics include activities that focus on:

1) **Science-in-the Making and the Role of Consensus in Science** – developing the ability to distinguish between, on the one hand, the activity and nature of science in contexts where disagreement and debate among scientists concerning the appropriateness of various forms of empirical data, including the methodologies used to derive the data, is normal. And, on the other hand, knowledge that, whilst socially constructed, is widely accepted by the scientific community.

2) **Science as One of Several Social Domains** – increasing student awareness of the multiple factors (e.g.: religion, politics, economics, cultural, etc.) in addition to scientific considerations that may relevant to formulating positions and offering decisions regarding socioscientific issues.

3) **Descriptive and Normative Statements** – detecting bias and underlying ideologies along with an examination of the credibility of the evidence used to support decisions; in short – learning to recognize how underlying scientific values influence particular scientific viewpoints.

4) **Demands for Underpinning Evidence** – examining the epistemological status of knowledge claims by the degree of support for those claims, facts, evidence and their consensus.

5) **Scientific Models as Context-Bound** – discovering the context-specific constraints that limit the application of generalized theoretical knowledge i.e. the results of a given line of investigations may not transfer to particular set of complex social real-world situations.

6) **Scientific Evidence** – understanding the criteria of what counts as various types of scientific, statistical and anecdotal evidence.

7) **Suspension of Belief** – realizing the role of skepticism and the importance of not jumping to conclusions until compelling and convincing evidence warrants a decision.

8) **Scrutinizing Science-Related Knowledge Claims** – learning to evaluate the importance of contextual factors for any scientific claims that are advanced such as the significance of social statues, institutional allegiance made or distinguishing pseudoscientific assertions from scientific evidence germane to the issue under consideration.

Exposing students to the normative aspects of the development of scientific argument can be a messy, difficult and complex endeavor. First, there is the question of what is normative – for the idealistic norms of scientific inquiry and argument may be accepted by the community of scientists but are often not strictly adhered to in practice (Driver, Newton & Osborne, 2000).

Even then, when studying contradictory positions and claims of moral and ethical issues related to science, teachers and their students are apt to be faced with fallacious argumentation – fundamental errors in student reasoning. What are these types of error and how can they be identified? Hence, as the pursuit of socioscientific issues become more accepted in science education, it becomes increasingly important for teachers to become better acquainted with certain fallacies common to argumentation and the sources of those errors.

Another dilemma confronting the science teacher is learning how to feel ‘at home’ with the consideration of plural perspectives in the science classroom. For the science teacher sees their primary rhetorical task as one of persuading his or her students of the validity of the scientific world view – a task which is aided and abetted by the excision of uncertainty and conflicting evidence to the extent that demonstrations are ‘rigged’ to ensure that the behaviour of the phenomenological world fits with the description proffered by the science teacher (Nott & Wellington, 1995).

How too, can the quality of the argument be evaluated? Many can instinctively distinguish a better argument from its inferior companion, but what are the salient features of one argument that makes it of superior quality to another? It is such questions that we seek to explore in this chapter.

EVALUATING THE QUALITY OF ARGUMENT

In seeking to answer how the quality of argument might be assessed our[1] research work in our ESRC funded project ‘Enhancing the Quality of Argument in School Science’ has focussed on discussions between grade 7 students who were asked to consider whether a new zoo should be built. Students were initially briefed by the teacher with a letter from the local council stating that they were considering allowing the building of a new zoo in the area. Students were then asked to consider in small groups, the arguments for and against zoos. In each class, two groups of 3 to 4 pupils were identified and their discussions were taped and transcribed. The transcripts were then searched to identify genuine episodes of oppositional analysis and dialogical argument. Opposition took many different forms and many arguments where co-constructed where students provided data or warrants for others’ claims. Transcripts of group discussions (2 groups per teacher) were examined to determine the number of explicit episodes of opposition in student discourse. In other words, the instances where students were clearly against each other were traced. Typically these instances were identified through the use of words such as “but”, “I disagree with you”, “I don’t think so” and so on. Once these episodes were characterized in the group format, they were re-examined for the interactions among the students in terms of who was opposing whom, and who was elaborating on what idea or reinforcing or repeating an idea. In this fashion, the pattern of interaction for each opposition episode was recorded for two groups from each teacher's classroom. The

[1] Osborne, Erduran & Simon

main processes identified in such episodes were opposing claims by other (O), elaboration (E) or reinforcement (R) of a claim with additional data, warrants, advancing claims (C) or adding qualifications (Q). Such analysis helped to identify the features of the interaction and the nature of the engagement between the students.

The Nature of Opposition

Each oppositional episode was analysed using Toulmin's Argument Pattern (Toulmin, 1958) to identify the principal components of an argument being deployed by the individuals in the group. In these episodes, claims were not always clearly stated but implied or extracted through questioning and the dialogue takes several iterative readings to identify its principal features. All episodes were read independently by two coders who then met to compare their analysis and resolve differences in interpretation. These oppositional episodes are characterised by a diverse range of arguments and examples are provided below to illustrate the nature of the analysis and the results.

Episodes without Rebuttals

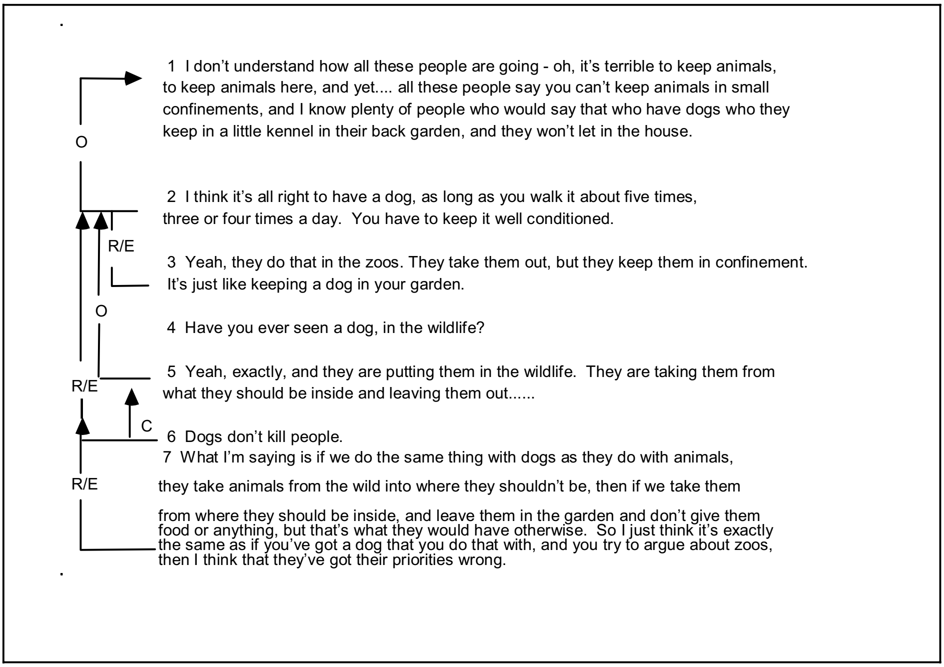
The first episode is a short simple disagreement, the second is much more complex as it involves one student providing a relatively sophisticated argument which does not appear to be understood by his opposers, who argue at a different level.

Episode 1

S1:	Right For
S2:	We are not for it
T:	First, write in then, then write things around it
S2:	I am not for it.

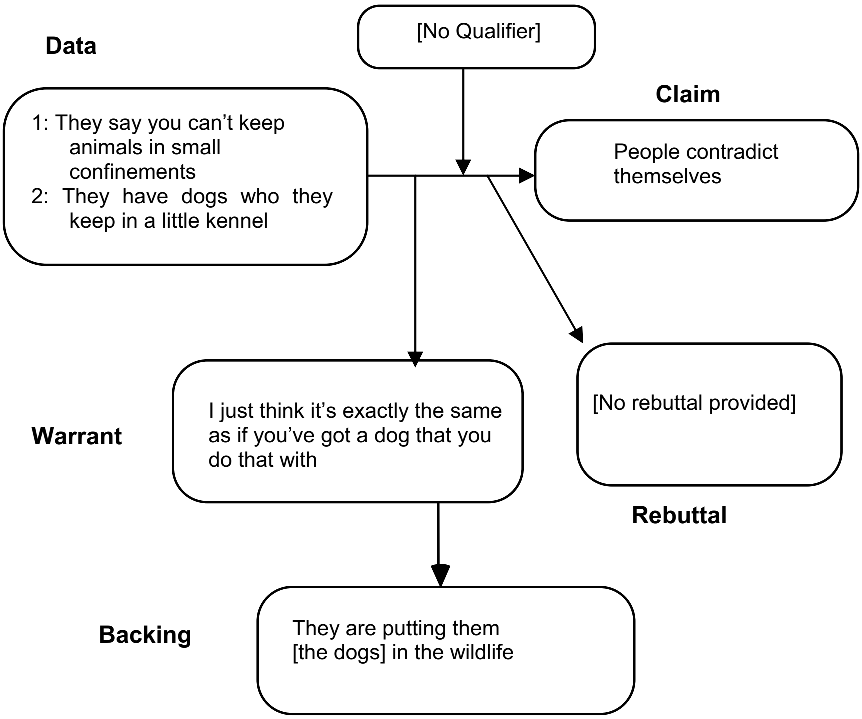
This episode is simply a claim for zoos – 'right for' followed by a counter claim 'we are not for it' repeated by 'I am not for it', making it an example of weak argumentation as the claim is unsupported and there are no rebuttals. Instead, there is simply a counter claim and, as such, there is no potential for the justification of belief to be examined and, hence, no possibility or resolution. This episode can be summarised simply as a claim verses counter claim.

Episode 2

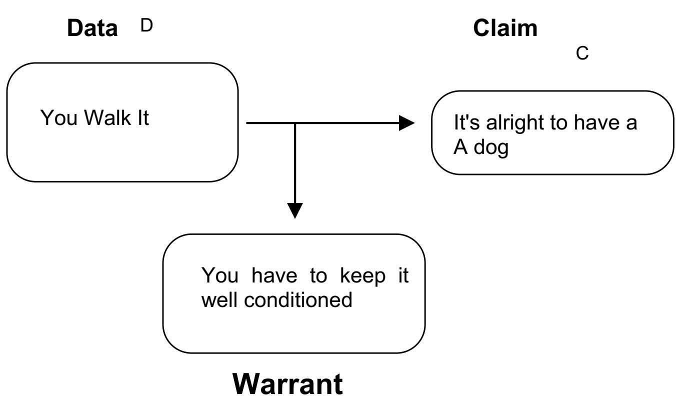


In Episode 2, one student has provided an implied claim (people contradict themselves), later reinforced by 'I think they've got their priorities wrong'. The student then appealed to two pieces of data – 'they say you can't keep animals in small confinements' and 'they have dogs who they keep in a little kennel'. A claim for such a contradiction would need to be substantiated by two pieces of data, which form the substance of the contradiction. A second student has opposed that proposition, through a counter claim that 'it's all right to have a dog'. This claim had the data 'you walk it' and a warrant 'to keep it well conditioned'. However without a rebuttal, the first student pursues and elaborates on his previous argument by extending his claim 'I think they've got their priorities wrong', including a warrant 'I just think it's exactly the same as if you've got a dog that you do that with' and adding a somewhat opaque backing 'they are putting them in the wildlife'. Notably, and crucial to this example, the first student fails to rebut the counter claims advanced by his opponent which might enable him to strengthen his position through counter-argument. These arguments can be represented using Toulmin's framework in the following format.

First Student's Argument



Second Student's Argument



Our summary of this example is that it consists of:

claim + data (2) + warrant + backing v counter claim + data + warrant

Thus, despite some embedded complexity, as an example of arguing we would contend that it is essentially weak as there is no attempt at a rebuttal (by either party) permitting the justification of belief by both parties to remain unexamined.

Episodes with Rebuttals

Episode 3

	N	It's not fair that animals should be caged up.
O	AM	Good, right, that's an against. Roxanne?
	R	But they are not always in the cages. They get to walk around and stuff.
O		
E	AM	They walk around a lot?
	R	Not when the zoo is open though, but sometimes.

Episode 3 begins with the claim: 'It's not fair that animals should be caged up' which is opposed by another student. The second statement rebuts the first student's claim by providing data for an implied counter claim which expressed colloquially is 'It's not necessarily not fair', with the warrant that 'They (animals) get to walk around and stuff'. This episode is of interest because the counter claim is a direct opposition to the claim used by the first arguer. The rebuttal effectively closes down the argument because the first arguer cannot refute it. The claim 'it's not fair' was rather weak and easily rebutted by a piece of opposing data. This example, can therefore be summarised as an example of:

claim v rebuttal (implied counter claim + data + warrant)

Episode 4 begins with a question being posed about how 'you would feel if everyone looked at you…', which implies a claim (you would feel embarrassed) which is then supplied by the next student. Thus the content of the question provides data that 'Your butt was sticking out' and a warrant 'everyone looked at you'. The implied qualifier for this argument is that the monkeys in question are located in cages. Opposition occurs in the form of a rebuttal of the qualifier – 'But you are not in a cage, you are outside in the open… there's like a long cage', which provides data for the rebuttal. The line of questioning of the first arguer in the episode elicits his claim from another student. The opposition is good because the rebuttal questions the qualifier for the first argument. Our summary of this argument is: implied claim (+ data + warrant + implied qualifier) v rebuttal of qualifier (+ data)

Episode 4

S1: I like the monkeys.

S2: They are very colourful and pretty.

S2: Especially their bums. Their pink squishy little bums.

E S3: Right, you three, how would you feel, like, if you were a baboon, how would you feel if everyone looked at you when you turned around and your butt, you behind, was sticking out?

S1: Well, I would feel embarrassed of

R T: Anthony, you go

O S2: I would feel rather embarrassed, jump out of my cage and smack

S3: But you are not in a cage though, you are outside in the open, not in the open, but there's like a long cage.....

The focus of this argument is on the claims advanced, their qualifiers and their rebuttal, rather than on the two opposing counter claims. Thus, although the argument may continue, the argument has the potential for resolution, making it an example of argumentation of better quality.

TYPES OF ARGUMENT AND THEIR QUALITY

Using such analyses we have so far identified a range of different types of arguments between pupils. In evaluating the group discussions for argumentation of good or better quality, our essential position is a commitment to the development of rational and analytic thought and discourse. In that we share with Toulmin a belief that 'a [person] demonstrates his rationality, not by a commitment to fixed ideas, stereotyped procedures, or immutable concepts, but by the manner in which, and the occasions on which, he changes those ideas, procedures, and concepts' (Toulmin, 972, p. v).

Changing one's thinking is not possible unless there are opportunities to externalise your thinking and hold up one beliefs and their justification for inspection by others. In that sense, we feel that one of the major achievements of our work has been to permit and encourage deliberative and dialogical interactions between pupils. Such opportunities are rarely a feature of school science classrooms which, in contrast, are dominated by monological interactions and triadic dialogue (Ogborn, 1996, Lemke, 1990).

Furthermore, within our work, we would contend that we do see a major differentiation in the quality of argument developed by pupils. Nearly all researchers have found the application of the Toulmin schema problematic as his criteria do not assist the ready resolution of data from warrants or backings resulting in poor reliability. Yet, in our work, we found little problem in the identification of claims or rebuttals but the distinction between data and warrants was often hard to make as it depended on contextual information which was either absent from the transcript or impossible to determine unambiguously from the video. Our schema for argument therefore transcends this problem by looking at argument from a less detailed perspective focussing on the most salient features of arguments – claims, data and rebuttals. Such a focus has enabled us to develop a schema that evaluates argument by 5 levels of quality.

Essentially, we see the simplest arguments are those consisting of a claim. The next level are arguments accompanied by data and warrants followed by arguments consisting of claims, data, warrants and rebuttals. Episodes with rebuttals are, however, of better quality than those without for individuals engaged in episodes without rebuttals remain epistemically unchallenged. The reasons for their belief are never questioned and are simply opposed by a counter claim, which may be more or less persuasive but is not a substantive challenge to the original claim. At its worst such arguments are simply reducible to the enunciation of contrasting belief systems. For instance, the confrontation between a creationist and a Darwinist without any attempt to rebut the data or the warrants of the other would have no potential *to change the ideas and thinking* of either. Oppositional episodes without rebuttals have the potential to continue forever with no change of mind or evaluation of the quality of argument. Thus, arguments with rebuttals are an essential element of better quality arguments. This analysis has led us to define quality in terms of a set of 5 levels of argument as follows:

Level 1: Level 1 arguments are arguments that are a simple claim v a counter claim or a claim v claim.

Level 2: Level 2 arguments consist of claims with warrants, backings or data but do not contain any rebuttals.

Level 3: Level 3 arguments consist of a series of claims or counter claims with either data, warrants or backings with the occasional weak rebuttal.

Level 4: Level 4 arguments consist of a claim with a clearly identifiable rebuttal. Such an argument may have several claims and counter claims as well but this is not necessary

Level 5: This is an extended argument with more than one rebuttal

The preceding analysis, while providing a useful gross measure of quality, does not offer any insights into the specific *nature* of argument and its potential weaknesses. In that analysis, it was not our intention to examine the nature of the data or warrant – it being sufficient that data or a warrant were present.

Fallacious Argumentation

The other dimension of evaluating argument is the identification of poor or fallacious reasoning. In a comprehensive review of literature related to fallacious reasoning Zeidler (1997) identified five major factors which influence the quality of scientific reasoning:

1) **Validity Concerns:** Many students can recognize valid deductive argument forms contained in syllogisms, where the conclusion is a necessary consequence of the premises regardless of the truth or falsity of the content contained in those premises. Many students base the premise of their arguments on the nature and context of the problem. In addition, they may hold commitments to prior beliefs that are scientifically erroneous. The corollary of this state of affairs is that it is quite possible for students to arrive at what they perceive to be a valid argument, which is based on erroneous premises.

2) **Naïve Conceptions of Argument Structure:** A similar problem emerges from their conception the nature of arguments. For when students begin to formulate propositional arguments and counterarguments, their lack of a conceptual awareness about the structure of arguments gives rise to misconceptions about the validity of their claims. Students tend to rely on a type of "makes-sense epistemology" – that is, whether or not a proposition seems intuitively correct. There is also a tendency for individuals to rely on a pragmatic heuristic that is likely to support their contentions. This heuristic enables them to focus their attention on supporting evidence to their claims and warrants. The problem is that students are apt to selectively sample information that is consistent with their claims and ignore information that may be inconsistent (or falsifying) leading to a type of confirmation bias.

3) **Effects of Core Beliefs on Argumentation:** As students engage in dialogue they are inevitably compelled to seek warrants for their claims. In science classes, this typically takes the form of acquiring evidence to support one's position. While the tendency to have "blind faith" in supporting evidence (i.e. confirmation bias) was noted above, the effects of this tendency on students' core beliefs are important to note. It has been shown, for instance, that studies which are consistent with initial student beliefs are judged to be more convincing than studies that run counter to their initial core beliefs. This propensity is described as "belief persistence" and illustrates how prior belief(s) compromise our ability to evaluate counter evidence and criticism. An unsettling implication is that the more controversial the argument at hand is, the more unlikely evidence contrary to one's position is to challenge pre-existing beliefs. And thus, the stronger an individual's initial beliefs, the more difficult accepting or explaining anomalous data becomes.

4) **Inadequate Sampling of Evidence:** What qualifies as acceptable evidence often differs across academic disciplines (and even within disciplines). Students, therefore, are often unclear about what constitutes sufficient or convincing evidence. As is quite often the case, students are prone to rely on personal experiences to advance claims even though they could strengthen their positions by pursuing and gathering further evidence appropriate to the relevant discipline. Both high school and higher education often produce students who are discipline-bound because instruction fails to make clear that what counts as legitimate support for an argument differs across disciplines (e.g., statistical data, case studies, exemplars, principles, theory, authority, interviews, historical evidence, personal narrative, etc.). Consequently, this may lead students to treat argumentation as arbitrary, capricious and fickle inasmuch as teachers may not clearly convey the epistemological expectations of that discipline. Commonly this leads to inadequate sampling practices that may result in hasty conclusions. Or overgeneralization where students may use too little data to warrant a firm conclusion, or to over generalize from particular instances to other settings.

Conversely, students may acquire voluminous amounts of information. The problem now lies in the pitfall of unwittingly giving equal weight to all studies or sources of data and failing to evaluate the epistemic merit of the different sources. Students may also over emphasize the frequency of rare events that contain inherent shock value (a toxic waste spill) but underestimate the occurrences of more common events such as over exposure to sunlight over years that may lead to skin cancer. Finally, students tend to have undue confidence in, and lack a functional understanding of, probabilistic and statistical information.

5) **Altering Representation of Argument and Evidence:** Students do not consider necessarily only the evidence presented to them. Rather, sometimes they inadvertently change or modify the facts, presuppositions, or premises of an initial problem or argument. Sometimes this occurs because students introduce pragmatic inferences into a problem. They may make assertions about the context of a problem that ultimately changes both the initial state of the problem under consideration, and the ensuing reasoning related to the problem's resolution. This stratagem results in student reasoning that exceeds the boundaries of the evidence presented thereby creating bias in the decisions made concerning those issues.

To illustrate such common fallacies, "samples of thought" collected from mini case studies of students' argumentation patterns in the context of socioscientific issues are provided and explored. Examining patterns of reasoning about socioscientific issues provides insight into how students use data, warrants or claims and help to identify areas of pedagogical concerns for teachers who wish to infuse their classes with discussions that are conducive to the development of moral reasoning.

Toxic Lipstick and Tiny Kamikaze Pilots: Teleological Paternalism

Examining the nature of students' arguments about socioscientific issues reveals the messiness of everyday (and typically naïve) "scientific" positions. In this context, a perennial problem is students' inability to discern arguments based on evidence from those based on personal, ethical beliefs. However, this problem is further compounded by a myopic worldview that equates social facts about the status quo with ethical imperatives. Data collected from high school and upper level college students who are reacting to the topic of animal research offers some insight into the discourse patterns used as students construct arguments. For this study, students were purposefully selected because they represented critical exemplars of contrasting ethical viewpoints with respect to the issues of animal research. Each pairs of students then discussed and argued about questions that were designed to elicit the participants' epistemological reasoning, facilitate their explanations for causal justification(s) of evidence, and to engage them in dialogic conversations that challenged each other's reasoning. Following a semi-structured protocol, students were interviewed using the following questions and epistemological probes:

1) I would now like each of you to restate your position to one another about to what extent you agree with the statement: "Animals should be used for research" – and explain the reason for your position. [Justification/Clarification Probe]

2) If you had to convince the other person that your view is right, what evidence or proof would you say or show to persuade him/her? [Justification/Evidence Probe]

3) Could the other person prove that you were wrong? Why? Why not? [Alternative Viewpoint/Alternative Theory Probe]

4) Could more than one point of view on this matter be right? Please explain. [Epistemological Probe]

5) How does either scientific knowledge or opinion play a role in each of your positions? [Epistemological/Evidence/Personal & Sociocultural Probe]

These interviews were tape-recorded and later transcribed, resulting in approximately 533 pages of transcripts. Field notes were also kept and used as a basis for validity checks during the discourse analysis and the students' original responses to the questionnaires were matched against the field notes to further corroborate the original data sources and further interpret conceptions of students. [Refer to Zeidler, Walker, Ackett & Simmons (2002) for a more detailed description of the methodology and topics under investigation] In the following excerpts, key points are identified by bold type. Consider the following justification of animal testing offered by a 12th grade (high school) student:

> I would much rather have a small animal put on toxic lipstick than me. If there is a fault in a product, I want to know before I buy it. I'm not saying that animals should be subjected to cruel and unusual punishment but I do think **that they are useful only when experimented on (or used for a greater purpose). Animals used for research provide endless benefits to the medical/science world. Those lab rats are kind of like tiny Kamikaze pilots, sacrificing themselves for the good of something greater.** We've learned so much about ourselves from animal experimentation…. **It is customary and expected. It is the food chain!** [Grade 12 High School Student]

In this excerpt, there are several elements of *validity concerns* (1) revealed through fallacious discourse. For instance, when the student states, "It is customary and expected. It is the food chain!" we can see evidence of the naturalistic fallacy as the student's use of the words "customary" and "expected" equate normative practices within their own culture and species with *all* cultures and species. In short, what does exist for one species is extended to all others. At the same time, this argument utilizes the student's observation of a biological "fact" – that there are inherent hierarchical orders contained in food chains. This "fact" helps to provide justification for the formation of his or her moral imperative (animals should be used for research) without any consideration of whether or not these social and biological facts lead *of necessity* to such conclusions about animal testing.

Another element of fallacious reasoning is essentially a paternalistic assumption about the value of the human species. In this excerpt, the student likens laboratory animals (in this specific example laboratory rats) to "tiny Kamikaze pilots, sacrificing themselves for the good of something greater." It's as if the student rationalizes that rats will accept their utilitarian fate for the greater good of human beings – essentially a teleological argument of fitness for purpose. The reasoning is fallacious resulting, in part, from *altering representation of argument and evidence* (5). Perhaps the student is aware of the cognitive dissonance operating here and lessens the emotional impact of such a controversial stance by transference of the student's perspective to that of the laboratory animal.

Paternalistic views transferred across species are not only limited to high school students! A similar justification for what another species would *wish* and how they would *act* is found in this upper-level college student discussing the same issue of using animals for research purposes.

> We are one of the few species that has an extraordinary brain with such physical capabilities. It's like how the food chain works. We use those inferior to us for survival. **If other species were capable to do what we can do they would.** I don't think that chimps and apes should be harmed in any way because they have the most human-like characters of all other species. [Upper Level College Student]

Such teleological arguments are embedded and defined from a perspective that sees human culture and human needs as predominant, and may be found among other high school and college students. The overall utility of an organism is defined simply by reference to the role humans play in the environment. This is an example *of naïve conceptions of argument structure* (2) or "makes-sense epistemology." Such arguments often reveal a sense of naïve vitalism where students believe that natural phenomena and order in nature are determined not only by mechanical means but by an over-all design or purpose in nature where all life serves the needs of humans. Consequently, ethical justifications for animal research rely on a view of preordained utility of all species for the success of human evolution – an argument that simply provides a warrant for viewing other organisms and their role as an evolutionary fait accompli. From this perspective, the success of animal evolution is often measured in terms of the potential similarity to humans. This latter point is particularly evident in the last quotation. Although the student had difficulty articulating the warrant for his/her claim, it is evident that an implicit warrant for this naïve, vitalistic view was present. Additional examples illustrating this point include:

> It is better to test on and sacrifice a small animal than to test on a human (at least for preliminary vaccination tests). **Humans have a greater impact on our society than rats do.** Some people may argue that "Rats are people too," or " We should test on criminals." Both of these are matters of opinion, just as mine. **I feel that the "lesser significant' lives of rats and mice are better for medical experimentation, as opposed to the selfish, yet, useful humans."** [Grade 12 High School Student]

> I believe that one of the reasons that animals are here is to benefit humans. **…Humans dominate the earth**, but should not be inhumane about using the animals for research. The conquest of human disease is worth the sacrifice of other species because **humans are more dominant**. [Upper level College Student] (Authors' Comment: Note the instance of "circular reasoning" also present in this example.)

> **God put animals on earth so that the life cycle would keep on going. The stronger predator will win. [Upper level College Student]**

> God put (animals) here as part of the food chain and in times past they were necessary for clothing. [Upper level College Student]

Clearly, the *effects of core beliefs on argument* (3) are present in this excerpt. In the last two examples we also see a fusion of personal and core beliefs (which may include internalized religious beliefs) with scientific epistemologies present in both the high school and college students reasoning about the use of animals in medical or consumer research. In some cases, such views usually entail a blending of personal fallacies (e.g. naturalistic fallacy) with factual information. For example, the descriptive factual statement that "**The stronger predator will win,**" while generally true, is blended with a personal ethical position that implies people *ought* to experiment on animals because of our perceived elevated predatory status in the food chain. In other cases, a blending of religious convictions (e.g., God's will) with scientific explanations (e.g. life cycle, dominant species, food chains, etc.) is evident in students' responses to socioscientific issues.

Normal People are Not Scientists: Morality, Evidence and Emotions in Science.

Students are often befuddled about the seemingly conflicting values and characteristics that scientists possess in contrast with everyone else – i.e., "normal people." There seems to be a pervasive consensus among many students that morality holds a back seat to decisions made possible by technological advancements. The idea that one *can* do x (made possible via technology) often leads to the conclusion that x *will* necessarily follow. Linked to this view is how emotions are perceived as an inconsequential source of input in the decisions made by researchers or scientists. While the use of evidence is viewed to be important in making personal (or technical) decisions for oneself (particularly among scientists) it does not appear fathomable to some students that the same evidence could be convincingly used to help sway someone else's point of view. Their uncertainty as to the role of evidence in deriving decision with emotive features illustrates *inadequate sampling of evidence* (4). Consider the following representative exchange between upper level college students:

> Interviewer: How might you account for those differences (points of view)?
>
> T: Well if they are scientists I would have to say it would be scientific evidence. Because **most scientists they do not go from emotion. I mean there are not too many emotional scientists. They go from facts and beliefs that they have from things they have learned about facts and stuff.**
>
> A: I mean there has to be some emotion behind it, **but not as emotional as *normal* people that are scientists. They have to have *some* emotion to believe in something and to really get the facts behind it.**

Here we find that while scientists may display *some* emotion it is only emotion tied to their research interests that enables them to focus on a given objective.

In some cases, students perceive that the availability of technology to scientists, technology may supplant the necessity to consider moral judgments. Rather, technology is perceived as an enabling factor that permits scientists to pursue their research without evoking any ethical considerations. At its most extreme, scientific reasoning is seen as being at odds and perhaps incommensurable with moral reasoning. In the following excerpts, two upper level college students clearly view the role of technology and ethical decision-making on the part of scientists as largely mutually exclusive (or non-interacting) domains.

> P: You see the gross disrespect people have for life in our society today, so I don't think even when we are talking cloning and stuff their [scientists] questions [are] more an [moral] issue they are avoiding. Like jumping in before they have the answers to all those issues and they are just going ahead because they have the technology. So only time will tell what kind of ramification are we going to have.
>
> D: So maybe there is not a lot of scientific evidence or reason behind a lot of the decisions we are making [based on scientists' research].
>
> P: They are going at it from purely a scientific, rather than a moral reasoning kind of thing. They are bypassing morality issues because they have the technology to do (research).
>
> Interviewer: How then do you feel about *your* position on using animals for research? Do you feel that you are going more on an issue of morality or an issue of using scientific evidence?

D: I think there is probably, **there is a mad rush to win awards. I mean the researchers in charge of these they can avoid many of those (moral) aspects.** The guy that cloned the sheep, I don't know his name but I know that had happen and I will always know that and my children will know that. That was a huge break through and he is famous because he made a sheep.

P: There was another thing in the paper where they took a woman and took out her DNA and they put another woman's DNA in that egg, and then they fertilized it. Now that child is going to have two biological mothers. Then there are all these **legal questions and every thing else they haven't thought through and here they go on ahead with their science thing.**

D: And by passing issues in morality for scientific advancements.

As for the role of *evidence* in arguing about socioscientific issues, students generally attribute an element of importance to it (particularly if one were a scientist or if one has *pictures* to show to someone else). However, some students believe evidence is nearly futile in convincing others to change their personal (ethical) position on a given topic. For example, when asked how she might use evidence to sway a classmate's position on the topic of animal research, one upper level college student stated:

P: **I would never try to change anyone's opinion because it is their opinion it is their core being**. It could possibly be modified a little bit, but then again that is only if they are open to it. And you will know at that time if they are open or not if not they will give you a blank stare and say no you can't do this**. I don't think you should attempt to change someone's mind**.

In another example, when an interviewer asked how might they use evidence to change someone's opinion, two grade 12 high school students stated:

B: Well, **you could show them pictures** of 'em [the animals**] but if their mind is made up cause that's their opinion**, I mean **it doesn't matter what the evidence is**.

P: I could **tell them to read this or that but you can't change someone's opinion because that's what they believe**.

This student's view that other's individual beliefs constitute part of their 'core being' may offer a snapshot of his/her own belief systems. The more entrenched one's initial beliefs were (i.e. "core beliefs"), the more polarized the beliefs become when confronted with contrary evidence. This propensity has been termed "belief persistence" (see Baron, 1985 & 1988; Baron & Brown, 1991) and reflects how prior beliefs compromise our ability to evaluate counter evidence and criticism. The implication is that the more controversial the argument at hand, the more futile evidence contrary to one's position becomes. Zeidler (1997) has suggested that if this is true, then it is possible that the degree of polarization that may occur when counter arguments and evidence are confronted is directly related to the strength of an individual's initial core beliefs, and hence, the likelihood of accepting or explaining the anomalous data is inversely related to the extent to which new ideas challenge pre-existing beliefs!

Similar to how students perceive a lack of emotions on the part of scientists in conducting research (see the beginning of this section), some students also believe that, the role of scientific evidence is often muted by the impact of human emotion. Consider these upper level college students' explanations:

Interviewer: Do you think that scientific evidence could be used to change somebody's belief on this issue? If there were a person who said "absolutely no way animals should *not* be used" and they are out there lobbying to get policies changed – do you think that you can show them or use scientific evidence that would change their belief?

L: Well you could try. **But not everybody thinks scientifically about emotional issues**. So you could find evidence, but I don't know that it could change anybody's mind. Because you feel that maybe the issue itself is **people are going to disregard the scientific information and just go with the emotional**.

D: We understand the scientific concept **but we have feelings** one way or the other. … I surely wouldn't tell someone how to believe, I think it is personal

S: I am not sure I would try to change their mind.

And finally.

Interviewer: Do you think scientific evidence could be used to change your beliefs or to change somebody else's beliefs on this?

E: I think **it is deeply embedded, your moral beliefs**, obviously because **there are certain things you can not change people's minds about no matter how much evidence you show**.

M.E.: pictures are more powerful because that hits your emotional side so that your know, **the facts are there and they help you make up your mind if you are looking at it logically and rational. But, if you see a picture then your emotions are going to come into play no matter what you do**.

CONCLUSIONS

In this chapter, we have presented initial work on developing argumentation in school science classrooms, its analysis and the assessment of its quality. Methodologically, we feel this work has made progress on two fronts in developing a framework for analyzing both the *process* and *content* of arguments in a socioscientific context. For one of the many problems that bedevils work in this field is a reliable systematic methodology for a) identifying argument and b) assessing quality. The use of Toulmin and its adaptation by Osborne, Erduran, Simon and Monk in the present chapter provides a method for identifying the salient features of argument and the components of what are commonly termed the ideas of science and their supporting evidence. For 'ideas', on the one hand, consist of hypotheses, theories and predictions, which are essentially claims, while the data, warrants, backings, rebuttals and qualifiers are the components and conditions of 'evidence'. The emphasis and identification of these features offers science teachers a richer meta-language for talking about the process of arguing in science. Moreover, the use of these features to develop a simplified framework for the evaluation of the quality of arguing offers a tool to aid the analysis and interpretation by practitioners of their students' arguments – a tool that is essential if such activity is to be fostered and scaffolded in the classroom.

Second, the analysis of the nature of the argument has helped to identify the salient features of the *content* of such arguments and the common fallacies that are deployed by students in the construction of arguments. While this chapter only permits a limited illustration of the nature of the fallacious reasoning deployed by students, the five major factors identified by Zeidler (1997) provide a useful framework for simplifying and categorizing the nature of the reasoning deployed in socioscientific deliberative discussion. Again, such a framework is an essential tool to enable the teacher to provide critical and formative assessment on their nature of students' arguments.

This chapter also points to the need for explicit instruction in the use of various forms of evidence in scientific research and how that evidence may be used in formulating ethical decisions. For example, in a related line of research, approximately 50% of tenth-grade high school students showed confusion in recognizing how empirical data may be used as a basis of support for scientific claims (Sadler, Chambers & Zeidler, in press). Students also tended to dichotomize personal beliefs and scientific knowledge. In evaluating how convincing two contrasting but parallel research articles about global warming were, many students declared that while one was perceived to have "better data and information" and therefore have more scientific merit, the article that aligned most closely with their preexisting positions was deemed more convincing (p.15). Certainly more research and investigations of actual classroom practices in terms of promoting moral reasoning and examining ethical issues in the context of science is needed. By providing opportunities for the examination of ethical issues in science classrooms, students can begin to discern the importance of informed discourse in rendering decisions that entail the use of scientific evidence from varied sources. More importantly, teachers who engage students in discussion need to be aware of how students may construe various issues and help to reveal possible weaknesses in their arguments. But teachers first need to be sensitive to patterns of fallacious reasoning and how students are apt to use evidence (or not) as they construct their own meaning on socioscientific topics.

The value of argument in the development of moral reasoning has been amply demonstrated in the research literature in terms of creating dissonance thereby allowing opportunity for re-examining one's beliefs and thought-processes. Being exposed to and challenged by the arguments of others compels the student to attend to the quality of claims, warrants, evidence and assumptions of their own belief systems. By examining the quality of argument and instances of fallacious argumentation, we hope to present science educators, teachers and researches with insight into how students attend to the kind of argumentative discourse likely to arise during the pursuit of socioscientific topics.

The significance of this work is that it offers a means of enabling argument in the classroom by adding and extending the lexicon and resources that constitutes contemporary practice in science education. Commonly, science teachers have seen little value in discussion and have been wary of a practice for which they perceive little cognitive development and for which they have had little or no training in its analysis and evaluation. Providing a vocabulary that addresses these issues is thus a first step for the re-evaluation of the role of argument in the learning of science. The challenge now facing the field is the translation of this work into forms that are accessible and usable by the practitioner community and the development of appropriate models of practice that can be presented and more widely adopted. Only then, can we hope to see argument and its practice, an activity, which lies at the core of science, occupy a similar position at the core of science education.

REFERENCES

Aikenhead,G.S. (1985). Collective decision making in the social context of science. *Science Education, 69*(4), 453-475.

Aikenhead, G.S. (2000). Renegotiating the culture of school science. In R. Millar, J. Leach & J. Osborne (Eds.), *Improving science education: The contribution of research*. Buckingham: Open University Press.

Baron, J. (1985). *Rationality and intelligence*. Cambridge: Cambridge University Press.

Baron, J. (1988). *Thinking and deciding*. Cambridge: Cambridge University Press.

Baron, J. & Brown, R.V. (1991). Toward improved instruction in decision making to adolescents: A conceptual framework and pilot program. In J. Baron & R.V. Brown (Eds.), *Teaching decision making to adolescents*. Hillsdale: Lawrence Erlbaum Associates.

Billig, M. (1996). *Arguing and Thinking* (2nd ed.). Cambridge: Cambridge University Press.

Berkowitz, M.W. (1985). The role of discussion in moral education, In M.W. Berkowitz & F. Oser (Eds.), *Moral education: Theory and application*. Hillsdale: Lawrence Erlbaum Associates.

Driver, R., Newton, P. & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*(3), 287-312.

Driver, R., Leach, J., Millar, R. & Scott, P. (1996). *Young People's Images of Science*. Buckingham: Open University Press.

Department for Education and Employment. (1999). *Science in the National Curriculum*. London: HMSO.

Howe, A. C. (1996). Development of science concepts within a Vygotskian framework. *Science Education 80*(1): 35-51.

Kolstø , S. (2001). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socioscientific issues. *Science Education, 85*(3), 291-310.

Kuhn, D. (1992). Thinking as argument. *Harvard Educational Review, 62*(2), 155-178.

Kohlberg, L. (1981). *The meaning and measurement of moral development*. (Vol. XIII: 1979 Heinz Werner Memorial Lectures. Worcester, MA: Clark University.

Lemke, J.L. (1990). *Talking science: Language, learning, and values*.

Norwood,NJ: Ablex.Millar, R. & Osborne, J.F. (Eds.) (1998). *Beyond 2000: Science education for the future*. London: School of Education, King's College.

Nott, M., & Wellington, J. (1995). Critical incidents in the science classroom and the nature of science. *School Science Review, 276*(76), 41-46.

Ogborn, J., Kress, G., Martins, I., & McGillicuddy, K. (1996). *Explaining Science in the Classroom* Buckingham: Open University Press.

Osborne, J. F., & Collins, S. (2000). *Pupils' and Parents' Views of the School Science Curriculum*. London: King's College London.

Sadler, T.D., Chambers, F.W., & Zeidler, D.L. (in press). *Student conceptualizations of the nature of science in response to a socioscientific issue. International Journal of Science Education*.

Toulmin, S. (1958). *The Uses of Argument*. Cambridge: Cambridge University Press.

Toulmin, S. (1972). *Human Understanding* (Vol. 1: General Introduction and Part1).Oxford: Clarendon Press.

Newton, P., Driver, R., & Osborne, J. & Osborne, J. (1999). The place of argumentation in the pedagogy of school science. *International Journal of Science Education, 21*(5), 553-576.

Watson, Swain & McRobbie (2001). In Press.

Wickman, P. & Ostman, L. (2002). Learning as discourse change: A sociocultural mechanism. *Science Education, 86*(5), 601-623.

Zeidler, D. L. (1984). Moral issues and social policy in science education: Closing the literacy gap. *Science Education, 68*(4), 411-419.

Zeidler, D. L. (1997). The central role of fallacious thinking in science education. *Science Education, 81*(4), 483-495.

Zeidler, D. L. (2001). Participating in program development: Standard F. In D. Siebert & W. McIntosh (Eds.), *College pathways to the science education standards* (p.18-22). Arlington, VA: National Science Teachers Press.

Zeidler, D. L., Lederman, N. G., & Taylor, S. C. (1992). Fallacies and student discourse: Conceptualizing the role of critical thinking in science education. *Science Education, 76*(4), 437-450.

Zeidler, D. L., Walker, K. A., Ackett, W. & Simmons, M. L. (2002). Tangled up in views: Beliefs in the nature of science and responses to socioscientific dilemmas. *Science Education,86*(3), 342-367.

CHAPTER 6

INTEGRATING SCIENCE EDUCATION AND CHARACTER EDUCATION

THE ROLE OF PEER DISCUSSION

Marvin W. Berkowitz & Patrica Simmons

INTRODUCTION

Moral education in school is practically hopeless when we set up the development of character as a supreme end, and at the same time, treat the acquiring of knowledge and the development of understanding, which of necessity occupy the chief part of school time, as having nothing to do with character (Dewey, 1944, p. 354).

In the 21st Century, science education must serve as a foundation for the education of an informed citizenry who participate in the freedoms and power of a modern, democratic, technological society. With the rapid development of scientific knowledge and the advent of new technologies, all members of society must have an understanding of the implications of that knowledge upon individuals, communities, and the "global village" in which we now live. Perhaps this is most evident in information technology, where computers and the Internet are becoming integral in all areas of our lives; however, these implications are also critical in other realms of science, such as agricultural engineering, genetic engineering, and medical technology.

For science and technology to be managed responsibly, ethically, and for the benefit of mankind, the participation by citizens is crucial. At the time this chapter was written, the U.S. government was struggling with the issue of federal funding for embryonic stem cell research. The issues embedded within the debate on the use of embryonic stem cells versus adult stem cells and the implications for cures of catastrophic diseases are complex, based on intersecting sets of religious, ethical and moral (Thiroux, 2001), legal, cultural, and historic beliefs. Clearly, in cases such as

D.L. Zeidler (ed.),
The Role of Moral Reasoning on Socioscientific Issues and Discourse in Science Education, 117-138.

this, citizens and future citizens must be able to understand the issues and implications of the decisions made by individuals and agencies, and very importantly, participate in and influence these decisions. Obviously, the need for an informed and responsible citizenry derives from the challenges of science and technology in our societies. This need has significant implications for education in general and science education in particular. Focusing only upon the scientific content of critical issues is not sufficient; we must embed the knowledge, understanding, and problem-solving components of science and technology within the context of effective moral agency. If our goal in education is to educate the entire person, then we must address science education and character education simultaneously.

In this chapter, we explore the overlap between three educational domains: science education, character education, and democratic education (see Figure 1). The goal is to understand the relation of science education to character and democratic education, and thereby to enrich the impact of science education. Character education, broadly defined, encompasses all aspects of schooling that impact upon the development of social and moral competencies of students, including the capacity to reason about moral and ethical issues. Democratic education refers to school-based initiatives that are designed to promote the development of students into competent, responsible citizens of a democratic society. The overlap between these two reflects those educational domains that focus on aspects of character that are relevant to democratic citizenship, such as responsibility and advocacy for common welfare (Berkowitz, 2000). The domains are not isomorphic because some aspects of character are not specifically relevant to democratic functioning (e.g., courage, beneficence) and some necessary components of democratic education are not matters of fostering character development (e.g., learning about the structure or history of democratic government). It is precisely this overlapping domain that we shall argue is central to a comprehensive approach to science education. Then we shall, by means of illustration, highlight one specific way science education can implement processes that dovetail with this overlap between character, democracy, and science, namely peer moral discourse. The following sections contain 1) an overview of character education in general and moral reasoning development in particular, 2) a rationale for linking character education, science education, and democratic citizenship and schools, and 3) the research-base for peer collaborative discussion.

WHAT IS CHARACTER EDUCATION?

The growing national interest in character education stems in part from the recognition (rediscovery) that there are two basic goals of education: intellect and character. Martin Luther King Jr. noted this when he stated that “Intelligence is not enough. Intelligence plus character – that is the goal of true education.” Such a recognition is not new to the field of education nor to specifically U.S. education, but has always been central to the conception of good education, at least in theory (McClellan, 1999).

What is often viewed as more controversial, however, is what counts as character and as character education (Berkowitz, Schaeffer & Bier, 2002). Fortunately, over the past decade or so, the goals of character education have become clearer and widely endorsed, while the methods of quality character education are becoming more clearly articulated and widely disseminated. Character is widely understood as the composite of cognitive, affective and behavioral development of moral understanding, moral commitment and emotion, and moral behavior. Berkowitz (1997) defined character as the composite of psychological characteristics that enable the individual to act as a moral agent: moral behavior, moral values, moral personality, moral emotion, moral reasoning, moral identity, and foundational characteristics. The Character Education Partnership ("http://www.Character.org") defines character education as under-standing, caring about, and acting upon core universal values such as respect, responsibility, honesty, and caring for persons. We can therefore understand character education as a comprehensive, intentional approach to fostering the development of those aspects of a child that promote moral functioning.

Educating for Democratic Citizenship

To function in a modern, democratic and technological society, citizens (teachers, principals) and future citizens (students) must not only understand the principles and values upon which democracies are built, but also be allowed to practice the conditions of democracy. Mosher, Kenny, and Garrod (1994) stated that: "Students have been taught about democracy, but they have not been permitted to practice democracy" (p. 1-2). Since democracy is based upon the character of citizens and public institutions, such as schools (Dewey, 1944), school systems must address and include the active participation of students as democratic citizens. Greene (1985) highlighted the obligation of educators to students as they progress through levels of schooling: "it is an obligation of education in a democracy to empower the young to become members of the public, to participate, and play articulate roles in the public space." Berkowitz (2000) listed four elements needed for educating students for democracy: learning about democracy; practicing democracy; fostering a psychological foundation for democratic participation; and developing general moral character. To educate students for democracy requires that schools focus on all four of these ingredients.

To do so, one needs a clear sense of what civic virtue is. Sehr (1997) listed five characteristics of a democratic citizen which can be developed and practiced by students: an ethic of care/responsibility; a respect for the rights of everyone; an appreciation of the significance of the public; a social perspective which is analytical; and a capacity for active participation in a democracy. These characteristics reflect the individual development of citizenship in students. To promote them, schools need to rethink their educational philosophies and processes. Students are part of a larger institution, their school, which also needs to be reorganized so that teachers implement curriculum and instruction for responsible citizenship.

The ideas of empowerment and participation and informed decisions are clearly central tenets of democratic schools. Apple and Beane (1995) described democratic schools predicated upon the following conditions:

- An open flow of ideas leads to an informed people;

- Collective and individual capabilities result in the resolution of problems;
- Critical reflection and analysis are employed to assess problems and policies;
- The "common good" is a principal concern guiding people;
- The dignity and rights of all members are respected;
- Democracy represents an idealized set of values; and
- Social institutions, such as schools, serve to promote and extend a democratic way of life.

Such practices do not merely apply to the education of students. They also apply to the school staff processes and practices that under gird the education of students. How the school staff makes decisions, resolves conflicts, sets priorities, and so forth should resonate with the principles of democracy. It is utterly hypocritical to promote democracy in students through autocratic staff practices (Sizer & Sizer, 1999).

HOW DOES MORAL CHARACTER DEVELOP?

The framework around which democratic citizenry and democratic schools can best be achieved is through the development of moral character. Because moral character is a complex psychological construct (Berkowitz, 1997), its development must be multi-determined and complex. Furthermore, it should be clear that character education is also by necessity multi-faceted and complex (Berkowitz, in press). It is beyond the scope of this chapter to offer a comprehensive account of character development or character education. Instead, a brief overview of some basic aspects of character development will be provided, followed by a brief overview of quality character education.

Character is first formed in the early years in the family (Damon, 1988; Lickona, 1983). Parenting is a critical element in the formation of character. Five critical parenting behaviors that foster character are: nurturance (love), demandingness (setting expectations), induction (evaluative reactions to the child accompanied with explanation and a focus on affective consequences for others), modeling, democratic family processes (Berkowitz & Grych, 1998). These five aspects are highlighted here because they are highly applicable to education as well (Berkowitz & Grych, 2000).

As children reach school age, this process of character development is strongly affected by schooling. It is clear from the research on character education that effective quality character education requires a comprehensive, intentional approach (Lickona, Schaps & Lewis, 1996), an explicit focus on moral issues, a caring context (school and classroom as a caring community) in which to educate students (Schaps, 2001), the promotion of peer interaction about moral issues, and integration of character throughout the school. Berkowitz (in press) identifies six central ingredients in effective school-based character education:

- Positive pro-social relationships among all members of the school community, including how others treat the child and how people treat each other in the child's presence.

- Clear and consistent expectations for good character for all members of the School community
- Authentic espousal of positive character
- Wide-ranging opportunities for students to practice good character
- Frequent opportunities for students to reason about, debate, and reflect on moral issue.
- Parents' active and positive involvement in the school, and particularly in the school's character education efforts.

Hence we can see that character is a complex set of psychological attributes that develop throughout childhood and adolescence. These attributes are affected most strongly by family, and then later by schooling. Furthermore, the variables that foster character development in family apply as well to schools and are supplemented by other school-specific processes. It behooves educators to rely on such processes throughout the school experience in order to optimally foster the development of character in students.

CHARACTER EDUCATION AND SCIENCE EDUCATION

To adequately integrate character education with science education, schools need to promote an understanding of the moral dimensions of science and technology, foster students' concerns about ethics in science and technology, and empower students to act responsibly in the realm of science and technology. When teachers and students address scientific and technological knowledge in the context of character education, they can experience the complexity of science and technology from a personal and social perspective; most importantly, they can participate in informed reflection about ethics in science and technology, and even engage in social activism around scientific issues. The implications of scientific and technological knowledge for society, for communities, and for individuals require science and technology to be taught as more than simply "the facts" or as a passing score on a standardized exam.

The National Science Standards (1994) identified the following topics as the eight unifying themes for content: science and technology, science in personal and social perspective, history and nature of science, unifying concepts and processes in science, science as inquiry, and physical, life, and earth and space sciences. The recommendations from the National Research Council expressed that a greater emphasis in science education should be given to "learning subject matter disciplines in the context of inquiry, technology, science in personal and social perspectives, and history and nature of science... science as argument and explanation... public communication of student ideas and work to classmates..." (p. 113). The National Science Education Standards also addressed understanding science in the context of society with the following goals for school science: "use appropriate scientific processes and principles in making personal decisions; engage intelligently in public discourse and debate about matters of scientific and technological concern" (1996, p.13). This is a far cry from the more traditional knowledge-transfer approach to science education represented by the transmission of scientific facts or verification laboratory activities used by teachers with students. Rather, it places science in a societal and global context, and raises issues of ethics and personal responsibility for all students; these kinds of issues must be addressed in more than a didactic manner.

There are vast implications here for changes in both the processes and content of science education. Science education is being challenged to incorporate more interactive, inquiry-based approaches and methods and to more effectively and extensively focus on the ethical and social content of science and technology. An even more radical and challenging step is to join the broader school agenda of fostering positive character development as an explicit goal of all aspects of the school curriculum and practices. This step flies in the face of recent trends to departmentalize the curriculum and dehumanize the student (Apple & Beane, 1995).

These kinds of transformations in curriculum and practice in science education are not occurring without resistance. A commonly voiced concern by many teachers is that they feel they are taking valuable classroom time away from their state or local mandated science curriculum to pursue topics that raise moral questions about science and technology or focus on Science/Technology/Society (STS) topics. STS is defined according to the National Science Teachers Association position statement (1993) as: “a focus on real-world problems which have science and technology components from the students' perspectives... lay the basis for empowering students so that as future citizens they realize they have the power to make changes and the responsibility to do so” (Yager & Roy, 1993). It is consequently feared that to do so would reduce the academic effectiveness and rigor of science instruction. However, the inclusion of topics that stress the role of STS did not impair students' academic achievement when compared with “traditional” science instruction (Pedersen, 1990). The most significant findings were that changes occurred in students' attitudes toward science and their perceptions of their problem-solving abilities; both were found to be significantly more positive when teachers employed STS organizers in science classes (McComas, 1993; Pedersen, 1993). In another series of studies on STS and environmental education (Ramsey & Hungerford, 1989; Rubba, 1989), students became active on issues after they had opportunities to learn about and apply how to investigate issues and how to take action to resolve issues. Furthermore, as we shall see later in this chapter, constructivist, peer discourse approaches to science education not only promote cognitive and socio-moral development of students, but also lead to enhanced science learning (Azmitia & Montgomery, 1993; Phelps & Damon, 1989; Teasley, 1997). Socioscientific issues require students and teachers to move beyond examining only STS interrelationships; they must also examine the connections to the moral dimension of such issues – moral reasoning and character education in the context of scientific inquiry. Again, these studies support the importance of embedding democratic learning in contexts where the development of scientific inquiry is promoted. This parallels findings in general character education that demonstrate that such a focus not only does not detract from academic achievement, but actually enhances it.

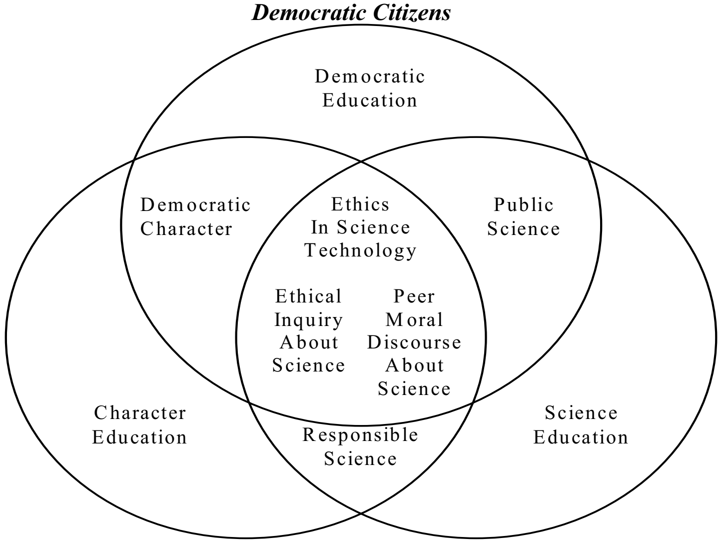
There are also concerns among science educators that the kinds of issues addressed in STS programs may be controversial. Certainly such issues can be controversial, but there is a vast range in the level of such controversy and in ways to use controversial issues to enhance academic performance. In the U.S., issues that bear on human sexuality and reproduction and evolution tend to be more divisive than issues that deal with ecology (although local ecological issues can generate great controversy). Educators can clearly select topics that fit their levels of comfort without necessarily become lightning rods for rancor and divisiveness.

INTEGRATING SCIENCE LEARNING AND TEACHING WITH CHARACTER EDUCATION

Educating for Democratic Character

The most appropriate context in which students can engage in exemplary science education practices and learn about the implications of scientific and technological knowledge is schooling experiences framed around the intersecting principles from democratic schools and character education (see Figure 1). The intersection of science and technology education and character education provides educators with a unique opportunity to implement the principles and practices underlying exemplary science learning and teaching with active democratic citizenship. The conditions for democratic functioning described by Apple and Beane, Berkowitz, Sehr and others are congruent with the goals enumerated in the National Science Education Standards (1996) and science education standards from other nations (UNESCO, 1991).

Figure 1 Education's Obligation to a Democratic Society Education For Democratic Citizens



To actualize science education practices through character education, teachers and students must be aware of the principles of democratic schools and principles of character education, how these principles function in their classroom settings, and how to utilize research about science teaching and learning to construct learning experiences that meet the goals of democratic schools of character. To accomplish the goal of student understanding of science inquiry and scientific literacy, teachers must employ appropriate methods that provide students with the opportunity to demonstrate learning and understanding. For example, when students engaged in activities where they experimented, solved problems, or manipulated variables (i.e., laboratory activities that are truly investigative in nature), their conceptual understanding in all science domains was enhanced (Gabel, 1994). These kinds of teaching methods empower the learner to "make meaning" based on the prior experiences they bring to the learning context. When such methods pervade the educational context and are additionally applied to the moral content of science (i.e., science ethics, STS), then they serve both to educate about science and educate for democratic character.

Teachers of Science or Teachers of Students: A False Dichotomy

One problem with convincing science educators of the merits of this argument is that they typically perceive themselves as teachers of science, rather than as teachers of students. This is particularly true at the secondary level. Furthermore, their understanding of their roles as teachers of science is often to transmit the content of the science curriculum. Interestingly, this is also part of the reason for the relatively low status of educators in our society. Writing in 1965 and from a European perspective, Piaget (1970) identified this problem clearly, "the profession of educator has not yet attained, in our societies, the normal status to which it has the right in the scale of intellectual values…The general reason is, for the most part, that the schoolteacher is not thought of, either by others or, what is worse, by himself, as a specialist from the double point of view of techniques and scientific creativeness, but rather as the mere transmitter of a kind of knowledge that is within everyone's grasp" (p. 11). If the focus for science educators is on science content, then the ability to transmit scientific content reinforces a static view of knowledge as an end product. If, on the other hand, the focus is on pedagogical process, then the educator may lay claim to the status of expert, drawing upon knowledge to create learning. It is just such pedagogical processes that are at the heart of effective character education, citizenship education, and, as we argue here, science education.

Among the bodies of research upon which teachers can draw are the findings and recommendations about student learning based on cognitive structural models (DeVries & Zan, 1994; Furth & Wachs, 1975; Lowell, 1979; Piaget, 1970; Sigel, 1979) and studies from moral reasoning and development (Berkowitz & Oser, 1985; Damon, 1982; Killen & Hart, 1995; Kurtines & Gewirtz, 1987, 1991a, 1991b, 1991c; Lickona, 1991; Power, Higgins & Kohlberg, 1989). Given the focus of science education on the development of scientific reasoning capacity, the focus on citizen education on promoting an engaged and critical perspective, and the focus of character education on fostering autonomous moral thinking, a constructivist approach to education seems highly appropriate. Constructivism can be viewed from a learning perspective and from a teaching perspective as an approach toward learning in which students build their knowledge and come to understand the world through physical and social means – "making meaning" out of their experiences (Driver & Oldham, 1986; Hein, 1998; Tobin, 1993; von Glasersfeld, 1995). Constructivism is a perspective that assumes that humans have cognitive structures through which they make meaning of the world. Such structures are systems of logic that are used to interpret experience and comprehend and create new knowledge and ways of thinking. It is this "construction" of knowledge that gives "constructivism" its name. Directly and symbolically encountering the world is critical to a constructivist perspective on education. Furthermore, such meaning making structures develop both by encountering and attempting to make sense of the physical world and by collaborating with others in such meaning making endeavors. Using constructivism to frame learning and teaching science would involve diverse processes from both the student's and the teacher's perspectives (see Table 1).

Table 1. Science Learning—Student and Teacher Perspectives

Science Learning—student perspective	**Science Teaching—teacher perspective**
A. Engage in learning at many levels of meaning from naïve/simple to sophisticated/complex understandings	Be aware of diversity in student conceptions of science ranging from naïve/simple to sophisticated/complex understandings
B. Engage in wide variety of science activities that capitalize on various modes of learning	Provide wide range of activities that allow for the differences in learning modalities
C. Approach problem-solving from range of views	Provide opportunities for students to solve problems where a range of solutions and perspectives are necessary for resolution
D. Engage in learning based upon life experiences	Draw upon life experiences or lack of experiences when selecting appropriate learning activities
E. Engage in learning that requires experimentation, conjecture, drawing conclusions, assessing and evaluating outcomes and consequences, projects implications of decisions and actions	Provide activities and a broader learning environment where inquiry is modeled and inquiry is the model around which student learning is accomplished
F. Understand that learning purposeful and the responsibility of the learner	Design learning tasks in ways where students make sense of "science as a way of thinking"
G. Engage in learning as an active process involving personal negotiation and social negotiation	Implement curriculum which includes learning tasks, resources, and discourse about science and technology

A science classroom can be viewed as a cultural domain in which teachers and students learn and apply science inquiry, that is, a "set of interrelated processes by which scientist and students pose questions about the natural world and investigate phenomena" (National Science Standards, 1994, p. 214). Students enter classrooms with preconceived ideas about how their world operates (Cobb, 1989; Driver, Guesne & Tibershien, 1985). When students are confronted with new experiences, they are challenged cognitively to either "fit" the new idea into their current mental schema or disregard or distort the idea. The process of integrating new knowledge into existing cognitive schemas requires learners to invoke current understanding, engage in learning so that the new task is related to the existing schema, and then reorganize the schema-"fitting" new ideas into previous schemas. Since the emphasis on learning is grounded in the learner's perspective, the external authority (represented by the teacher) does not determine the construction of the learner's schema. The consequence of this view is that the emphasis for learning is shifted from the teacher's perspective of the "correct" answer to the learner's organization of successful experiences. The teacher's role (see Table 1A-B) is to be aware of the diversity in student understanding (based on how well students integrate new ideas into existing schemas) and to provide the range of learning activities that allow for differences in conceptual understanding and for the variation in learning modalities.

The principal issue for science learning is that students learn not only through their personal cognition, but very importantly, learn through social construction of knowledge. In a science classroom, there is a dynamic relationship between what the student knows and the integration of new understandings about science (Tobin, 1993). This understanding comes about through social interactions. The interactions where ideas are explored, exchanged, reinforced, manipulated, and reaffirmed are critical for students to integrate their new understandings of science concepts and inquiry (see Table 1-G). Just as the scientific community engages in the complex process of building models, explaining phenomena, validating experiments through a socially defined community, so too must students experience the construction of science understanding and concurrently, the development of moral reasoning. For the maximal impact of such educational processes on character and democratic citizenship development, there should also be an explicit focus on social and moral goals (Dalton & Watson, 1997).

Nonetheless, simply focusing on such constructivist principles is not enough. If we merely want to foster the acquisition of scientific understanding and the development of logical capacities necessary for scientific thinking and learning, then we may be able to limit our educational prescription to such traditional practices. As we have noted repeatedly, for comprehensive education in general and comprehensive science education in particular, it is necessary to also foster moral character development and democratic citizenship. To do this, one must not only rely on a constructivist approach, but also apply the appropriate learner-centered methods to specific socio-moral aspects of schools in general and the science curriculum in particular. For example, in using collaborative learning techniques for science inquiry, students in groups should be instructed to focus not only on the scientific concepts being explored but also on the intentionally social task of the collaborative process (e.g., sharing, turn-taking, leadership/followership, consensus building).

Instructional Models

Although students must ultimately individually come to understand science concepts and develop moral reasoning skills and civic virtue, they must also interact in classroom settings to explore the personal and social implications of scientific and technological knowledge. In classroom settings, teachers can employ specific teaching models that allow students to explore and develop a greater depth of understanding of science and societal issues associated with science and technology, while at the same time fostering character development. The most effective strategies to engage students in understanding science concepts and inquiry involve the family of instructional strategies known as the inquiry models (Joyce & Weil, 1986) and the social family/cooperative learning models of teaching (Johnson, Johnson & Scott, 1978; Slavin, 1980).

Inquiry Models

As one example, the Inquiry Training Model focuses students on training their thinking skills toward causal reasoning and building their understanding about science concepts by collecting information, building and testing hypotheses. The Biological Science Inquiry Model represents one inquiry model where students engage in "academic" research as would scientists in their laboratories (Schwab, 1965). These inquiry models, however, emphasize the content and process of science, which also appeals to many teachers who stress these two aspects of science teaching in their classrooms. Although students are encouraged to generate questions about many aspects of science, the explicit goal of this model does not stress ethical issues. The emergence of ethical issues is much more likely to be addressed in the social family models used largely in social studies classes or in science classrooms where teacher implement STS organizers.

Social Family/Cooperative Learning Models

Among the models in the social family/cooperative learning models are the jurisprudence model (studying thinking about social policy), the group investigation (building education through the democratic process), social science inquiry (studying social, economic, and political life), and role-playing (studying social behavior and values) (Joyce & Weil, 1986). Many of these models place students in positions as learners who must engage in the social construction of scientific knowledge and implement their understanding of inquiry. These models involve students in contexts where they:

- Share and discuss information to complete learning tasks and resolve problems;
- Work in cooperative groups to accomplish the tasks;
- Use peer tutoring;
- Prepare for and engage in public debates (i.e., mock town councils);
- Identify issues and generate questions;
- Determine what information is needed to answer questions and resolve issues;
- Gather and process information and determine how to represent and communicate information;
- Determine the validity and reliability of information;
- Synthesize possible strategies and/or resolutions; and

- Predict possible consequences of actions and inactions on local, regional, national, and international levels.

Ethics-based Models

Additional models or strategies that have been modified or derived from this family and the inquiry model are models such as STS models (Yager, 1993), bioethical decision-making (Hendrix & Mertens, 1990), and environmental ethics (Simmons, 1994). These strategies and models all have at their core an emphasis on ethics and science and technology. They employ methods that both foster character and reasoning capacities and incorporate ethical content. However, to meet the goals for science education, we must also consider a model that empowers students and teachers to address ethics and science drawn from a strong research base from the cognitive sciences and moral development—transactive discussion.

Transactive Discussion as a Model for Comprehensive Science Education

We have argued thus far that science education cannot be divorced from the goals of education in general. Beyond the argument that science education is part of broader schooling, we have also asserted that science education is specifically linked to the social-emotional goals of education, what is often called character education. To be a citizen, especially of a democratic society, one needs to be an active thoughtful and informed participant who can engage and understand in public debates about the uses of science and technology. To be a scientist, one needs to understand the relationship of science and its practitioners to the broader society. It is up to schools to promote both ethical scientists and reflective, responsible citizens who are scientifically literate. Science education must reflect both the goals of producing scientists of character and scientifically literate and responsible democratic citizens.

Both the processes of character education and the content of science ethics are relevant to achieving these ends. It may appear that so many disparate goals for science education, citizenship education, and character education have been presented that it would be virtually impossible to incorporate them all in the science classroom. At this point we offer an illustrative example of how the different components we have addressed in this chapter can dovetail and provide the bases for a core set of exemplary experiences in science learning.

Researchers in education (i.e., constructivist studies based on Piaget's works) have reported that the inquiry approach to learning can be applied to both standard academic and socio-moral outcomes. It is generally understood that the way one understands (or fails to understand) both physical and psychological phenomena is largely a product of one's current system for making meaning of the world or one's cognitive stage or structure. Such structures evolve into more adequate ways of knowing as a product of the interaction between one's direct grappling with the world (either alone or with others) and the world that one is trying to comprehend (e.g., a moral dilemma, a scientific phenomenon). The core of this process for structural development (i.e., the development of more effective ways of thinking about the world) is social interaction about cognitive problems, whether logical, physical, or social. These social interactions in schools rely heavily on peer discussion of curricular topics. The topics may be scientific in nature (e.g., what DNA is and how it affects who we are) or socio-moral in nature (e.g., how absolute is the right to life), or may contain elements of both (e.g., the moral implications of cloning humans). Furthermore, the goals of such peer discussion programs can focus on students' understanding of the curriculum (e.g., science and technology) and/or understanding the socio-moral world (e.g., ethics, character). The basic tenets of such an educational approach are the same: implementing developmentally stimulating programs of peer discussion in the classroom that serve both the goals of science education and the goals of character and citizenship education. The interest in developmental peer discussion arose almost simultaneously in quite different arenas. Followers of Piaget in Switzerland employed peer interactive methods to promote development of Piaget's logico-mathematical structures of reasoning (e.g., Doise, Mugny & Perret-Clermont, 1975; Mugny, Perret-Clermont & Doise, 1981) in the 1970s, while Scott Miller was doing likewise in the U.S. (Miller & Brownell, 1975). At about the same time, Berkowitz, Gibbs, and Broughton (1980) studied the same processes as applied to peer discussions of moral issues, which were designed to stimulate the development of socio-moral reasoning structures. In all of these cases, the peer interactive process was assumed to promote disequilibrium within the reasoning structures of the discussants. In turn, peer interaction fostered stage development. The interactive process itself was stimulated by the experimental method employed but was not directly studied.

In the 1980's, researchers began to examine the interactive process itself, particularly the nature of peer discussion, in order to better understand how peer discussion fostered cognitive growth. Damon and Killen (1982), Bearison (1982), Miller (1980), and Berkowitz and Gibbs (1983) all began more serious consideration of the features of peer discussion that could be empirically linked to the structural developmental outcomes of peer interactions. Damon and Killen, Bearison, and Berkowitz and Gibbs relied on socio-moral content, while Miller used standard Piagetian physics problems as the basis for peer discussions (e.g., the Piagetian balance beam task). The idea for this research, however, was that certain forms of peer discussion would be more likely to stimulate the development of logical structures.

Berkowitz and Gibbs (1983), in the most detailed account of such interactive processes, identified a form of peer interaction called "transactive discussion." Transactive discussion occurs when one discussant demonstrates clear discursive evidence of reasoning about another discussant's reasoning. The highest form of transactive discussion is termed "operational." This occurs when the reasoning about another's reasoning is transformational; i.e., it entails some element of actively, cognitively operating on the other's reasoning, such as elaborating it, critiquing it, extending it, or integrating it with one's own reasoning. A lower form is called "representational." This is when one merely re-presents the other's reasoning such as by paraphrasing it. A third form is "elicitational." This occurs when one elicits reasoning from another without representing it; e.g., asking for a clarification (see Table 2).

The presence of transaction in peer discussions is related to significant structural gains in children and adolescents (Berkowitz & Gibbs, 1983; Damon & Killen, 1982; Kruger, 1992; Walker & Taylor, 1991). These findings clearly suggest that such types of peer interaction are also important for the cognitive developmental goals of science education; i.e., to foster the development of scientific reasoning and problem-solving.

Another important implication for science education is that students who used more transactive discussion in peer interactions also learned to solve scientific and mathematical problems more effectively. Azmitia and Montgomery (1993) demonstrated that peer discussions with friends produced better solutions to isolation of variables tasks than did peer discussions with acquaintances. More importantly, however, is their finding that the advantage in friend dialogues was due to "their greater tendency to evaluate their problem-solving outcomes and engage in transactive conflicts" (p. 218). These findings have been substantially replicated in a study of peer musical composition collaborations (Miell & MacDonald, 2000). Teasley (1997) reported two studies that presented physics problems through computer simulations. Dyads exhibiting more transaction during their problem-solving interactions improved their solutions and were better able to predict the outcomes of the scientific experiments. Furthermore, subjects who worked alone and were instructed to speak out loud evidenced some transaction. Teasley concluded that "collaborations lead to learning not because of the partner but rather because having a partner increased the likelihood that children would produce transactive statements" (p. 380).

In attempting to understand both the power of peer transactive discussion and its particular relevance to science education, Teasley (1997) has argued:

> Various factors related to improved reasoning are decidedly dialogic: interpreting, explaining, and justifying experimental outcomes appropriately. In theory, transactive discussions should be particularly effective in scientific reasoning tasks, because this type of discussion forms the basis for the epistemic actions (Pontecorvo & Girardet, 1993) relevant to this domain. For example, work by Kuhn and her colleagues (e.g., Kuhn, Amsel & O'Laughlin, 1988) has demonstrated that careful interpretation of evidence is critical for successful reasoning. Similarly, Klahr and his colleagues (e.g., Dunbar & Klahr, 1989; Klahr, Fay, & Dunbar, 1993) have shown that constructing and revising coherent explanations of the data are an essential part of the reasoning process. Because transactive discussions specifically act on reasoning, this type of discussion should have a significant effect on children's success with scientific reasoning tasks by supporting the types of activity that Kuhn, Klahr, and others have shown to be crucial to successful experimentation. (p. 364)

Clearly, transactive peer discussion is not a panacea for education in general or science education in particular. It can be applied effectively to reasoning tasks, but not to rote memorization tasks (Phelps & Damon, 1989). It is not automatically produced in peer interactions, and peer interactions themselves do not result in learning without the presence of significant amounts of transactive discussion (Teasley, 1997). Certain types of social units are more likely to produce more transaction. Teasley found that dyads used more transaction than individuals instructed to speak aloud. Friends tended to use more transaction than non-friends

Table 2. Transactions

A. Representational Transacts
  1. *Feedback Request(R):* Do you understand or agree with my position?
  2. *Paraphrase (R):*
    (a) I can understand and paraphrase your position or reasoning.
    (b) Is my paraphrase of your reasoning accurate?
  3. *Justification Request (R):* Why do you say that?
  4. *Juxtaposition (R):*Your position is X and my position is Y.
  5. *Dyad Paraphrase (R):* Here is a paraphrase of a shared position.
  6. *Competitive Juxtaposition (R):* I will make a concession to your position, but also reaffirm part of my position.

B. Hybrid Transacts
  7. *Completion (R/O):*I can complete or continue your unfinished reasoning.
  8. *Competitive Paraphrase (R/O):* Here is a paraphrase of your reasoning that highlights its weakness.

C. Operational Transacts
  9. *Clarification (O):*
    (a) No, what I am trying to say is the following.
    (b) Here is the clarification of my position to aid in your understanding.
  10. *Competitive Clarification (O):* My position is not necessarily what you take it to be.
  11. *Refinement (O):*
    (a) I must refine my position or point as a concession to your position or point (subordinative mode).
    (b) I can elaborate or qualify my position to defend against your critique (superordinative mode).
  12. *Extension (O):*
    (a) Here is a further thought or an elaboration offered in the spirit of your position.
    (b) Your position implicitly involves an assumption that is questionable (premise attack).
    (c) Your reasoning does not necessarily lead to your conclusion/opinion, or your opinion has not been sufficiently justified.
    (d) Your reasoning applies equally well to the opposite opinion.
  13. *Contradiction (O):* There is a logical inconsistency in your reasoning.
  14. *Reasoning Critique (O):*
    (a) Your reasoning misses an important distinction, or involves a superfluous distinction.
    (b) Your position implicitly involves an assumption that is questionable (premise attack).
    (c) Your reasoning does not necessarily lead to your conclusion/opinion, or your opinion has not been sufficiently justified.
    (d) Your reasoning applies equally well to the opposite opinion.
  15. *Competitive Extension (O):*
    (a) Would you go to this implausible extreme with your reasoning?
    (b) Your reasoning can be extended to the following extreme, with which neither of us would agree.
  16. *Counter Consideration (O):* Here is a thought or element that cannot be incorporated into your position.

Table 2. Transactions (continued)

17. *Common Ground/Integration (O):*
    (a) We can combine our positions into a common view.
    (b) Here is a general premise common to both of our positions.
18. *Comparative Critique (O):*
    (a) Your reasoning is less adequate than mine because it is incompatible with the important consideration here.
    (b) Your position makes a distinction that is seen as superfluous in light of my position, or misses an important distinction that my position makes.
    (c) I can analyze your example to show that it does not pose a challenge to my position.

(Azmitia & Montgomery, 1993) or child-mother dyads (Kruger & Tomasello, 1986). Children of different abilities also tended to use more transaction (Berkowitz & Gibbs, 1983; Faulkner, et al., 2000). Only certain forms of transaction may be relevant to learning in certain domains; e.g., Azmitia and Montgomery (1993) reported that specifically conflictual transactions fostered the development of scientific learning in their study of friend and acquaintance dyadic interactions.

It is quite clear from the results of research studies cited here that a greater presence of transactive discussion in social interactions is significantly related to both the development of reasoning capacities and the solution of scientific problems. Science educators ought therefore to be very interested in how to harness this educational and developmental potential in peer interactive classroom processes.

PUTTING IT ALL TOGETHER

In this chapter, we have addressed the overlap between science education and character education by illustrating how the goals for science education and for the education of an informed and responsible citizenry can be advanced through the integration of character education and science education. An examination of the conjoint goals of character education and science education reveals some overlaps and some unique goals. Science education should promote scientific literacy and the development of scientific reasoning. The latter includes both the methods and processes of science as well as the basic cognitive capacities required for effective scientific thinking and problem-solving. We have argued that science education needs to focus on the relation of science to society through STS and science ethics, and that this goal must include a focus on citizenship education, at least as it relates to scientific issues. Whereas promoting science literacy is not a central goal of citizenship or character education, all of the other goals overlap between science education and character/citizenship education. For example, part of character is socio-moral reasoning; therefore, the focus on fostering cognitive development applies to both disciplines. But we have also argued that science education should prepare students to be citizens of a democratic society, both generally and as they engage in public debate about specifically scientific and technological issues. Science education should focus on the social and ethical concerns in the fields of science and technology. This latter goal includes experience in democratic processes, knowledge about the roles, functions and obligations of a democratic citizen, and the character to be a responsible and participatory member of a democratic society. Science education cannot be divorced from the general goals of the broader school to promote the overall moral character of students. The opening quote from John Dewey underscores this issue as does the ubiquitous statement by former U.S. President Theodore Roosevelt that "to educate a person in mind and not in morals is to educate a menace to society."

We have presented the concept of transactive peer discussion as an example of how developmental psychology can contribute to serving the goals of science education. Transactive discussion is a process that occurs in peer collaborative tasks (although Teasley, 1997, has demonstrated that it can occur in individual "talk aloud" tasks as well). When educators create an inquiry-based classroom in which students collaboratively explore scientific issues and solve scientific problems, then transactive discussion is more likely to occur. That is, students are more likely to engage each other's reasoning about the scientific and ethical concepts and subsequently both understand them better and solve the problems more accurately and quickly.

Peer collaborative science education will improve scientific learning and will also foster the development of more mature ways of thinking about the physical world, ways that provide pathways for continuing life-long learning. Hence the many curricular and developmental goals of science education are supported by a greater reliance on peer collaborative learning methods, especially when those methods increase the use of transactive discussion.

Such methods also serve other goals for science education as well. These methods increase the responsibility of students both for their own learning and for controlling their own behavior, and for allowing all of the social developmental benefits that have been reported for collaborative learning in general (Johnson, Johnson & Scott, 1978). In other words, peer collaborative methods help foster character development in general and specifically as it applies to the development of civic character for a democratic society.

The final value of transactive discussion in the science classroom comes when the teacher incorporates science ethics into the curriculum; e.g., through STS curricula. Students will learn ethical issues in science and at the same time stimulate moral reasoning development through their moral transactive interactions. Whereas transaction can foster students' logical development by focusing on scientific problems and issues, teachers can foster the development of social and moral reasoning by focusing on ethical and social issues.

We can see therefore that the inclusion of peer collaborative scientific and ethical problem-solving and inquiry in the science classroom has the potential to promote the diverse goals, both traditional and non-traditional, of science education. One of the great fallacies of education has been the assumption that students come to school with the capacity to engage in productive discussion. We routinely tell parents what supplies children need for the opening of school each year and they dutifully trudge to school with backpacks bursting with pencils, paper, tissues, calculators. Teachers teach children the rules of decorum in their classrooms and the procedures for getting permission to go to the toilet or for recess. Rarely do schools teach children how to engage in productive discussion. Certainly we teach children what not to do; e.g., not to interrupt, not to use pejorative language, but we tend not to equip children with the peer interactional skills that are likely to make collaborative inquiry-based education work optimally. It behooves us as educators to pay serious attention to teaching children how to learn collaboratively by spending time on the peer interactional processes that serve the goals of the classroom and curriculum; i.e., processes like transactive discussion.

Educators can also increase the likelihood of rich transactive interactions by pairing students with different levels of understanding of the learning task on hand. Students can be assessed individually on their comprehension of and solutions to the tasks to be confronted collaboratively, and then paired in groups that do not have similar initial understandings.

Since we know that working with friends produces more learning and development than does working with others, teachers can allow students to form their own pairs or, from a character education standpoint, work specifically on increasing the positive relationships between all students in the classroom. We know that schools and classrooms that are most effective at character education have students who perceive their schools and classrooms as caring communities where people tend to be benevolent and get along well (Solomon, et al., 2000). Building positive relationships is at the heart of most successful school reform and character education models, and therefore ought to be a goal of the science educator as well.

Tasks that engage problem-solving and reasoning are more likely to engender transactive discussion than tasks that rely heavily on rote learning of facts (Phelps & Damon, 1989). Collaborative tasks should therefore be designed around more open-ended inquiry-based learning to maximize the amount of transactive discussion that occurs in the peer interactions. A further way to enhance this is through the instructional set given to the students. Instructions that push students to having to reach agreement or consensus often forces them to engage each others' reasoning, rather than simply settling for their initial disparate points of view (Berkowitz & Gibbs, 1983; Maitland & Goldman, 1974).

CONCLUSION

As Dewey (1944) stated, the obligation of schooling is to enculturate students into an informed citizenry that can function effectively as members of a democratic society. Recent calls to action for science education reform have emphasized the critical need and obligation to provide the foundation for students to engage in scientific thinking (i.e., problem-solving) and to take actions arising from their understanding of science and technology, alongside the traditional goal of increasing scientific literacy. It is insufficient for students merely to pass a test on scientific knowledge without understanding the societal, cultural, moral, and economic/ political contexts in which scientific and technological knowledge is generated and negotiated within the scientific community and society at large. If we expect students to understand the implications of scientific and technological knowledge, we must provide learning contexts in which they engage in and experience learning and functioning within a democratic society. As science educators we cannot understand teaching and learning without understanding civic character and moral reasoning as integral parts of science inquiry. As educators, we cannot leave the development of character and moral reasoning to chance. We need to study and incorporate educational methods that foster such development. Collaboration through transactive peer discussion not only fosters the development of moral reasoning and social skills, but also increases science learning and provides egalitarian experiences that pave the way for future participation in a democratic society.

We cannot rest on our laurels of knowledge transfer in science and technology and turn a blind eye to the prevalence of unethical and irresponsible uses to which such knowledge is routinely put by scientists or others who are brilliant but immoral. As the Reverend Martin Luther King, Jr. noted, "Our scientific knowledge has surpassed our spiritual… We have guided missiles and misguided men." Or as one concerned citizen implored educators,

> Dear Teacher,
>
> I am a survivor of a concentration camp. My eyes saw what no person should witness: Gas chambers built by learned engineers. Children poisoned by educated physicians. Infants killed by trained nurses. Women and babies shot and burned by high school and college graduates. So, I am suspicious of education.
>
> My request is: Help your students become human. Your efforts must never produce learned monsters, skilled psychopaths, educated Eichmans.
>
> Reading, writing, arithmetic are important only if they serve to make our children more humane. (Sadker & Sadker, 1977).

As educators, especially as science educators, our ultimate task is not to teach science, but to teach human beings.

REFERENCES

Apple, M. & Beane, J. (1995). *Democratic Schools*. Alexandria, VA: Association for Supervision and Curriculum Development.

Azmitia, M., & Montgomery, R. (1993). Friendship, transactive dialogues, and the development of scientific reasoning. Social *Development*, *2*, 202-221.

Bearison, D.J. (1982). New directions on studies of social interaction and cognitive growth. In F. Serafica (Ed.), *Social-cognitive development in context* (p. 199-221). New York: Guilford.

Berkowitz, M. W. (1997). The complete moral person: Anatomy and formation. In J.M. Dubois (Ed.), *Moral issues in psychology: Personalist contributions to selected problems* (p. 11-41). Lanham, MD: University Press of America.

Berkowitz, M. (2000). Civics and moral education. In B. Moon, S. Brown, & M. Ben-Peretz (Eds.), *Routledge International Companion to Education* (p. 897-909).New York: Routledge.

Berkowitz, M. W. (In press). The science of character education. In W. Damon (Ed.), *Future directions in character education*. Stanford CA: Hoover Institute Press.

Berkowitz, M. W., & Gibbs, J.C. (1983). Measuring the developmental features of moral discussion. *Merrill-Palmer Quarterly, 29*, 399-410.

Berkowitz, M. W., Gibbs, J. C., & Broughton, J. M. (1980). The relation of moral judgment stage disparity to developmental effects of peer dialogues. *Merrill-Palmer Quarterly, 26*, 341-357.

Berkowitz, M. W., & Grych, J. (1998). Fostering goodness: Teaching parents to facilitate children's moral development. *Journal of Moral Education, 27*, 371-391.

Berkowitz, M. W., & Grych, J. (2000). Early character development and education. *Early Education and Development, 11*, 55-72.

Berkowitz, M. W., & Oser, F. (Eds.), (1985). *Moral education: Theory and applications*. Hillsdale, NJ: Lawrence Erlbaum and Associates.

Berkowitz, M.W., Schaeffer, E.F., & Bier, M.C. (2001). *Character education in the United States. Education in the North, 2001-2002, 1*(9), 52-59.

Cobb, P. (1989). Experiential, cognitive, and anthropological perspectives in mathematics education. *For the Learning of Mathematics, 9*(2), 32-42.

Dalton, J., & Watson, M. (1997). *Among friends: Classrooms where caring and learning prevail*. Oakland CA: Developmental Studies Center.

Damon, W. (1988). *The social world of the child*. San Francisco: Jossey-Bass.

Damon, W., & Killen, M. (1982). Peer interaction and the process of change in children's moral reasoning. *Merrill-Palmer Quarterly, 28*, 347-367.

DeVries, R., & Zan, B. (1994). *Moral classrooms, moral children: Creating a constructivist atmosphere in early education*. NY: Teachers College Press.

Dewey, J. (1944). *Democracy and education*. New York: The Free Press.

Doise, W., Mugny, G., & Perret-Clermont, A.N. (1975). Social interaction and the development of cognitive operations. *European Journal of Social Psychology, 5*, 367-383.

Driver, R., Guesne, E., & Tibershien, A. (Eds.) (1985). *Children's ideas in science*. Philadelphia: Open University Press.

Driver, R. & Oldham, V. 1986. A constructivist approach to curriculum development in science. *Studies in Science Education, 13*, 105-122.

Faulkner, D., Joiner, R., Littleton, K., Miell, D., & Thompson, L. (2000). The mediating effect of task presentation on collaboration and children's acquisition of scientific reasoning. *European Journal of Psychology of Education, 15*, 417-430.

Furth, H.G., & Wachs, H. (1975). *Thinking goes to school: Piaget's theory in practice*. New York: Oxford University Press.

Gabel, D. (Ed.), (1994). *Handbook of research on science teaching and learning*. New York: Macmillan Publishing Company.

Greene, M. (1985). The role of education in democracy. *Educational Horizons, 63*, 3-9.

Hein, G. (1998). *Learning in the Museum*. New York: Routledge.

Hendrix, J., & Mertens, T. R. (1990). Empowering teachers to meet students and peers' educational needs. *The American Biology Teacher, 52*, 219-24.

Johnson, D., Johnson, R., & Scott, L. (1978). The effects of cooperative and individualized instruction on student attitudes and achievement. *Journal of Social Psychology, 104*, 207-216.

Joyce, B. & Weil, M. (1986). *Models of Teaching*. Englewood Cliffs, NJ: Prentice Hall Inc.

Killen, M., & Hart, D. (1995). *Morality in everyday life: Developmental perspectives*. NY: Cambridge University Press.

Kruger, A.C. (1992). The effect of peer and adult-child transactive discussions on moral reasoning. *Merrill-Palmer Quarterly, 38*, 191-211.

Kruger, A.C., & Tomasello, M. (1986). Transactive discussions with peers and adults. *Developmental Psychology, 22*, 681-685.

Lickona, T. (1983). *Raising good children*. NY: Bantam Books.

Lickona, T. (1991). *Educating for character*. NY: Bantam Books.

Lickona, T., Schaps, E., & Lewis, C. (1996). *Eleven principles of effective character education*. Washington DC: Character Education Partnership.

Lowell, K. (1979). Intellectual growth and the school curriculum. In F.B. Murray (Ed.), *The impact of Piagetian theory on education, philosophy, psychiatry, and psychology* (p. 191-208). Baltimore: University Park Press.

MacDonald, R., Miell, D., & Morgan, L. (2000). Social processes and creative collaboration in children. *European Journal of Psychology of Education, 15*, 405-415.

Maitland, K., & Goldman, J. (1974). Moral judgment as a function of peer group interaction. *Journal of Personality and Social Psychology, 30*, 699-704.

McClellan, B. E. (1999). *Moral education in America: Schools and the shaping of character from colonial times to the present*. NY: Teachers College Press.

McCommas, W. (1993). STS education and the affective domain. In R. Yager, (Ed.), *What Research Says to the Science Teacher: The Science, Technology, Society Movement. VII*, (p. 161-168).

Miell, D., & MacDonald, R. (2000). Children's creative collaborations: The importance of friendship when working together on a musical composition. *Social Development, 9*, 348-369.

Miller, M. (1980). *Learning how to contradict and still pursue a common end – The ontogenesis of moral argumentation*. Unpublished paper, Max Planck Institute, Starnberg Germany.

Miller, S. A., & Brownell, C. A. (1975). Peers, persuasion, and Piaget: Dyadic interaction between conservers and non-conservers. *Child Development, 46*, 992-997.

Mosher, R., Kenny, R., & Garrod, A. (1994). *Preparing for Citizenship: Teaching Youth to Live Democratically*. Westport, CT: Praeger.

Mugny, G., Perret-Clermont, A.N., & Doise, W. (1981). Interpersonal coordinations and sociological differences in the construction of the intellect. In G.M. Stephenson & J.M. Davis (Eds.), *Progress in applied social psychology (Volume 1)* (p. 315-343).

National Science Education Standards (1996). Washington, D. C.: National Academy Press.

Pedersen, J. (1993). STS issues: A perspective. In Yager, (Ed.), *What Research Says to the Science Teacher: The Science, Technology, Society Movement. VII,* p. 17-22.

Phelps, E., & Damon, W. (1989). Problem solving with equals: Peer collaboration as a context for learning mathematics and spatial concepts. *Journal of Educational Psychology, 81*, 639-646.

Piaget, J. (1970). *Science of education and the psychology of the child*. New York: Viking Press.

Power, C., Higgins, A., & Kohlberg, L. (1989). *Lawrence Kohlberg's approach to moral education*. NY: Columbia University Press.

Ramsey, J. & Hungerford, H. (1989). The effects of issue investigation and action training on environmental behavior in seventh grade students. *Journal of Environmental Education, 20*, 29-34.

Rubba, P. (1989). An investigation of the semantic meaning assigned to concepts affiliated with STS education and of STS instructional practices among a sample of exemplary science teachers. *Journal of Research in ScienceTeaching, 26*, 678-702.

Sadker, M., & Sadker, D.M. (1977). *Now upon a time: A contemporary view of children's literature*. NY: Harper and Row.

Schaps, E. (2001, Jan-Feb). Community in school: The key to violence prevention and more. *Safe Learning,* 20-21.

Science/Technology/Society Position Statement. (1993). In National Science Teachers Association Handbook. Washington, DC: National Science Teachers Association.

Schwab, J. (1965). *Biological sciences curriculum study, Biology teachers' handbook*. New York: John Wiley and Sons.

Sehr. D. (1997). *Education for public democracy*. New York: State University of New York Press.

Sigel, I. E. (1979). Piaget and education: A dialectic. In F. B. Murray (Ed.), *The impact of Piagetian theory on education, philosophy, psychiatry, and psychology* (p. 209-224). Baltimore: University Park Press.

Simmons, P. (1994). *Ethics in science and technology*. National Science Teachers Association Annual Conference, Anaheim.

Sizer, T. R., & Sizer, N. F. (1999). *The students are watching: Schools and the moral contract*. Boston: Beacon Press.

Slavin, R. (1980). Cooperative learning. *Review of Educational Research, 50*, 315-42.

Solomon, D., Battistich, V., Watson, M., Schaps, E., & Lewis, C. (2000). A six-district study of educational change: Direct and mediated effects of the Child Development Project. *Social Psychology of Education, 4*, 3-51.

Teasley, S. D. (1997). Talking about reasoning: How important is the peer in peer collaboration? In L.B. Resnick, R. Saljo, C. Pontecorvo, & B. Burge (Eds.), *Discourse, tools, and reasoning: Essays on situated cognition* (NATO ASI Series F, Vol. 160) (p. 361-384). Berlin: Springer-Verlag.

Thiroux, J. P. (2001). *Ethics - theory and practice*. Upper Saddle River, New Jersey: Prentice-Hall.

Tobin, K., (Ed.). 1993. *The Practice of Constructivism in Science Education*. Washington: AAAS Press.

UNESCO (1991). *Values and Ethics and the Science and Technology Curriculum*. Asia and the Pacific Programme of Educational Innovation for Development. Bankok.

Von Glasersfeld, E. (1995). *Radical constructivism. A way of knowing and learning*. London: The Falmer Press.

Walker, L. J., & Taylor, J. H. (1991). Family interactions and the development of moral reasoning. *Child Development, 62*, 264-283.

Yager, R. & Roy, R. (1993). STS: Most pervasive and most radical of reform approaches to “science” education. In R. Yager, (Ed.), *What Research Says to the Science Teacher: The Science, Technology, Society Movement. VII*, p.7-16.

CHAPTER 7

THE ASSESSMENT OF ARGUMENTATION AND EXPLANATION

CREATING AND SUPPORTING TEACHERS' FEEDBACK STRATEGIES

RICHARD DUSCHL

INTRODUCTION

A trend in education is the adoption of performance assessment strategies. Some are benchmark assessments in which the students are directed to assemble a portfolio of information that demonstrates achievement. Other performance assessment strategies are on-demand standardized test formats where students, in the case of science, are provided with a set of materials and instructed to design, implement and evaluate an experiment. Clearly the validity of these performance tests rests on the opportunities learner's have during the school year to engage in and receive feedback on the task domains that comprise the educational goals targeted by the curriculum.

Performing, be it as a writer, a musician, a dancer, an engineer, a teacher, or a scientist, is a complex task made up of many sub-tasks. I was very impressed, then, and pleased that my daughters' beginning piano teacher had a wonderful sense of the multiple skills and knowledge bases she would need to develop in order to achieve high levels of performance by her students. As I recall there where no less than 4 sets of goals: the development of strength and flexibility in the hands and fingers, the development of the ability to read musical notation, the development of the ability to learn musical phrasing and playing with feeling, and the nurturing of creative musicality. Students would receive feedback on each of these 4 domains of piano playing at each weekly lesson.

D.L. Zeidler (ed.),
The Role of Moral Reasoning on Socioscientific Issues and Discourse in Science Education, 139-161.

I was struck by this layered or multiple-goal approach because at the time my colleagues and I were beginning to apply a very similar thinking to science instruction. Our emerging idea was that the ability to perform as a science student in middle grade levels would require feedback on multiple domains of practice as well. Alternative assessment strategies like the use of classroom portfolios and instructional practices that promote the use of classroom portfolios were seen as mechanisms for making performance criteria a shared, public and practiced classroom commodity.

Not unlike the piano teacher preparing students for regularly scheduled performances, teachers of science need to develop in their students a set of competencies and skills, often overlapping, and knowledge bases to prepare them for scientific performances. I stress the term set because the emphasis placed on each of the domains of feedback leads quite naturally to a prioritization, intended or otherwise, of 'what counts' as the standards and goals for performance. Such 'what counts' occasions of learning I will call epistemic contexts.

The theme of my paper is straightforward. Science education policy and decision makers have misplaced goals and priorities for the design of curriculum, instruction and assessment models. I want to argue that a primary emphasis on concept learning – the content of science if you will – is the wrong approach for the principal design of science learning environments. Instead, the primary emphasis should be on the development of tools, criteria, standards and rules students can use to investigate, assess and especially evaluate scientific claims. Peter Fensham (1988) has made a similar argument in his historical review of 20th century science education curriculum development. His position is that the almost exclusive emphasis on the conceptual goals of science has depleted science education of its cultural and social contexts. The language of science is not exclusively the enunciation of terms and concepts, facts and laws, principles and hypotheses. The language of science, owing to the restructuring character of scientific claims about method, goals, and explanations, a character firmly established in the history, philosophy and sociology of science (Duschl, 1996; Duschl & Hamilton, 1998), is a discourse that critically examines and evaluates the numerous and at time iterative transformations of evidence into explanations. In order to appreciate conceptual, cultural and/or social contexts of science, some kind of evaluation process is necessary. The role of evaluation standards or criteria in science is an important aspect of doing science. Epistemological goals are needed to judge scientific claims and to guide inquiry. Epistemic contexts should, I feel, stand between the conceptual and the cultural and social contexts as evidence is shaped into explanations.

One widely known model of the evidence to explanation transformation process is Toulmin's Argument Pattern (Toulmin, 1958)[1], a generic representation of scientific discourse from data to conclusions. Applying Toulmin's Argument Pattern (TAP) as a tool for understanding actions in science classroom is not new. Russell (1981) employed the framework to analyze teachers' presentations and representations of science during instructional lessons. Russell's focus was to understand the

[1] See Chapter 5 of van Eemeren, Grootendorst, & Henkemans (1996) for a modern interpretation of Toulmin's Model of Argumentation and the influence it has had on contemporary developments in Argumentation Theory.

nature of authority, rational vs. irrational, given to scientific claims. Diaz de Bustamante and Jimenez-Aleixandre, (1997) and Jimenez-Aleixandre, Bugallo and Duschl (1997) are using TAP to examine students' discourse during investigations with microscopes. Carlsen (1997) also used TAP to analyze high school classroom discourse during science lessons. Continuing with his program of research examining the affect teacher's subject matter knowledge has on classroom discourse, Carlsen "found arguments in the unfamiliar-subject setting were less complex and more philosophically problematic" (p. 14). Eichinger, Anderson, Palincsar and David (1991) used the TAP framework as an argumentation heuristic to guide students' conversations during inquiry lessons. Here students were provided with a blank argumentation form and asked to fill in the relevant information (i.e., data, warrants, backings, rebuttals, conclusions) for the investigation underway.

When the goal of instruction is an understanding of the canonical science, i.e., the accepted knowledge claims, you can think of using the TAP framework as a template for organizing the evidence used, the warrants and backings invoked, the qualifiers employed, and the rebuttals raised by a scientist(s) in the construction of an explanation, a theory, or a model. I have used TAP in precisely this way when teaching non-science students Darwin's arguments for natural selection and evolution. Specifically, students used TAP as a scaffolding device to identify, analyze and then report on the claims Darwin puts forth in the *Origin of the Species*. Following Eichinger et al (1991), using the TAP framework this way enables students to monitor the quality of reasoned arguments and solutions to problems.

The difficulty of using TAP as a template though is the interpretations one allows or accepts for the inclusion/exclusion of claims about the data, the warrants, the backings, the qualifiers, the rebuttals and the conclusions. In other words, what one chooses to monitor and against what criteria shapes the discourse. Here, then, at the level of making decisions about 'what counts' is where I want to claim science is properly done and, subsequently, where classroom discourse and assessments should focus. That is, the focus should be on epistemic contexts.

When the goal of instruction is engaging students in scientific inquiry and when the organization of curriculum, instruction and assessment models provide students with opportunities and encouragement to develop, report, evaluate, revise and defend choices, as well as provide teachers with opportunities to capture, monitor and assess student ideas, epistemic contexts will soon dominate classroom discourse. In particular, when students are provided opportunities to develop and revise, challenge and defend a scientific claim, an observer encounters (1) wide ranging conversations in small groups and in whole class, (2) a diverse reporting of ideas in student reports, and, very importantly, (3) a shift in authority from textbook and teacher to evidence and students. Under such conditions, the role of the teacher becomes one of facilitation and, perhaps more importantly, one of provocateur. Hammer (1997), studying his own teaching in a physics class, asserts that successful teaching begins with a set of planned observations and ideas but involves unplanned divergence's brought about as students engage in meaningful learning. Successful instruction, according to Hammer, is dependent on the teachers' unanticipated perceptions and insights of student' needs and meanings. Such curriculum-in-the-making teaching he refers to as "discovery teaching".

The design of science learning environments that promote “discovery teaching” and student inquiries into the status of scientific claims is dependent on the incorporation and sequencing of activities and tasks that engage students in asking and debating ‘what counts’ and ‘what’s the next move’. The science learning environment ought to provide teachers, and students, with opportunities for receiving information and providing guidance and feedback on such activities and tasks again, “discovery teaching”. The idea of shifting the focus of science education to an assessment of knowledge claims[2] is not a new one. Of particular note, is the work of the ‘Patterns of Enquiry Project’ (Connelly et al., 1977). Their emphasis on developing students’ habits of mind, on the important role of discussion and argumentation, and on the need for enquiry to engage in an evaluation of knowledge claims was ahead of its time. In particular, the goal of having students be able to assess the status of a knowledge claim and the degree of legitimate doubt that can be attached to a knowledge claim is critically important for doing science. Just as good written communication requires writing and rewriting, good science requires explaining and re-explaining. Science instruction must reflect the consensus building features characteristic of moving from evidence to explanation. Here is the full list of goals (Connelly et al., 1977) suggest for the learning and teaching of science as enquiry:

Learning as Inquiry

- To develop an understanding of the most important content.
- To develop an understanding of the parts of a pattern of enquiry[3].
- To develop the reading skills and habits of mind so as to be able to identify and understand knowledge claims.
- To develop the evaluative skills and habits of mind so as to be able to assess the status of knowledge claims.

Teaching as Inquiry

- Identify the degree of legitimate doubt attached to science knowledge; i.e., the validity of the knowledge claim or belief.
- Assist in providing opportunities for students to deduce patterns and to develop intellectual capacity to inform oneself.

[2] Here claims is used in a very broad sense to represent claims of knowledge, of method(s), and of goals reported by scientists

[3] The Pattern of Enquiry is a five-step process developed for the Pattern of Enquiry Project. The process was developed for the purpose of guiding reviews of actual scientific reports appearing in journals or proceedings. Hence the emphasis is on analyzing scientific research and reports of research. The five steps, followed in italic with an example, are 1) Identify the Guiding Conceptions, *Light travels in straight lines*; 2) State the Problem for Enquiry, *Why do shadows form?*; 3) Examine the Data Base, *Measurement of lines and angles, shadow data*; 4) Examine the Interpretation of Data, *Shadows form as predicted*; 5) Evaluate the Outcome of Enquiry, *The conception of light as traveling in straight lines adequately explains why shadows form.* The authors stress the importance of using the guiding conceptions to examine the data and data interpretation and to evaluate the outcome of enquiry.

- Employ a strategy of teaching that allows for discovery, focuses on the central role of discussions, and promotes effective argumentation.

Hence, the argument is that in addition to the selection of conceptual and sociocultural contexts for the design of curriculum, instruction and assessment models, we must also consider epistemic contexts that promote learners' abilities to engage in, and teachers' capacities to assess, performances that require both the development and the evaluation of scientific claims. For reasons owing to the nature of the structure of scientific knowledge, such performances should emphasize the development and evaluation of scientific arguments, scientific models, and scientific explanations.

The first part of the paper continues the argument for focusing curriculum instruction and assessment models on the epistemic goals coupled with concept and performance goals. Specifically, the argument is grounded in contemporary philosophical perspectives of science that support the idea of epistemic rules functioning within communities of scientists. Next the discussion turns to the design of learning environments that support students 'doing' science. In particular, I will focus on the role of assessment during learning and the integrated features of curriculum-instruction-assessment models that promote students development and evaluation of scientific claims. Examples of student work and science-in-the-making instruction are included here. The paper concludes with a set of recommendations for future directions of research on science learning environments that seek to promote the teaching of science as inquiry employing epistemic contexts.

EPISTEMIC COMMUNITIES

The broadening of science studies in this century, from the exclusive domain of philosophy of science, to an integration of perspectives from philosophy, history and sociology of science, has challenged perspectives about what should count as the basic unit for doing science. The established or received view of the individual scientist as the unit or agent of conceptual change is being replaced by a view that has communities of scientists as the fundamental unit of change. One view of developments in 20th century philosophy of science is the trend toward understanding science in the making (Kelly & Duschl, 2002).

Hull captures the essence of the changes that are taking place among philosophers when he writes, "[t]he objectivity that matters in science is not primarily a characteristic of individual scientists but of scientific communities (Hull, 1988; p 4). Woody (1997), commenting on a theory of rational theory development, posits that any constraints placed on theory development must assume: 1) humans have certain cognitive capacities (and not others), and, 2) scientists function within intellectual environments (social, technological) that restrict the changes in theory which any scientist may reasonably consider. Woody's perspective shares a great deal with the nature/nurture arguments surrounding the innate abilities of young children to be scientific thinkers; i.e., engage in theory building. Labeled the "theory theory " problem (Gopnik, 1996), the interfield dialogs between cognitive scientists, neuroscientists, and philosophers of science on the "theory theory" topic has implications for science education (Duschl et al., 1999).

Longino (1990 & 1994) is another philosopher of science who advocates locating objectivity in the group dynamics of communities of scientists. One example she gives of consensus building toward scientific knowledge is the peer review processes that occur in scientific communities, e.g., publishing in refereed journals, conference presentations, and grant funding reviews. Longino (1994) lists four conditions that a community must meet in order for a consensus to qualify as knowledge:

> 1. There must be publicly recognized forums for the criticism of evidence, of methods, and assumptions about reasoning.
>
> 2. There must be uptake of criticism. The community must not merely tolerate dissent, but its beliefs and theories must change over time in response to the critical discourse taking place within it.
>
> 3. There must be publicly recognized standards by reference to which theories, hypotheses, and observational practices are evaluated and by appeal to which criticism is made relevant to the goals of the inquiring community.
>
> 4. Finally, communities must be characterized by equality of intellectual authority. What consensus exists must be the result not of the exercise of political or economic power, or of the exclusion of dissenting perspective, but a result of critical dialogue in which all relevant perspectives are represented. (Longino 1994, p. 144--5)

Kitcher (1993) is yet another philosopher who argues for a consensus building process as a measure of objectivity as well as progress in science. His approach is slightly different in that it relies more on cognitive processes that govern and explain individuals' conceptual progress and explanatory progress. In each case of progress, the focus is on the elimination of options toward a consensus opinion. The consensus forming or elimination process is what characterizes scientific objectivity. Kitcher writes,"[c]onceptual progress is made when we adjust boundaries of our categories to conform to kinds and when we are able to provide more specifications of our referents" (p. 95-6). "Explanatory progress consists in improving our view of the dependencies of phenomena. Scientists typically recognize some phenomena as prior, others as dependent" (p. 105).

The emerging perspective for philosophers of science is that the objectivity of scientific claims is borne out of the arguments and debates that occur between different factions of investigators seeking a consensus about knowledge claims, methodological claims and aims of scientific inquiry. According to Longino (1994), the epistemic criteria used to forge a consensus opinion, or challenges to a consensus opinion, are established at many different levels of inquiry by members of inquiring communities, the size and beliefs of which change as the scientific claim moves from the private confines of the 'lab' to the public corridors of scientific conferences, proceedings, and refereed publications.

Creating science learning environments to reflect Longino's 4 consensus making conditions is quite appealing. Clearly, there are social implications with regard to how students or learners are to engage in science. Like my daughters piano instructor, layers of skills and knowledge are needed for the acquisition, development, communication and evaluation of scientific claims. However, engaging students in judgments about scientific claims requires some further radical changes in the design of science learning environments.

ASSESSMENTS IN EPISTEMIC CONTEXTS

The traditional curriculum approach to science education has been one that stresses ‘knowing’. Traditional curriculum practices in science education ask “What do we want students to know and what do they need to do to know it?” The ‘hands-on’ approach as practiced in the majority of schools embodies this dictum. The things students do are done in the service of attaining conceptual goals. The goal is acquisition of what scientists’ know. Very little, if any, time is typically taken to examine and discuss the nature of the problem being investigated, to explore the assumptions and beliefs held by the investigators, to discuss the data gathering strategies one might use, to examine the raw data and decide which measurements should be repeated and which data to use for analysis, to examine the selected data for patterns and debate which of several alternatives would be the best way to model and represent the data, and finally to consider which of several alternative explanations would best account for the evidence.

Learning what is known without learning how we have come to know it and why this way of knowing is better than this or that way of knowing eliminates any chance of students appreciating the social, cognitive, conceptual and epistemic processes that give science its status of being overtime an objective and rational way of knowing. Designing learning environments that both engage and empower learners in the construction and, importantly, the evaluation of transformations of evidence to explanation is possible. Having evaluation as a curriculum goal requires, a shift in priorities away from, but not divorced from, conceptual goals. Simply put, time must be made available for learners to develop an understanding of the criteria used to conduct evaluations of, for example, the design of experiments, the composition of models, the evidential support of explanations, and the fidelity of data.

A word on the process of knowledge construction is warranted at this point. The goal is not to have students replicating the canons of science – i.e., building models of the solar system or of the cell. Rather the goal is to engage students in an emergent construction, i.e., science in the making, and learning process where modifications, restructuring and at time abandonment of positions about selected data, patterns of data, and explanations of data take place.

Such ‘emergent instruction’, to be successful requires that a commitment be made to teaching and monitoring the epistemic features of scientific inquiry – the semantic (meanings), syntactic (structure) and pragmatic (contextual) structures of doing science. Over the past 10 years, my colleagues and I have been studying the design features of classrooms that promote students engagement in epistemic features of scientific inquiry. Presently, we have developed 3 instructional units in physical science, in chemistry, and in earth science (see Table 1). Respectively, the epistemic goal for each unit is a causal explanation for buoyant forces, a pictorial and symbolic model of acid/base neutralization reactions, and a scientific argument for the potential occurrence of an earthquake or volcano in a designated location.

Table 1. SEPIA Curriculum Units

Problem/Context	**Conceptual Context**	**Epistemic Context**
Design a Vessel Hull to maximize load capacity(Duschl & Gitomer 1997)	Buoyancy, Flotation, Water Pressure	Causal Explanation of Flotation and for Design of Vessel
Identify Unknown Acids & Bases, Develop strategy for safe disposal (Erduran 1999)	Neutralization, strength, concentration	Models and Modeling of Acids, Bases & Neutralization
Probability of Earthquake/Volcano in a Region (Smith 1995)	Geological tectonics, stratigraphy, age and type of rocks	Argument

Thus, our designs of learning environments reverse the science curriculum goal question by asking, "What do we want students to do and what do they need to know to do it?". Rhetorically, the shift is simple. At the level of the classroom, however, the shift is quite dynamic. When the doing becomes the construction of models, explanations, experiments, and arguments, very different curricular, instructional, and assessment dynamics are required to support and motivate student efforts.

1. There is a need to blur the boundaries between curriculum, instruction, and assessment. The teacher should be empowered to alter the path of the curriculum and of instruction in light of judgments made from the assessment of students understandings, skills, ideas, and habits of mind, to name but a few.
2. The learning environment must stimulate and nurture learners' communication of scientific information.
3. There needs to be a set of criteria and goals to direct the evaluation of the scientific claims, in particular epistemic criteria and goals.
4. The primary role of the teacher should be coordinating feedback on student products, representations and ideas, being a provocateur or devil's advocate if you will. Listening on the part of the teacher and learning to listen to students in different ways is so important.
5. Students are to be accountable for the quality of products and ideas they present. Hence, access to prior work and ideas, their own as well as that of other students in the class or community of inquirers[1], is important. So too is the opportunity to revise and redo assignments important.

[1] The advent of Internet communications now makes it possible for students examining the same problem or question to engage in the sharing of ideas and products within and between classrooms.

SHIFTING THE FOCUS OF INSTRUCTION: LESSONS LEARNED

Designing learning environments to promote argumentation and assessment requires adjustments to other elements in the curriculum. To date, some of the lessons we have learned about designing learning environments that promote argumentation and assessment of epistemic contexts are the following. One, there needs to be a limit on the number of core concepts addressed in the science unit. We have found that keeping the concepts to a minimum (n=20) facilitates creativity and deep processing of scientific information and ideas. Two, instructional time should be allocated for careful feedback (assessments) on what students are doing and how students are performing. Three, providing feedback suggests that learners be given opportunities to revise, rework, and re-present products and ideas. The point to be made at this time is that curriculum developers, and I include classroom teachers as full partners in this enterprise, need to seriously consider ways to revise and alter curricula by anticipating and structuring where in a unit of instruction certain enactment's that assess the doing – epistemic enactment's if you will – should occur.

So what then is the script we are to follow in preparing curricula that give some consideration to epistemic enactment's of teachers and students. I have some suggestions. Staying within the performing arts, please allow me to invoke another analogy – writing plays and stories. Good plays and stories have multiple plots and messages, some explicit and some implicit. For example, "The Man of La Mancha" the play adaptation of Cervante's "Don Quixote of La Mancha" uses windmills to invoke human struggles, Arthur Miller's "The Crucible" is a comment on the witchhunts being conducted in the US during the McCarthy era, and Beckett examines the depths of the human spirit in "Waiting for Godot". A common element is each play takes a familiar context to communicate complex moral, ethical, and social messages. Embedded within the songs, the story, and the lines are other subliminal messages that compel the viewer to commit to the play for its duration. I want to suggest that we need to write curriculum units as if they were plays.

The reform agenda in science education is, for me, principally a curriculum problem. Teachers and students need scripts[2] to follow and messages to explore to set up the conditions that sustain learning with understanding and shape the consensus activities of doing science. Like a play there would be a structure to the curriculum- at times strict at other times open to improvisation. There would be acts, scenes, props, parts, and lines for students and teacher to build, learn and perform. Some of the messages would be explicit and obvious while others would require reflection and analysis to understand. The plot(s) and the interpretations of plots would need to be compelling to motivate the audience to stick with the play 'til the closing curtain. Let us now turn to a discussion of the features of science units that engage students in epistemic enactments.

[2] The use of scripts here is not intended to strictly imply the information processing scripts that emerge from task analyses of cognition in domain-specific contexts. However, such research does indeed inform the design of learning environments and hence the preparation of scripts to follow.

ENGAGING EPISTEMIC ENACTMENTS

Scientific inquiry is fundamentally an iterative process of moving back and forth between evidence and explanation until a consensus position[3] is reached by members of an inquiry community. In general, our units of instruction are sequenced and formatted to provide students with experiences that, one, solve empirical problems (e.g., Where are igneous rock located in Pennsylvania?) and two, avoid conceptual problems (e.g., Is the City of Pittsburgh located near the boundary of a tectonic plate?).[4] The evidence to explanation discourse in our units involves students in:

1. decisions and discussions about the data collected and the data that will be used (selected or hard data) and that which will be excluded;
2. decisions about the guiding conceptions and techniques that will be used for locating and determining patterns in the selected data; and
3. debates and arguments about the array of potential and viable explanatory statements that account for the selected data patterns.

At each of the three transition steps, decisions, arguments, and debates that shape the objectivity of knowledge claims are possible. Each transition is a potential 'epistemic enactment' opportunity. The point to stress here is that the degree of legitimate doubt one can attach to a scientific knowledge claim is not solely directed to the outcome of an inquiry or the conclusion of an investigation. Just like the evaluation of an argument where you attack the premises and not the conclusion, the consensus building process – the examination and critique of scientific claims – should assess the premises of the inquiry process across all three of the transition steps:

1. raw data to selected data; from the total pool of data, which data are selected for inclusion in subsequent analyses and which data are designated as outliers, artifacts, or anomalous data? What are the reasons? Alternative strategies for obtaining raw data are subject to debate as well.
2. selected data to patterns or models of data; given the sample of selected data, what are the possible models, empirical laws, patterns, or trends that fit the data?
3. patterns or models of data to explanations; given the patterns and models, what are the plausible explanations that account for the patterns and models? How do the explanations cohere with best beliefs?

Each of the transitions or transformations represents a distinct discourse and assessment opportunity. Learners are given the opportunity to develop tools, criteria, standards and rules they can use to investigate, assess and evaluate scientific

[3] A consensus opinion does not need to be one where there is 100% agreement. Rather the consensus process is a dynamic one that at best arrives at a reduction of alternative claims. Although the goal is a reduction in options, challenges and alternatives to existing consensus claims typically always exist in scientific communities. This constant challenge to consensus is what led some philosophers of science to challenge Kuhn's idea about normal science by asserting that science is at all times revolutionary. Importantly, historians and philosophers of science recognize a distinction between theory pursuit and theory acceptance. One can use a theory without being committed to a belief in the theory.

[4] This problem-solving and problem avoidance approach is taken from Laudan (1997) as a basis for distinguishing progressive and degenerative research programmes.

knowledge claims. Teachers are given the opportunity to provide feedback to students on the use of tools, criteria, standards, and rules.

Anderson, Kurth, and Palincsar (1995) propose a similar design tool they call The TOPE Framework. They write: [TOPE] is intended to enhance the teacher's craft by helping us both to plan the construction of rich problem spaces and to recognize the scientific potential of students' language and actions. Briefly, the TOPE framework suggests that in constructing problem spaces, teachers and students need to consider at least four interrelated scientific practices. These are:

- Techniques, students try to make reliable and accurate observations, conduct experiments, or make things happen,
- Observations, student record, compare, communicate about the systems and phenomena that they are studying, either orally or in writing,
- Patterns, students seek to make rules or generalizations describing regularities in what they have observed,
- Explanations, student develop arguments that use models or theories to make sense of the patterns that they have observed.

At each of the three data transformations or the stages of TOPE it is possible, and desirable, to explore the premises of epistemic contexts. The students can ask 'What counts?', 'What do we consider, what do we ignore?'. How do we know? How does it fit with what be already know or believe? How would we show or convince someone else? Asking such questions shapes the consensus building processes of science and, in turn, the objectivity and rationality of scientific claims. We are finding that the iterative process of shaping scientific claims as experience and evidence grows is an activity children can do and do quite well.

LESSONS LEARNED

Research on the design of learning environments with particular attention on how to coordinate teacher and student engagements with epistemic contexts is needed. The issue is a classroom management problem but not in the traditional behaviorist sense. The management problem is about information and ideas. Consider the case of A, a 7th grade female student who during the first week of the Acids & Bases Unit researched the topic of acids and bases on here home computer:

Field Notes, 5th Period 5/6/97

The class began with Mr. D sitting on the table in the back of the room. He was surrounded by four or five students. All were listening to a very excited A as she went line by line, section by section, through a 3 page set of written notes on Acids and Bases she had obtained from a CD-rom encyclopedia 'Encarta'. A was describing the Bronsted-Lowery Theory of A&B – acids are proton donors and bases are proton acceptors; she kept referring to the British Theory and the American Theory. Her mispronunciation of words like logarithm (low-garth-em) and ion (eon) suggests she was not assisted by a parent, nor did she discuss her notes with an adult prior to sharing them with Mr. D. She presented one "neat" idea after another with enthusiasm that made one feel it was partially staged on her part. R, a classmate, was very excited, for example, and gave A a great deal of attention. When A went to the board to explain the pH scale and the powers of 10 (i.e., 10, R stood nearby in excitement. The dialog between A and Mr. D lasted for approximately 10 minutes. By the end of the discussion A was making claims that she was going to determine which of the two theories (American or British) was right during the course of completing the Acid and Bases Unit.

The class comes to a close – Mr. D hands out the homework and while doing so talks about how the ideas are under construction. He explains the homework – "find items in your house that have the following acids and bases". A scans the list. One student asks if these are all acids. A says "no the last two have hydroxyl so they are a base". "A" then says the list is just like the one on the CD-ROM, "Did you get it from there?", she asks.

Occurrences like this are not uncommon during SEPIA units. Students frequently bring concepts, evidence, information, and ideas to the classroom, a feature of the learning environment we attribute to the epistemic structure of the unit and use of assessment conversations. Hammer (1997), Roth (1995) and Warren, Roseberry & Conant (1992) report similar findings about students introducing core knowledge to the classroom. On the same day A brought her encyclopedic-knowledge to class, Mr. D conducted an assessment conversation on the explanatory models students had generated for a) the properties of acids and bases obtained from using sense perception data and b) what would occur if you mixed an acid with a base. A copy of the activity appears in the Appendix.

To prepare for the assessment conversations (see Table 2), Mr. D sorted and selected 7 samples of student work from the two classes of students working with the Acids & Bases Unit – periods 5 and 7. He had color transparencies made of the student work. If the student was in the classroom, he had that student come to the overhead to explain their models. Our goals were to share the diversity of models students had made and to provide feedback on representations of models that explain. As is typical of students at this age, when asked to draw a model that explains many will just depict the items used in the activity (e.g., slices of lemons) and not get at the epistemic structure. During the lesson a variety of explanations (appearing in bold text), and challenges to explanations (appearing in italic text) occur. Relevant samples of student work appear in the Appendix

Field Notes: 5th Period, 5/6/97

The first drawing displayed on the overhead was by Y (7^{th} period). Mr. D. asks, "Does the use of words help?' The students say yes. Mr. D encourages the students to begin making changes on their own drawing using the ideas from the work he is showing. Here the student is commenting on the assertion in the drawing that "carbon makes acids burn". Again Mr. D asks if the words help. One student responds "Not really because someone may think carbon in a base". Mr. D presents this as a theory about acids. Sitting near A, I can see she is very engaged in this alternative idea to her encyclopedic explanation. Mr. D talks through the drawing pointing out the symbols and key used to depict carbon and fat. Y in the mixing A&B together box, has written 'acid and base mixed together make a salt'. A is heard to say, "That's right".

The next picture put on the overhead is A 's. It is the first abstract drawing. Comments by Mr. D at the beginning of class indicate he has made a decision about the order he wants to show the pictures. A 's frustration about doing this creative activity from the day before now gives way to some level of excitement. She begins to describe her picture: "the spikes are"… she struggles for the right word which is finally offered by a classmate "tangy". Mr. D reinforces the use of a drawing to explain and capture the feeling an acid has on the tongue (there was some discussion the day before about taste (flavor) and taste (texture)). A then starts to describe the pits "holes" on the surface of the acid particle and begins to try and use some of her encyclopedic knowledge. She uses the word "molecules" and then "hydrogen", but hydrogen is presented in a manner that suggests she does not see the connection between the terms.

A then begins to describe her base drawing, a plain rectangle to depict dull. Mr. D states it is like a brick "Foundation to a building" is heard from someone in the class. A then describes how her A&B together drawing labeled with the word "neutral" is a composite of the two drawings, the wavy lines being like water which is "7.0 on pH, little bit of acid and little bit of base". (This is the first of what will become many references to acids and bases coming together in such a way that properties of each are preserved – this model of physical properties being preserved is a major and important theme and research discovery of the lesson*)*.

The next drawing is by L (7th period). She provides sentence descriptions of her drawing of acids and bases. Her theory is "carbon is made up of oxygen and carbon and when combined it has a burning chemical change". "Carbon dioxide sticks to tongue and causes it to burn". "A base has no carbon dioxide causeing(sic) it to not bubble and sting". A is intrigued by yet another alternative idea. Mr. D ties it to a previous lesson and emphasizes the idea of a chemical change. L , as well shows acids and bases coming together to make salts. (Mr. D was absent on Monday and the substitute let some students go to the library to get information on A&B – one item introduced was A&B = salt). One student can be heard to ask if the salt is NaCl, A says to her the Na is an acid and the Cl is the base because they are + and - .

Next the class is shown B's (7th period) picture. Yet another theory – fumes cause sour, tingling comes from air bubbles. Air pressure pushes on the base to make it thick and moisture makes it feel wet. Labels are used. Not much discussion.

Next is P's picture from 5th period but he is absent. This drawing is the first to use colors as well as shapes to depict the properties of acids and bases. Mr. D asks the class what do you see? "bright and citrusey" (words from word bank), "base is dull", "uses sharp edges" "zingy – zing around" Mr. D highlights some marks in the drawing that are not that visible to help establish that the yellow jagged things are moving around. The idea of energy (look like lighting bolts) is brought up by A trying to assimilate this drawing with her knowledge. She is heard to say "energy to give and energy to take. The interesting feature of the drawing is how P has taken some of the features of A and some of B to drawing

> the A&B together. A student says " they don't really combine completely". A, says, "Which is part of the English Theory" One student then provides an analogy to cookies "It's like when you make cookies, you can't see all the parts (flour and baking soda) but you can see some (choc. chips)." Students are now calling out all sorts of ideas, brainstorming "part solution, part mixture".

An interesting feature of this lesson was the students' enthusiastic responses to the abstract representation by P. Whereas the majority of students models of neutralization could be classified as concrete representations of the objects employed (e.g., slices of lemon, tongues, jars of milk), it was a surprise to see how the abstract drawing engaged the students. An epistemic enactment was occurring with several epistemic contexts being addressed.

The Project SEPIA (Science Education through Portfolio Instruction and Assessment) research program is learning how to develop curriculum, instruction, and assessment models that put the primary emphasis on epistemic, representational, and cognitive goals of science learning. Several years into this effort the teachers, researchers and advisors working on Project SEPIA feel the approach proceeds from five key features:

- The topic of investigation is an authentic question or problem that has some consequence to the lives of the children.
- Conceptual goals are kept to a limited number so as to facilitate an understanding and adoption of criteria that assess the accuracy and objectivity of knowledge claims.
- Assessment of students' understandings and ideas proceeds from assignments that by design produce a diversity of outcomes and thus promote a need for consensus building.
- Both the criteria for the assessment of students' products and performances and the products and performances themselves are publicly shared employing a direct teaching discourse strategy labelled an 'assessment conversation'.
- The depth of student understanding is assessed and communicated employing a portfolio culture process.

Taken together the five design principles contribute to the development of a learning environment that promotes science as inquiry and students' understanding about scientific inquiry. Table 2 presents more information about each of the 5 features. In addition to the features of the units, the goal structure of the units are multifaceted, too. In any one unit, there are epistemic goals, conceptual goals, and representation or communication goals.

Table 2. SEPIA Design Principles

Feature	Description of Feature
Authentic Problem	The context of the problem has relevance for the students (See Table 1) The use of data, data representation and data formats are like those used by scientists.
Constrained Conceptual Goals	Constraining and focusing the number of concepts in the unit makes it possible to emphasize the relationship between the most important concepts, to explore students' competing representations and meanings of the conceptual relationships, and to model and explore the application and delimitation's of these conceptual relationships as evidence in scientific reasoning and the epistemic goals of the unit. The general guiding principle is to include concepts that are both necessary and sufficient to execute the epistemic goals of the unit.
Diversity of Student Work	The design of specific activities follows guidelines that promote a diversity of outcomes, ideas, or products by students. A range of responses makes it possible to select samples of student work that promote conversations, debates, and arguments, for addressing unit goals and giving feedback to students. We call the process 'assessment conversations' since they provide feedback to students and develop consensus opinions about what counts or what needs to be examine next.
Assessment Conversation	The 'assessment conversation' is a 3-stage discourse structure that promotes and coordinates understanding and reflection on meaning making and reasoning among members of the class. 1. Receiving information – implementation of an activity that produces a diversity of student outcomes and concludes with the public display of the diversity. 2. Recognizing information – teacher examines and appraises the diversity with respect to the unit's goals. 3. Using information – students are asked to apply what has been learned to evaluate previous efforts or to design investigations to advance the present domain of inquiry.
Communication and Assessment by Portfolio Process	Students use the contents of their folder to complete subsequent activities and tasks. We refer to specific activities as Portfolio Items (PI). The extraction or consolidation of information in the folder for the purpose of stating or defending a position is the portfolio process. This can occur within the course of the unit and naturally occurs at the end of each of our units

Combining the 5 features and 3 goals of a SEPIA unit is a complex problem for teachers to manage (Duschl & Gitomer, 1997). The assessment conversation on the various models students produced brought to the discourse not only creative representations of neutralization but also a diversity of sources of evidence. From the classroom discourse it is possible to assign sources of evidence to one of several categories: P=portfolio, PL=previous lesson, EI=evidence from investigation, EO=evidence from outside the classroom, PO=personal opinion. Tracking the evidence found in student discourse it is possible to ask questions such as:

- What is the frequency of use for each category?
- What trends in the frequency of use exist over the course of the unit?
- What learning environment factors promote instances of P, PL, EI, in assessment conversations?

We are finding that very different thematic structures begin to emerge during implementation of SEPIA units. For example, the traditional triadic dialogue (Lemke, 1990) is replaced by student argumentation, the authority for knowledge claims is found to shift from teacher to student experiences and evidence. Understanding the character of the thematic structures that arise out of epistemic enactments is an important area of research deserving of far more attention.

In addition to the analysis of evidence students bring to the classroom discourse, we are also analyzing the structure of the discourse in terms of the arguments students employ. Guided by the research of Pontecorvo and Girardet (1993) we are looking at the epistemic operations used by students (Duschl, Ellenbogen & Erduran, 1999). Both formal and informal logic structures are studied. Two dynamic and emerging fields of inquiry are argumentation theory (van Eemeren et al., 1996; Walton, 1996) and argumentation discourse in science education (Duschl & Osborne in press). The research is showing that individuals employ a wide variety of argumentation schemes within the context of practical discourse. The emergent research questions include the following:

- What combinations or patterns of selected data/evidence emerge in assessment conversations?
- How do the patterns of data affect discourse patterns and argumentation schemes?
- What is the frequency of argumentation schemes use in assessment conversations?
- What trends in the frequency of argumentation scheme use exists over the course of the unit?

CONCLUSION

The construction of theory is a central task of doing science. The evaluation of theory is as well. Studies in the history, philosophy, and sociology of science suggest that theory building is in practice a continual process of revision. The established claims that theories are always underdetermined by evidence and that scientists will often pursue a theory independent of believing the theory, suggests that a major component of epistemic reasoning is presumptive in nature. Hence, the intellectual environments of epistemic communities, be they scientists or science students will shape the consensus building processes and, in turn, establish the rules and standards of the inquiry community. The parade of scientific claims from the private communities to the public communities involves a set of nested epistemic communities like Russian Dolls. Adopting the perspective of emergence from the philosophy of biology, the characteristics and rules of one level of community (i.e., organism) cannot predict nor account for the characteristics and rules of a high level of organization (i.e., species). Thus, the claims by cognitive psychologists (Gopnick, 1996; Carey, 1985) and philosophers (Schwitzgebel, 1999) that children are themselves theory builders is worthy of careful consideration. That is, claims about the rules of theory-building or criteria for explanations at one level, should not totally dictate the structure of rules, criteria, or claims at another level. One must remember, however, that there are always goals and there always exists Woody's intellectual environment (social and technological) for theory builders, be they child or adult scientists. More rigorous analyses of the discourse occurring in epistemic communities will, I hope, contribute to a richer understanding of the various ways teachers can provide feedback to students during the consensus building processes that naturally occur when evidence is transformed into explanations.

The challenge of teaching science as inquiry for teachers is fundamentally one of managing the ideas and information that are generated by students. Of particular importance to the management of ideas and information is the need to coordinate the feedback given to students. Recognizing the importance of feedback, our theory of science curriculum is based on a portfolio assessment process (Duschl & Gitomer, 1997). The advantage of the portfolio assessment process is it makes it possible to address and coordinate a complex set of goals over an extended period of time. Our research has found that the management of the portfolio science learning environment requires teachers to attend to three domains of feedback:

1. Feedback on conceptual and epistemic structures.
2. Feedback on cognitive and metacognitive practices.
3. Feedback on communication and representation strategies.

The careful sequencing of instructional tasks coupled with the classroom assessment conversations combine to facilitate students' understanding (1) of the purpose of activities and tasks, (2) of the standards of evaluation used to judge these, and (3) of the links or relationships that are sought between activities and tasks The portfolio process and SEPIA design principles make it possible to engage in and provide feedback on both the cognitive and metacognitive activities that characterize science as an objective way of knowing. The integration of curriculum-instruction-assessment is based on a commitment that doing science requires developing an understanding of the standards and criteria used to judge and evaluate scientific knowledge claims and investigative processes. Classroom conversations, presentations, debates and arguments focus on the coherence between evidence and explanation, experiment and theory. Content thus becomes more of a context and less of a goal. The goal is scientific reasoning as it pertains to evaluating evidence and explanations.

REFERENCES

Anderson, C. W., Kurth, L., & Palinscar, A. S. (1996). *Design principles for collaborative problem solving in science*. Paper presented at the meeting of the American Educational Research Association, New York, NY.

Carlsen, W. (1997). Never ask a question if you don't know the answer: The tension in teaching between modeling scientific argument and maintaining law and order. *Journal of Classroom Interaction*, *32*, 14-23.

Carey, S. (1985). *Conceptual change in childhood.* Cambridge, MA: Bradford Books/MIT Press.

Connelly, F. M., Finegold, M., Clipsham, J., & Wahlstrom, M. W. (1977). *Scientific enquiry and the teaching of science: Pattern of enquiry project*. Toronto, Ontario: OISE Press.

Duschl, R. A. (1994). 'Research on the history and philosophy of science', in D.L. Gabel, (Ed.), *Handbook of research on science teaching and learning*, Macmillan Publishing Company, New York, 443-465.

Duschl, R., Deak, G., Ellenbogen, K. & Holton, D. (1999). Developmental and educational perspectives on theory change: To have and hold, or to have and hone? *Science & Education, 8*, 525-541.

Duschl, R., Ellenbogen, K. & Erduran, S. (1999). *Understanding dialogic argumentation among middle school science students*. Paper presented at the meeting of the American Educational Research Association, Montreal.

Duschl, R. A., & Gitomer, D. H. (1997). Strategies and challenges to changing the focus of assessment and instruction in science classrooms. *Educational Assessment, 4*(1), 37-73.

Duschl, R. A., & Hamilton, R. J. (1999). Conceptual change in science and the learning of science, in B. Fraser & K. Tobin, (Eds.), *International Handbook of Science Education*. Dordrecht: Kluwer Academic Publishers, 1047-1065.

Duschl, R. & Osborne, J. (in press). Supporting argumentation discourse processes in science education. *Studies in Science Education.*

Eichinger, D. C., Anderson, C. W., Palinscar, A., & David, Y. M. (1991). *An illustration of the roles of content knowledge, scientific argument, and social norms in collaborative problem solving*. Paper presented at the meeting of the American Educational Research Association, Chicago: IL.

Erduran, S. (1999). *Merging curriculum design with chemical epistemology: A case of teaching and learning chemistry through modeling*. Unpublished Ph.D. dissertation Vanderbilt University, Nashville, TN, USA.

Fensham, P. (1988). *Developments and dilemmas in science education*. London: Falmer Press.

Gopnik, A. (1996). The scientist as child. *Philosophy of Science, 63*(4), 485-514.

Hammer, D. (1997). Discovery learning and discovery teaching. *Cognition and Instruction, 15*(4) 485-529.

Hull, D. (1988). *Science as a process*, University of Chicago Press, Chicago.

Jimenez-Aleixandre, M.P., Bugallo-Rodríguez, A., & Duschl R.A. (1997). *Argument in high school genetics*. Paper presented at the meeting of the National Association for Research in Science Teaching, Chicago: IL.

Kelly, G. & Duschl, R. (2002). *Toward a research agenda for epistemological studies in science education*. Paper presented at the meeting of the National Association for Research in Science Teaching, New Orleans.

Kitcher, P. (1993). *The advancement of science*. New York: Oxford University Press.

Laudan, L. (1977). *Progress and its problems*. Berkeley, CA: University of California Press.

Lemke, J. (1990). *Talking science*. Norwood, NJ: Ablex Publishing Co.

Longino, H. (1990). *Science as social knowledge*. Princeton, NJ: Princeton University Press.

Longino, H. (1994). The fate of knowledge in social theories of science. In F.F. Schmitt (Ed.), *Socializing epistemology: The social dimensions of knowledge*. Lanham, MD: Rowan and Littlefield (135-158).

Pontecorvo, C., & Girardet, H. (1993). Arguing and reasoning in understanding historical topics. *Cognition and Instruction, 11*(3&4), 365-395.

Rosebery, A. S., Warren, B., Conant, F. R. (1992). Appropriating scientific discourse: Findings from language minority classrooms. *Journal of the Learning Sciences, 2*(1) 61-94.

Roth, W-M. (1995). Inventors, copycats, and everyone else - The emergence of shared resources and practices as deining aspects of clasroom communities. *Science Education, 79*(5) 475-502.

Russell, T. (1981). What history of science, how much, and why? *Science Education, 65*(1), 51-64.

Schwitzgebel, E. (1999). Children's theories and the drive to explain. *Science and Education, 8*(5) 457-488.

Smith, M. (1995). *Pedagogical challenges of instructional assessment in middle school earth science: Two case studies*. Unpublished Ph.D. dissertation, University of Pittsburgh, Pittsburgh, PA, USA.

van Eemeren, F. H., Grootendorst, R., Henkemans, F. S. (1996). *Fundamentals of argumentation theory; A handbook of historical backgrounds and contemporary developments*. Mahwah, NJ: Lawrence Erlbaum Associates.

Walton, D. N. (1996). *Argumentation schemes for presumptive reasoning*. Mahwah, NJ: Lawrence Erlbaum Associates.

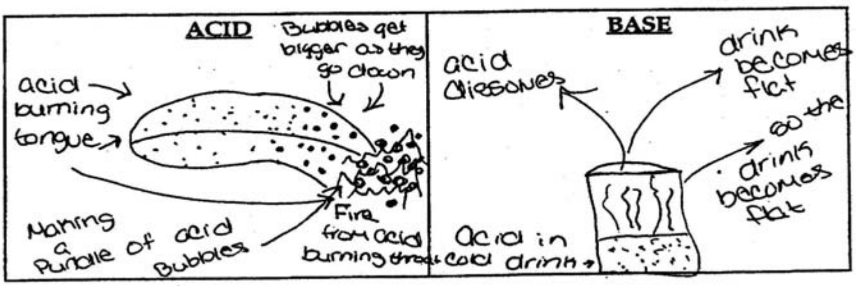
Woody, A. (1997). Personal Communication, November, 1997.

APPENDIX

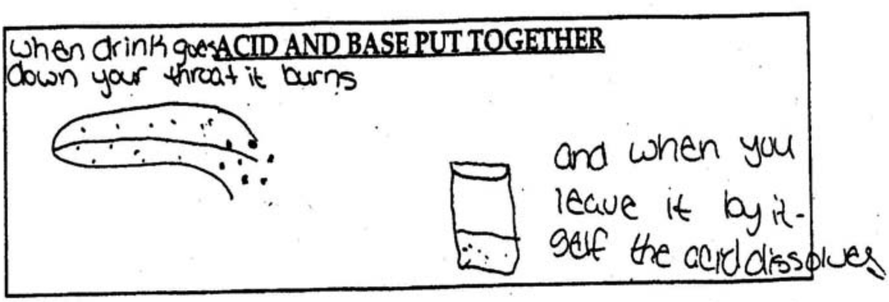
YOLANDA

Portfolio Item 2C Model of acids and bases

Draw a series of pictures to show a model of an acid and a model of a base. These models are to explain why we sense acids and bases in a certain way. Look back at Portfolio Item 2A to remember the acids and bases you tested with your senses.



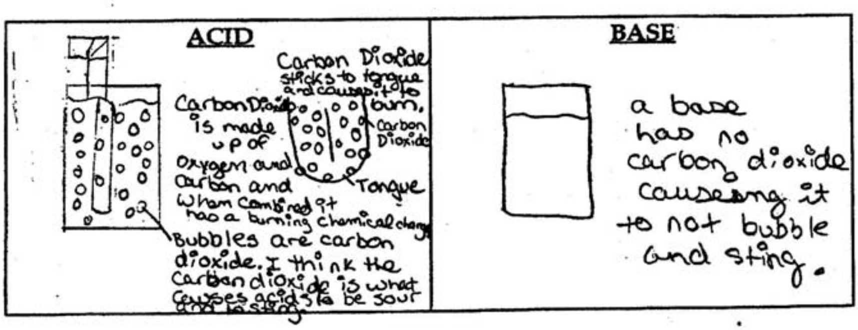
Draw a picture to show what you think would happen when we put the acid and base together.



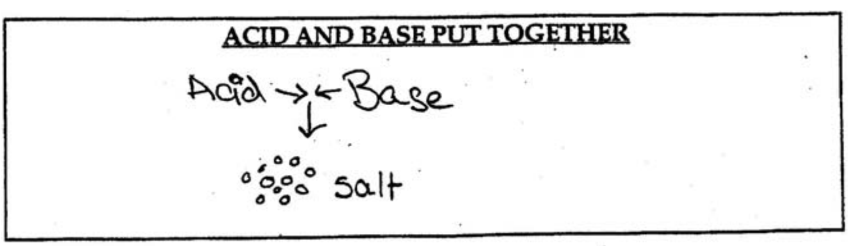
LAURA

Portfolio Item 2C Model of acids and bases

Draw a series of pictures to show a model of an acid and a model of a base. These models are to explain why we sense acids and bases in a certain way. Look back at Portfolio Item 2A to remember the acids and bases you tested with your senses.



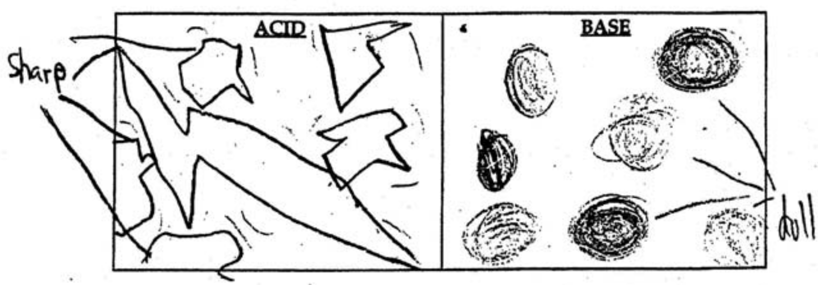
Draw a picture to show what you think would happen when we put the acid and base together.



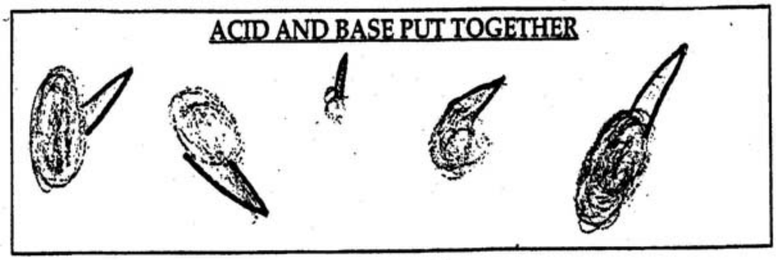
PETER

Portfolio Item 2C Model of acids and bases

Draw a series of pictures to show a model of an acid and a model of a base. These models are to explain why we sense acids and bases in a certain way. Look back at Portfolio Item 2A to remember the acids and bases you tested with your senses.



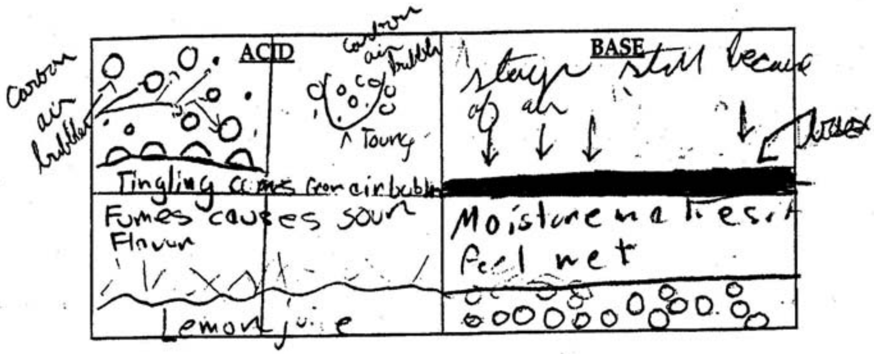
Draw a picture to show what you think would happen when we put the acid and base together.



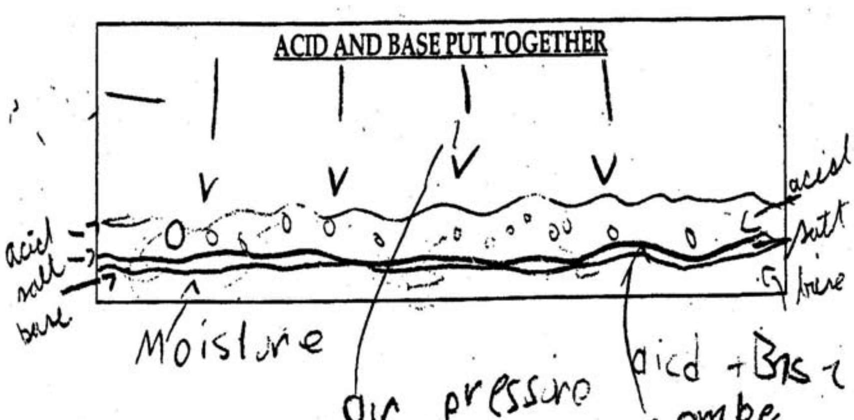
BRIAN

Portfolio Item 2C Model of acids and bases

Draw a series of pictures to show a model of an acid and a model of a base. These models are to explain why we sense acids and bases in a certain way. Look back at Portfolio Item 2A to remember the acids and bases you tested with your senses.



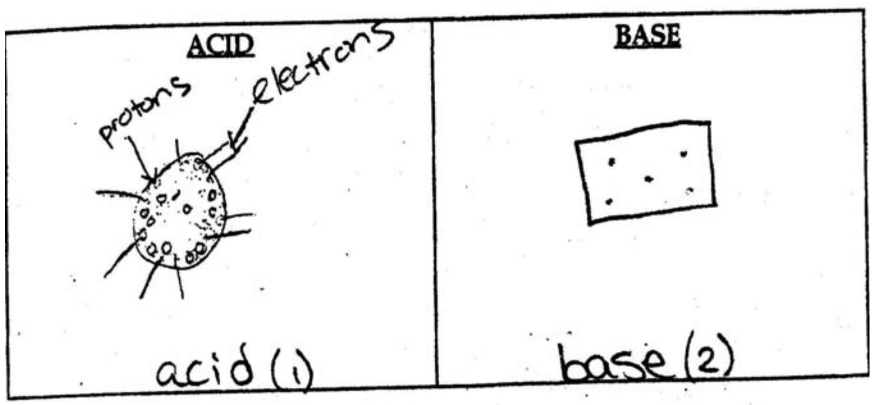
Draw a picture to show what you think would happen when we put the acid and base together.



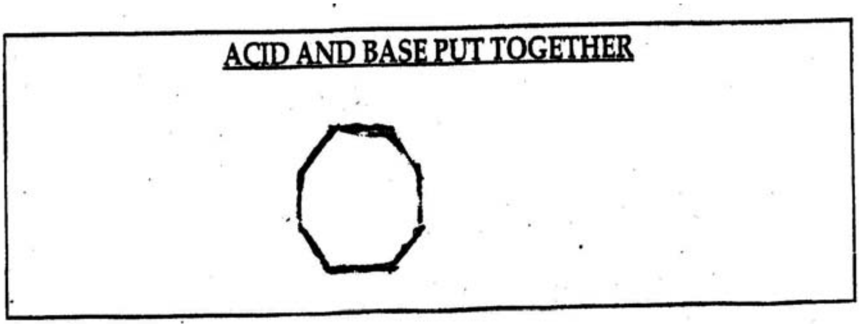
ANGELA

Portfolio Item 2C Model of acids and bases

Draw a series of pictures to show a model of an acid and a model of a base. These models are to explain why we sense acids and bases in a certain way. Look back at Portfolio Item 2A to remember the acids and bases you tested with your senses.



Draw a picture to show what you think would happen when we put the acid and base together.



SECTION IV: CULTURAL ISSUES

CHAPTER 8

MORALITY, SPIRITUALITY AND SCIENCE IN THE ELEMENTARY CLASSROOM

KLAUS WITZ & NANCY MACGREGOR

INTRODUCTION

Many teachers and parents feel that the moral, aesthetic and spiritual sides of a young person need to be fostered and developed together with his/her intellectual, affective and social sides. And more than a few teachers feel that "together with" here should not mean "in addition to", but "united with". "Spirituality... is not something that needs to be 'brought into' or 'added onto' the curriculum. It is at the heart of every subject we teach... " (Palmer, 1998, p. 8). One subject matter area where there is an acknowledged tradition of fostering moral and aesthetic engagement as a natural part of the student's overall involvement with learning is children's literature (Coody, 1992; Estes & Vasquez-Levy, 2001). Elsewhere, however, the picture is bleak. An elementary school teacher discovers quickly that 5th grade science or social studies texts keep away from moral or aesthetic issues. At the 2001 National Association for Research in Science Teaching meeting in St. Louis, when some of the contributors to this volume discussed this problem with (science-) teachers, one group reported "we all pondered and doubted that there were currently any fifth grade books (science or otherwise) with any moral dimension whatsoever". The need for deeper moral and aesthetic engagement seems particularly great in science, which pervades all aspects of the Western worldview and through technology shapes almost all aspects of modern life.

One factor contributing to this state of affairs is certain general attitudes concerning science. Since the second half of the 19th century, science has been largely regarded as value free, and as handing down "essentially unproblematic" bodies of knowledge (Edge, 1985; Hargreaves & Hargreaves, 1983). This orienta-

D.L. Zeidler (ed.),
The Role of Moral Reasoning on Socioscientific Issues and Discourse in Science Education, 165-182.

tion still dominates popular discourse, and science education continues the "tradition... to teach science in a moral vacuum" (authors' and teachers' discussion group at the 2001 St. Louis meeting). Another factor is the fact that intellectual and moral development are largely taken as unrelated to each other. This is reflected in the lack of serious moral engagement in the science classroom. Finally there is a tendency in our educational system to regard moral education as something to be implemented in the form of a program, involving particular activities and moral knowledge content. This approach has the effect of associating "being moral" with things like "knowledge, attitudes, motivation, and behavior", the major categories of mainstream psychology (which provides much of moral education's research base). But these categories do not necessarily address teachers' and parents' personal understanding of "being moral".

In this paper we argue that children and adolescents need to engage in science in a way that involves them as whole (including moral, aesthetic and spiritual) persons, so that their relation to science can become part of their "deeper subjective (including moral) being", part of the core of their self. We first suggest that in elementary school, the student's moral and ethical nature manifests in his or her "deeper (subjectively experienced) being", involving the most intimate parts of his or her self. Many elementary school teachers concerned with promoting their students' moral-ethical development have an intuitive appreciation of their "students' moral being as part of their general nature" (section 1), and this figures significantly in their efforts to facilitate the students' moral engagement. Then we discuss "three cases of engagement in science activities" in a science camp for 3-5th graders (section 2) where the engagement has strong moral dimensions.

STUDENTS MORAL BEING AS PART OF THEIR GENERAL NATURE

One way to introduce the problem of facilitating students' moral engagement in a subject matter area like science is to note that in praxis any deeper understanding of morality in another person involves some kind of subjective understanding of that person's feelings. In the classroom teachers use their own personal feelings regarding the moral aspects at hand and also try to be sensitive and respond to the subjective feelings and motivations of their students. Many are concerned with things like *respect*, *honesty*, with aspirations and *having ideals*, *conscience* and *compassion*, and consideration of *feeling* kind and actually *being* a kind person. All these terms have highly developed subjective connotations, and are used by parents and many teachers when they talk about their philosophy of education, their vision and hopes and concerns with the students, and tell stories from their experience. They deal with subjective experience and exemplify a level of thinking about and understanding of morality, which we might call "subjectively experienced morality". The subjective element is vital. Teachers would like their students not merely to exhibit behavior that looks honest from the outside, for example, they would also like them to have the kind of feelings and subjective experience that go with honesty. Teachers have an idea of what it is to have "internalized honesty as a value", and they would like their students to have the opportunity to internalize honesty and other values and to become aware of them as important elements in themselves and in their life.

While teachers often understand and deal with morality in the classroom at the level of subjective feeling and experience, talking about their experience presents some difficulties. The subjective aspects involved in almost any moral-ethical phenomenon or quality – honesty, kindness, or selflessness, for example – may be highly differentiated and subtle and may vary enormously both within the same person across different periods in life as well as from one person to another. It is true that there has been growing support for a "reinstatement of the subjective as a core topic in psychology", in the sense that "description, interpretation, explanation and facilitation of experience should play a more central role in psychology..." (Henry, Pickering, Stevens, Valentine & Velmans, 1997, p.117; Valentine, 1999). But qualitative research – which traditionally deals with subjective experience – rarely focuses on describing the subjective aspects of moral and ethical experience. How is selflessness experienced in one's consciousness and being, for example? What do we know about the phenomenology of conscience in natural contexts, or about the nature of conscience as an essential component of the core of a person? What is it to approach an earthworm with respect as an object of study? In all these examples we feel both a lack of vocabulary to describe the manifestations of the phenomenon or quality in question, and of an overview of different types of manifestations.

Besides the lack of descriptive empirical studies there is also another, more subtle problem. Teachers often have a deeper intuitive understanding of their students. A teacher may understand *the way an individual student is as a person,* she may have an intuitive feeling for this student's "being" (what kind of a person the student is, how he/she typically feels, responds), *and this may include an understanding of the student's "moral being"*. When an elementary school teacher intuitively apprehends a student's moral engagement in class, for example, she is often only able to do so because she can draw on the larger understanding of the student as a whole, which she has developed in the school year. Seeing a child looking at a pond animal in biology class, for example, the teacher may suddenly realize that the child is feeling compassion for the creature, and that feeling compassion like this is part of the way this particular child is. In fact, the teacher may only be able to recognize the child's engagement as real moral engagement *because* of her knowledge of the child as a whole – *because* of her understanding of the child's "(way of) being", including the child's "moral being".

The suggestion that teachers often have a specific, very holistic understanding of their individual students' morality and that this understanding plays a role in estimating and facilitating their students' moral engagement in specific situations is supported by Macgregor's (2001) recent work on students' engagement in multicultural cultural literature. The setting for MacGregor's research was her own fifth grade classroom, and students from her class served as participants. In four individual case studies, MacGregor shows in detail how the essential aspects of the children's involvement in these books are part of their unique general natures ("this is how [the student] is, this is the kind of person he is, this is this child's very nature", cf. Witz *et al*., 2001, p. 201). In addition, since the children typically relate to the characters in the book in terms of people and their relationships with people in their own life and vice versa, their involvement in the books tends to have a large moral-ethical component. In general, MacGregor describes each child's general nature or individual "way of being" as a *specific essential quality or gestalt*, with the child's "moral being" or morality *inseparably embedded in or associated with this essential quality or gestalt*. While these *gestalten* were developed after data collection in over a year of painstaking analysis, they basically expand and deepen the understanding of the children, which MacGregor had at the time as their teacher. Because of the fundamental importance of MacGregor's work for any view of the deeper relation between teacher and child (see below), we briefly summarize her description of one of her participants, Marco. To fully appreciate what follows the reader may want to consult the complete portrait in MacGregor (2001).

Marco

Marco is a tall and engaging African American eleven year old. Always cool, with a disarming charm (which he expertly manipulates), he is one of the leading figures in the class. Underneath his varied exterior however is " ... an active mind that is constantly searching, analyzing, and reflecting on the world around him ... Every aspect of his life is subject to reflective analysis, and he conducts an ongoing dialogue with his inner voice as he ponders how to live his life." (MacGregor, 2001, p. 62). This comes out particularly in his one-on-one interviews with MacGregor, as in the following (in connection with the book *Junebug*):

> **[1]** But [here in this school] if you say no I don't want to fight 'cause you get suspended [pause] and [pause] but [pause] I don't see why people do fight, because if you fight one day then for one, you gonna get supspended [sic], and then when you get home, you prob'ly have a fight which [sic] yo' mom because she gonna whup you, and you gonna be suspended from school, and then when you come back to school, then if you do it all over, it's just goin' to be keep on, keep on doin' that. [Did they suspend kids in Alabama for fighting?] ... Yeah, sometimes. [Did they get paddled?] Yeah, that's why they didn't supsend [sic]. See [in Alabama] you get choices [pause] to get paddled or you could go home...but shoot, if you go home and give your mama a note saying you got suspended, or you don't tell your mom, he [the principal] paddle you three times. [Explains why you get paddled] If you fight or something real bad and still continue to be bad, that's three licks [pause] especially from our principal Mr. Brown. He'd tap [pause] 'cause he used to be a baseball player. He'd tap one time, two times, then whack you real hard. I got paddled for that [pause] for three times because I had gotten in a fight with this boy, you know, Demetrius?... [Explains why Demetrius wasn't punished]...but my dad said you should fight because, you know, he's a fighting person, 'cause he got hands like this [gestures to show very large hands]...big, big hands, and I saw him punch a guy and the guy ssshhhhhh [makes an arc with his hands] ... If he punch somebody they flying, and when they get on the ground they start rollin'. (MacGregor, 2001, p. 63-64)

Listening to this passage many times and becoming aware of nuances such as prosodic contours, the manner in which something is being said, and overall tone, and seeing similar characteristics in many other passages, one gets a feeling for "what Marco is like", or "how he is [as a person]". Typically his inner gaze comes to rest on something, and he contemplates, almost as if in awe at the mystery, on some quintessential aspect or some juxtaposition, which to someone else may be small, but which to him is full of significance. It is almost as if he tastes the feeling that this aspect gives him, and tries to sense its implications, its meaning. Then he moves on to something else connected with it, and stops to reflect again. This general manner is typical of how he is in the interviews with MacGregor generally, and can to some extent also be seen in reading group. In reading group the images and reflections may not stand out quite as clearly and powerfully, and the inner movement from one image to another is often superseded by the wiles of the easy-going and charming, but deftly manipulating leader. But there is often again the same wondering and remembering in poignant images and searching for meaning and contemplative weighing. This is "part of the way Marco is" – showing the poignancy of the world he lives in, searching, and in this manner in intimate dialogue with himself.

If in the evocative but at the same time searching and questioning manner in [1], Marco is showing his deeper self or soul, then this same manner also shows moral-ethical and spiritual concerns that are vital to this self or soul. In other words, at the same level where we feel a sense a self-questioning and intimate dialogue with himself (or at the level where we can half intuit his "inner being"), we (researchers, teachers, parents) can also sense true moral and possibly spiritual engagement. For almost all of the dozen or so points in [1] where he reflects and contemplates have moral-ethical overtones, represent moral-ethical paradoxes, or raise questions. In most of the 20 longer passages which MacGregor quotes in her portrait, Marco is "conscious of the contrasts in the human condition", constantly "worry[ing] about the ethical aspects of such vast ideas as wealth versus poverty, racism, discrimination, and constantly question[ing] why things are as they are" (MacGregor, 2001, p. 62). Not only do these topics mark his inner dialogue as a moral-ethical search, there is also his unique manner of standing back and objectively contemplating all the peculiar circumstances and incongruities and mysteries of the situation on which he has fixed his inner eye. He contemplates them with a certain objective clarity – seeing each clearly, as a whole, feeling the nuances involved, and not being overwhelmed by them. He examines as it were the validity of all viewpoints, "teasing out what he perceives to be the truth" (MacGregor 2001, p. 64). Of course he often ends up affirming to himself that his own behavior was or is reasonable. For example "[If s]omebody be constantly hasslin' you for like two weeks and stuff ...[y]ou know ... you all gonna beat on each other's faces and stuff. And then you fight. Yeah!" (MacGregor, 2001, p. 64-65).

Finally "the way Marco is" cannot only be seen in his questioning manner, the wondering about whether something is fair or good or right as illustrated in [1]. It also includes his uncanny ability to evoke by means of a few words a whole image or situation. Each point which he elaborates (seemingly for his own, but in reality also for the listener's contemplation) is evoked with a minimum of number of words as a complete whole. He operates completely naturally with extraordinary verbal ability. This is characteristic of him not only in the interviews, but also in the discussions in reading group and in social interactions generally. In addition MacGregor (2001) hints, and we believe a detailed investigation would show, that Marco's deeper being (or the inner intelligence, self, soul, whatever) that can be seen in MacGregor's numerous excerpts manifests itself somehow also in his outer behavior. MacGregor explains:

> **[2]** Every act reflects Marco's internal tension. Although he is respectful and courteous, usually fair-minded, and blessed with an easy-going, devil-may-care charm that beguiles adults and children alike, he is also a shrewd manipulator of the truth who often "borrows" from his classmates without asking permission. Yet he is unfailingly generous and shares what he has with others. An acknowledged leader, he is an

> instigator who convinces other children to do his bidding and uses words and innuendoes to provoke and harass other students; however, he is also sensitive to the feelings of others and often rushes to the defense of less able students. Although physically aggressive, he virtuously draws the line at violence against females.
>
> **[14]** "My mom told me... only fags hit girls... boys that wanna be girls and stuff..." Innuendo and harassment are acceptable as long as "I didn't touch her or nothin'!" He rationalizes his actions, and exonerates himself ... (MacGregor, 2001: 62)

In general the levels of being or self in [1] are integrated with outer behavior into a larger whole, for the outer expression in [2] is just as characteristic of "the way Marco is" as [1]. Thus what we have been calling "the way Marco is" is actually part of a unitary essential "way of being" that involves personality, moral-ethical being and concern, and extraordinary specific type of verbal ability all fused into one.

Summarizing, in Marco we have a ubiquitous general manner or general way of being, outwardly and inwardly, a unified combination of personality and temperament, mental ability, and feeling and aspiration. This is perceived by researcher, teacher and parent as an essential quality or gestalt, a single essence or configuration of essential qualities, both in the child's consciousness at the moment and in his/her abiding self, which we called "the way he is" or his "essential way of being". MacGregor (2001) basically described this essential configuration of qualities ("the way Marco is") and showed how it expressed in his involvement with the multicultural books. Our argument here was that MacGregor's analysis could be extended to include the child's moral nature or "moral being". Namely, the moral engagement which was evident both in Marco's deeper engagement with the books and in his multifaceted colorful behavior in class were also part of his general way of being. His "moral being" that manifested in these contexts could be intuitively felt as part of his "essential way of being".

It goes without saying that the essential individual character of different children, and hence their moral being and the way they may manifest their own morality, may take utterly different forms. Rick for example, another of MacGregor's participants, is a 12 year old with a Caucasian father and Latina mother. From age 7 on Rick took on responsibilities for the family because his mother was an alcoholic. This experience of being a "parentified" child (Jurkovic, 1997) affected all aspects in him that usually enter a child's essential individual being (personality and temperament, aptitudes, and social, moral-ethical and aesthetic sensitivities and aspirations), and its effects still seem to reverberate in his consciousness today. Slow to react and sensitive, he dwells on the things he hears and reads, taking them very much to heart. As with Marco, much of the enterprise of Rick's intimate self is a moral-ethical one. His moral being, like Marco's, is an essential aspect of and completely pervades his individual nature, but manifests in completely different ways.

THE MANIFESTATION OF THE STUDENT'S MORAL BEING IN THE CLASSROOM

We have said that often the student's moral being can be felt as part of his/her deeper individual nature (his/her "essential way of being"). The reason that an intuitive understanding of the student's individual nature is so important for a teacher is that such an understanding enables her to estimate the student's real moral engagement and facilitate his/her moral engagement and unfolding. For example the teacher might recognize and immediately appreciate one of the specific points Marco raises in [1] as true moral-ethical involvement on his part *because* she has come to be in tune with "the way Marco is" in class and developed a sense of his deeper individual being. Many teachers develop this kind of understanding naturally, motivated by love for and dedication to their students. A researcher-analyst who is similarly dedicated can develop a similar understanding through intensive immersion in the participant's voice and micro-analytic nuances on the tapes (Witz *et a*l., 2001).

Although her focus was the students' engagement in multicultural literature, not their morality and ethics, MacGregor saw deeper moral engagement in all four of her case study participants. The students constantly saw and understood characters and situations in the book in terms of their own subjectively experienced relationships with family members and friends, and conversely, they brought new insight to their understanding of their own experience by thinking about the situations in the book. Under these conditions moral engagement was natural, because the students' subjective understanding of their relationships with family and friends often involved moral feelings or experience of moral conflict. Is there analogous natural subjectively experienced moral engagement in the science classroom? Literature in science education tends to focus primarily on cases where the teacher herself introduces a moral or ethical issue relevant to the current subject matter. Here we will look instead at hands-on science activities where students have some freedom to explore an object or phenomenon on their own. In such situations the science teacher is in a somewhat similar position as the literature teacher. Interest and engagement are largely prompted by the material at hand (the story to be understood, the object or phenomenon to be investigated), and real engagement, including real moral engagement, arises naturally in the course of working with the material. It is in such situations then, when students have some freedom to think and bring in their own ideas and concerns, that we expect their personal larger moral being to play a significant role. And it is here that the perspective that their morality is part of their essential individual nature or being is useful. In the following examples we will not try to describe the students moral being as part of their essential individual nature (the data are not at all suited for that), but we will discuss the students' engagement with this perspective in mind.

THREE CASES OF ENGAGEMENT IN SCIENCE ACTIVITIES

We discuss three cases of children's engagement in science activities where the engagement has a moral dimension. They are drawn from three dissertations presenting qualitative studies of children's science activities based on video tapes from an annual summer science camp described in Brown and Sinclair (1993) and Brown, Beck and Frazier (1997). The camp, two weeks, four days a week and 8 hours a day for 3^{rd} – 5^{th} graders from the community, was part of a graduate course for teachers called *Grow in Science*. The course consisted of 3 weeks of working with teachers on hands on activities, then 2 weeks of trying the new ideas in the science camp (two teachers and 20 kids per class room), and then one week of concluding discussion by the teachers. The focus of the camp was "engaging children in genuine inquiry."

Case 1: Touched by the pill bug.

Science camp is conducted in University classrooms with children working at small tables (four children per table). Rath (1995) describes four episodes ('segments') of the students at one of the tables, with the same four students in each episode: Palab, a bilingual Asian American boy, Ashley, John and Cathy. In the first episode, Palab and Ashley are supposed to describe "the characteristics and behavior" of a pill bug. Palab has the idea that pill bugs and other insects are basically robots. But at some point as he is watching the creature there is a sudden change and from then on he relates to the pill bug as a living being like himself.

The whole episode takes only about 3 minutes and consists of three "phases". (Rath has a fourth phase where a teacher joins the group and Palab discusses with her what he observed). In phase 1, the teacher brings the group a pill bug, which is soon taken over by John. At first Palab and Ashley crouch half over the table over animal to get a good look at it and argue whether it has a brain. (Palab says no but then admits it has a very tiny one.) But Palab is beginning to get interested in the creature and stands up to watch what John is doing to it (apparently putting tape on it?!). After about 1 1/2 minutes the teacher delivers a second pill bug, this one for Palab and Ashley (start of phase 2). The new pill bug starts to crawl on the table, and Palab "seems really excited and is practically shouting out his observations of the pill bug" (Rath, 1995, p. 62).

[3] 28. Ashley: Uh, he is eating my finger, he clamped down on my finger.

29. Palab: Look this one's walking, this one's walking.

30. Ashley: Hello, Little Guy. ...

34. Palab: This one's walking.

35. Ashley: Hi little Guy. This one is really active. Don't, you are going to make him not breathe. ... (Rath, 1995, p. 63)

A minute later starts phase three. Ashley is hovering over the pill bug and basically hoarding him, while Palab sits about two feet back from the table and is watching the animal intently.

[4] 52. Ashley: He's moving again. He's alive.

53. Palab: Look. Just keep him back.

54. Ashley: Look here.

55. Palab: Hahaha. Look what happened.

56. Ashley: We have the most active pill bug in the whole wide world.

57. Palab: He's, oh my god.

58. Ashley: I think he's nice, he's baby.

59. Palab: He can crawl real good, he's a good crawler.

60: Ashley: A baby pill bug.

61. Palab: A baby. [End of phase three] (Rath, 1995, p. 66-67)

Rath describes the episode in a very objective manner, trying to avoid attributing to the children any particular subjective feeling experience. The critical moment occurs at line 55 when Palab laughs involuntarily.

> **[5]** The laugh is the central feature of this segment... [Palab] is reacting in a spontaneous way, giving vent to his feelings. His laughter seems to indicate something important has happened.... He seems to be laughing about something the pill bug is doing on the table, but the laughter is also indicative of a new feeling.... No longer is the pill bug a science experiment, but it is a living creature with whom he has a connection. This type of connection is common between kids and animals... between most living creatures. It is a common experience... The relationship which has developed as a result of this connection is... based on sympathy and identification. (Rath, 1995, p. 67)

Rath explains that Palab suddenly “connected” with the little creature. The connection he experienced was the feeling or state which kids naturally feel when they face animals ([5]); they look at them with sympathy and identification as alive and conscious like they are themselves. Our own interpretation of the episode is that the pill bug was most likely trying to scale an obstacle and Palab was touched by seeing the animal strenuously exert himself. This is based both on Rath's account and on the impressions one of us got from the original tape. Judging from Palab's sudden reaction (an involuntary laughter, and then the “oh my god”, line 57), he must have seen something rather specific, and this touched him. Perhaps he had a sudden awareness of the animal as a living creature with its own desires, trying to achieve its own goal, and suffering its own travails. Rath says explicitly that Palab “sympathized” and “identified” with the animal. The laughter was an involuntary release at the moment of realization: “It is a private thought and an audible laugh, and as soon as the laughter escapes his lips he looks a little sheepish and embarrassed about it ... the self-consciousness only lasts a couple seconds” (Rath, 1995, p. 67). Immediately afterwards when Mrs. Burke joins the table and asks the children what they have noticed at this early stage, Palab says “they have like, those armored, hmm... like an armadillo... those, hm, that's what you call like, kinds of skin, armor plate” (Rath, 1995, p. 71). When a pill bug is trying to overcome an obstacle (like when he climbs a Petri dish), one sees it struggling against its armadillo-like armor, and this may have evoked Palab's “sympathy” and “identification.”

Regardless how we interpret Palab's experience, however, we can say that there was a moment where Palab was “engaged with his intimate self” (Rath: “an intimate thought”, and for a moment Palab is “embarrassed”, [5]). Palab's interaction with the pill bug was at a moral-ethical level. It changed his whole relationship to the animal, from “a [inanimate] science experiment .. [to]... a living creature with whom he has a connection” (Rath, [5] above). Having a “connection” with the object of study as a living being is a subjective state that includes strong moral-ethical tendencies and feelings. Palab is now worried about the pill bug ([4] line 57), he starts to look at it like Ashley as something to care for ([4] line 61). A single moment of being touched can unlock the child’s sympathy (something that is still natural at this age) with profound consequences.

Granted that Palab's interaction with the pill bug involved real moral-ethical consciousness, can we also say that consciousness was part of his essential nature or being, comparable to Marco's engagement with the book *Junebug*? In a certain sense yes, although not as fully as in Marco's case. What distinguishes Palab from many other children his age is that like a true scientist he regards the world as an object of independent interest of its own and worthy of study. A reading of the transcripts suggests that for him the characteristics and behavior of animals as well as inanimate objects are of interest on their own. They are of interest beyond the temporary attraction they exert because of their novelty. They have an independent importance as features of the observable universe. From this point of view, the involuntary little laugh marks a major change in his personal scientific orientation.

Case 2: Characteristics and behaviors.

Our second example is more complex. Beck (1997) described the experience of four children working at the same table over the course of the whole camp on a day-by-day basis. Her constant question was "what is the nature or essence of the [children's] experience of learning [in such relatively unstructured science activities]" (Beck, 1997, p. 6, reflecting van Manen, 1990, p. 10). We look at her account of Day 5, where the children are working for the first time with animals.

The children are to observe and record "characteristics and behaviors" of the animals on a sheet, and the teacher discusses these concepts and gives many examples. "Be careful you don't do anything that will hurt them" (Beck, 1997, p. 157). Finally each group gets a plastic container with a crayfish, and soon the kids in Beck's group crowd around the animal and are talking. And almost immediately a small incident sets them off in a special direction.

> **[6]** 226. Annie: He jumped high! (all laugh).
>
> 227. Jennie (the teacher): Would that be a behavior or a characteristic?
>
> 228. Eddie: Behavior. Make it jump again, okay?
>
> ... The children laugh and the tone at the table changes. The children start wiggling and moving ..., ... leaning into the center. Eddie wants the crayfish to jump again (line 228) and the thought seems to excite them. ... Thinking that they might be able to cause a repeat of this performance emboldens them and it seems that repeating this fun experience takes precedence over concerns for the creature. ... [it] turns the crayfish into an object. There is much laughter. Frequently two or three of the children are talking at once and when they are not talking they are laughing. Only occasionally do concerns for the crayfish as a living creature get expressed ... (Beck, 1997: 158-159)

Beck continues to describe the rest of the day in this manner for three more pages and then pauses. Her "first reaction to Day 5 had been that it was a good day," but then "closer observations… of the transcript and the video tape changed... [her] mind about Day 5" (Beck, 1997, p. 161). The crayfish (the group got two others in the afternoon) were "subjected to being picked up, to being struck with the magnifying glass, and to being poked with a pencil. ... "

> **[7]** 317. Eddie: lets see what happens if I hold his leg.
>
> 318. Billy: Don't.
>
> 319. Annie: Yes do.

645. Eddie: I pushed her against it. I jammed him up against the wall ... (Beck, 1997, p. 163)

The intimate self that shows in the child's way of being is taken with the crayfish jumping, and soon becomes entranced with making the creature do other things. The initial connection to the animal as a wondrous other is lost. The children delight in the new possibility, but without them realizing it, the new focus "turns the crayfish into an object" ([6] above). The teachers do not specifically notice. Throughout the day they are primarily interested in the children recording their observations.

[8] 656. Eddie: ... [The crayfish has] two black eyes.

657. Jennie [a teacher]: That's a good thing to write down. Is that a characteristic or a behavior?

658. Eddie: Someone threw a rock at him and now he's got two black eyes.

659. Jennie: Okay, so is that a behavior or a characteristic that he has two black eyes? (Beck, 1997, p.164)

But Beck's data does not stop here!

[9] It is around this time that I first noticed a change in the children's discourse. ... There were no statements of "I am going to..." or I have..." The statements instead were commands... put, pick, touch, most of them having to do with "doing something to the crayfish... A series of orders to manipulate the creatures.

907. Billy: Zig'm, zag'm, zig'm, zag'm (said as Kelly moves the crayfish around the cage using the magnifying lens as prod).

908. Eddie: Scoop one up from behind. Why don't you pick one up and put one out?

909. Annie: Make them get married.

910. Billy: Put them together.

911. Eddie: Drag his head along.

912. Billy: Lets drag his head along.

This "commanding sequence" is an example of the day's conversation. Notice that each utterance begins with a command. These commands seem to coalesce the group. They are a kind of discourse the students understand and are used to hearing. The commands seem to focus their attention and show the assertiveness and authority of the speaker, an assertiveness and authority that is used by all. In addition it strikes me as very similar to the way we talk to ourselves – self talk – (no pronoun is used; none is necessary if one is talking to oneself.) leading me to the sense that the group is almost functioning as one organism.

942. Annie: Pick one up.

943. Eddie: Billy, pick one up and put him on the table, okay?

(repeats).

944. Annie: Let him out now.

945. Kelly: Let the little one out now. trap the big one. Oh they want to get married. Come on. Let them get married.

947: Annie: I cant see nothing. (Beck, 1977, p. 164-166)

The students' "stories" about the crayfish were in the same self-talk mode:

> **[10]** 1009. Billy: We are trapping them together.
>
> 1010. Kelly: To see what they do.
>
> 1011. Jennie: When they are together, what d they do?
>
> 1012. Mate. I need to get my penny.
>
> 1013. Pile one on top of the other one. (Repeats). (Beck, 1977, p.166).

Beck identifies two basic phenomena. First, she suggests that segments like 907-912 and 942-946 (and we would add 1009-1013) are "self-talk". They suggest a state where the intimate self or the child's being, delighting in what is going on, is in intimate dialogue with itself. The children are happily abiding in their own sphere, all guards are down and they are happily "doing things to" the crayfish. There is a certain entertainment value in what they are trying to do; in Beck's terms, they have an "entertainment focus". But Beck sees something even more significant: this phenomenon of self-talk has also a collective aspect. "These commands seem to *coalesce the group*"; "[They] ... show the assertiveness and authority of the speaker, *an assertiveness and authority that is used by all*"; "... the sense that the group is almost *functioning as one organism*" ([9] above, italics added).

> **[11]** The physical closeness of this group of students on this day was initially a result of the phenomenon in the center of the table that was there for them to observe. However the students in this group remained in close proximity to each other throughout the day, much of the time with their heads only inches apart. Also throughout the day there were signs of affection - touchings and hand pattings, and at the end of the day Eddie gives Billy a great big hug. The students did not want to go out for recess and two of them stay and clean desks at the end of the day long after the other students have left.
>
> ... [I am] still intrigued by the groupness - the letting down of boundaries so that the group seemed to be "one" organism. ... the sense of energy and closeness that the students felt can hardly be denied. Even if they were not opening up to the creature there was an opening up to each other and an acceptance of things said and done ... (Beck, 1997, p. 169)

These are powerful observations (first paragraph of [11]). Although the children are proceeding self-absorbed in their being, entranced by the magic of the creature reacting to their proddings, the magic of making the creature do things, each child also seems to intuitively know that the others beside him/her are sharing a similar experience. Beck's observations raise a host of serious issues for science education as well as for science, and she tries her best to focus only on the good in what she has seen (second paragraph of [11]). At the very end of her study, she writes about her personal struggles with these events as a teacher.

> **[12]** ... [our work as teacher researchers also] encompasses looking at what that culture [of the scientists] is and making judgements about what parts of it we want to promote in children, what patterns we want to change. ... I realize that for me the questions are a lot broader than how to foster scientific literacy or ... or how to produce better science students. I was drawn to a study of science initially because studying science is about studying the stuff of life. I am fascinated by spider webs and awed by how little seeds become huge plants. Coral reefs, mushrooms, and thunderstorms captivate me and the miracle of birth in all its forms remains for me just that - a miracle. It is all endlessly fascinating, interesting, but even more than that it inspires in me a deep sense of humility that I am part of and can partake of all of this marvelous wonder. It is this

> sense that I want to share with children, the sense of marvel at it all. And it is precisely this sense of awe and respect that I find missing, in most adults and from too many classrooms...
>
> My commitment to a certain kind of science education cannot be divorced from [my] philosophy of life. For example, I worry about Eddie talking about squishing the earthworm and stomping on lightning bugs. Eddie seems to have a great deal of "objective knowledge" about many things. However, what Eddie knows does not prevent violent suggestions and behaviors. In this world now, the life of one earthworm is not considered of any consequence. In fact, the using of all sorts of living thing for our benefit and amusement is a way of life. In this milieu, how does one teach a deep respect for an earthworm? This is not an easy question, but seems to me to get at the heart of what is lacking in science education. Having no moral compass, all is OK if it is in the name of science. (Beck, 1997, p. 255-257)

Obviously Beck is agonizing, but her own priorities are clear. Many elementary teachers want to share with the children a sense of wonder at the endless richness of Nature and of ourselves being part of this richness. And many would like to teach respect for all life, and would agree with Beck that "this sense of awe and respect ... [is] missing, in most adults and from too many classrooms". But for Beck awe and respect are not merely desirable but essential, and they are essential both in science education and as *aspects of lived science* – of the "culture of science". For her, teaching *deep* respect (cf. [12]) lies at the heart of science education. She knows that in situations like the one on her Day 5, the teacher who sees what is happening in the deeper self of the child has an opportunity, not to step in and preach, but to redirect using her own inspiration and inner resources. But Beck's conscience also leads her to face larger issues. As an educator and researcher she has to decide "what parts of ... [the culture of the scientists] to promote in children, what patterns ... to change"., otherwise "all is OK if it is in the name of science". At the end of [12] Beck is speaking to the community of scientists, to science itself and to society. Science needs to have a moral compass; the need for being moral-ethical in one's being when doing science needs to be addressed both by the scientists and social policy makers.

Perhaps the problem started not when the crayfish jumped, but when the teachers focused only on behaviors and characteristics rather that on a proper relationship to the object of study. Behaviors and characteristic also make the animal (the "object of study") into an object. "Becoming enamoured with the [scientific] model easily affects one's capacity to do the object of study justice. One is in danger of giving one's heart to how the object ... can be manipulated according to the model ...". As scientist, one "needs to remain centered in one's fundamental relation to and concern for the object, ...without improper indulgence and desire" (Witz, 1996, p. 605). The crayfish has a mechanical structure the moving parts of which (like a model) automatically invite manipulation (cf. [7] line 317), and the students are naturally eager to see how it will respond. No wonder they become absorbed in exploiting this possibility. But at the same time their behavior does not seem to be altogether innocent. Earlier in the day they "had ready answers when asked 'what kind of things can we do to the creatures and what kind of things should we not do?'" and "had been told what they would like done to them if they were small and a giant was observing them" (Beck, 1997, p. 162). They cannot have been completely unaware that they were not quite playing by the rules. The fact that they were huddled together for much of the day with heads almost over the crayfish and completely oblivious of the adults, and the peculiar closeness and affection that develops between them suggest that they had at least an inkling that they were getting away with something and that they were in this together.

Case 3: Ernie the budding scientist.

Frazier (1996) was already an experienced, creative and highly respected seventh grade science teacher when he began his investigation. Like Beck, he studied four children at the same table, but rather than giving a day-by-day narrative, he focused on his participants individually. He had taught hands on science for many years and wanted to see what the kids were really doing and thinking in such contexts. But he was also interested in whether the children showed any consistent patterns of engagement in science.

On Day 5 Ernie works for almost an hour with a soft shell turtle. At first it looks as if there is a similar kind of situation as with Beck's kids, but the problem is of a different nature. Frazier first establishes that there is a common pattern of rational investigation in all three of Ernie's activities, which he studied, a pattern that is in fact reminiscent of the "canonical scientific method".

> **[13]** He begins his investigation with a meandering exploration, searching simple systems like the battery, bulb and wire, or [merely picking up and then returning] different creatures like the tadpole and minnows, messing about. Once he decides on a tentative direction for examination, or intervention, he moves delicately, probing lightly, looking deeply, contemplating. As he grows in awareness of the object or creature of interest, his confidence grows; he pushes his manipulations to a greater limit and exercises them with greater control. The confidence blooms as he reaches a conclusion, as the invention works, as the animal is trained. The device is "cool", the turtle "trusts [him]". ... Since the turtle naturally bites, and scratches, and jumps, scientific propositions and manipulations should naturally be directed toward such behavior. The pile of inanimate pieces of material comes to life, the parts are grasped and fingered with dexterous touch. [Frazier spent some time showing that at a certain stage, Ernie's way of touching the turtle was similar to his handling the bulbs]. A living creature is understood and tamed, the fingers touch lightly and, in the crowning moment the turtle is grasped with both hands. The two entities come to the same place for Ernie, and he has taken the same road to both. (Frazier, 1996, p. 87)

Frazier writes with some passion. But what really it is that disturbs him? Ernie has the turtle from ca. 9:10 to 10:00 am.

> **[14]** Much of the early episodes of touching seem tentative and exploratory.... The touches and prods are delicate and sometimes seem to cross from curious provocation to affectionate petting. Ernie can occasionally be heard to call sweetly as he touches, "Turtle." (Frazier, 1996, p. 77)

> **[14]** at one point he giggles to himself and says to no one in particular, "whenever I touch this turtle's head it just puts it in". He laughs with curious delight and pokes and prods the turtle. (Frazier, 1996, p. 81)

But then around 9:30 am there is a change, and from then on holding the turtle is common. "Holding where the fingers are wrapped firmly around the back of the turtle's shell requires much more confidence and control than single finger stroking" (Frazier, 1996, p. 77). Frazier documents the change as scientifically as possible by time sampling and histograms. The number of utterances peaks strongly from 9:20

to 9:30, "follow[ing] a period of exploration indicated by particular touching and looking", and then again from 9:50 to 10:00, "match[ing] the period of extended holding at the end of the class" (Frazier, 1996, p. 80).

> **[16]** [Around 9:48 am] he says in his uniquely sweet voice "turtle, open [your mouth] wide", and then, "its just me". ... He speaks even more publicly and confidently. ... At 9:51 he says as definitely as anything recorded on the tapes, "I made a test. Can his claws tear through this? They are sharp. They hurt. I am testing whether his claws can tear through this." ... Ernie has picked up the turtle and has wrapped a piece of paper towel over its head and shell. He has discovered a test, a way of checking the limits of performance of a noticeable behavior - the turtle tries to bite when it is picked up. ... Ernie's confidence and pride seem to swell.

Soon Ernie claims that "the turtle has learned some things. He'll open his mouth and I let him down." (Frazier, 1996, p. 83). When the teacher joins the table he explains that he is "starting to train the turtle. Whenever I pick him up he opens his mouth immediately". "Oh he won't bite me. I know he won't ... He ah, he trusts me a little more than he trusts Mrs. - Mr. S." (lines 567-569, Frazier 1996, p. 84). "The certainty and the public declarations of his knowledge [of the turtle scratching, biting, feeding, jumping and falling] seem different" from his earlier tentative cautious, exploratory manner. In the discussion the next day he tells the group "you have to learn [that] if he drops on something, he doesn't care". And when Mr. S. is skeptical, he elaborates: "He's landed on his shell and his belly and it doesn't hurt".

> **[17]** Is the portrait a portrait of Ernie? ... A case could probably be made that his exploration, tentative testing and confident demonstration have something of the canonical scientific method in them. ... Ernie would seem a model science student, interested in the same phenomena the teacher has arranged, engaged in the same sorts of questions the teacher has posed. He shows an independence of mind as well ...
>
> I am bothered by the way Ernie's engagement with the turtle ends. My discomfort makes Ernie's portrait more valuable to me. Ernie's progress deeply challenges beliefs and assumptions I have about teaching science. I confessed earlier to a once confident belief that salient phenomena were the key to successful science teaching and learning. ... I have listened sympathetically to the calls for process and enquiry and dialogue and debate in science. I have nurtured the faith that what young children construct in their enthusiastic investigations of the world must be largely good. But what Ernie has taught me is that that a reserve of curiosity, a fascinating creature and phenomenon, and an all purpose way of working may not necessarily combine into the result I might hope for in science students. I am troubled that Ernie turns his fascination with the turtle into claims of domination, that his gentle touches of investigation become prods of manipulation, that his working mode is successful - not so much in building electrical boxes, but rather in reducing a living wonder to a trainable toy. (Frazier, 1996: 90-91)

What really bothers Frazier seems to be that Ernie seems to have a lot of potential for scientific work and that one would expect him to be successful, but he is not. Ernie has some of the qualities of a serious investigator – the others in his group call him "freak scientist." Alone among the four kids he has an idea that there is some kind of reality there that beckons to be elucidated, and that it can be elucidated by observing, interacting with, and experimenting. This is something that can develop into beautiful science. But what unfolds in his activity is only distorted science and a distorted relationship to a living creature. From wonder and gentle tentative touching he has in the space of an hour come to a point where he holds the turtle with its head wrapped in a paper towel to "test" how sharp its claws are – a topic with which he became fascinated while prodding the turtle. He is convinced that he was able to train the turtle, and that he was able to do so *because* the turtle trusted him. So the phenomenon Frazier sees with Ernie and the problems that it raises are different from Beck's. Beck's children got caught up in wanting to see the crayfish “do things”. A sensitive, experienced and committed teacher might be able to redirect their “entertainment orientation” without too much difficulty. Ernie, also his intimate self (cf. [14]-[15]), got carried away with being scientific investigator. In working with the turtle, Ernie uses his aptitude and disposition for scientific investigation and follows to some extent the canonical scientific method. In spite of all this the results were less than what one “might hope for in science students” ([17] above).

Frazier says that he was too enamoured with his own philosophy that “salient phenomena” and “noticing” were the key to successful science teaching and learning, and that he learned from Ernie that uncritical confidence in these principles by the teacher may do students a disservice. In other words the problem was one of him being too narrowly focused in his educational philosophy. Another lesson, however, is that the scientific approach to the world needs to be practiced with wisdom and a larger moral-ethical vision. This is also a message in the other two cases. With Palab and Eddie and his friends we are dealing with a more general issue but one that always necessarily arises in the context of biology, viz. how to relate to and treat living things in a moral and ethical way. But in the case of Ernie and the turtle the issue revolves more specifically around the scientific method and the general attitude of the scientific investigator when the objects of study are living things. For then the scientific method is not characterized only in terms of formulation of hypotheses and systematic experimentation. It needs to have at its core a moral-ethical orientation to the object of study.

CONCLUSION

In this paper we have pursued two lines of argument. The first was that to genuinely address children's moral and spiritual unfolding, the teacher needs to deepen her own already existing ways of trying to intuit and be in touch with the deeper being of her children. Both children and adults feel themselves to have a moral-ethical nature, which is part of their being. To really address the ethics and morality in another person one needs to intuit that person's being, or his or her general nature, and understand the person’s moral being as part of that. This is possible only with love and dedication to the children. We can imagine a teacher noticing and encouraging Palab in his realization that the pill bug was a living being with its own agenda and difficulties. Or, seeing how Ernie was getting off the track, we can see how she might be able to redirect some his hypotheses and procedures. If she already had an appreciation of these particular children's nature or being, then her judgment will be more sure, her response will likely be more appropriate, and helping the child focus in his/her reasoning will certainly be more effective.

Our other main argument was to draw attention to the fact that true dedication to the moral-ethical unfolding of the children in the science classroom is likely to require intensive engagement and soul searching on the part of the teacher, not only in regard to her role and deeper aims as an educator but also regarding the nature of science and it's role in life and society. Some science teachers may regard science as a given, and see their task as giving their students some basic current scientific knowledge and an understanding of scientific processes. But today the traditional objectivism of science, the nature of the knowledge that it produces, and its role in society have been questioned (e. g. Longino, 1990; Lenk, 1986; Bernstein, 1983). Under these conditions many teachers who are dedicated to the deeper moral-ethical and spiritual unfolding of their students feel bound to examine their own convictions in these areas. This is illustrated in the cases from Beck (1997) and Frazier (1996). If, as Beck feels, the essential being of the future adult should include deep respect for the object of study and wonder at the endless beauty and depth of nature, then there is no question that these qualities need to be fostered in the elementary grades. But how to do that in a genuine way that connects with the deeper being of the child ("how does one teach a deep respect for an earthworm?", [11] above) is a basic problem which does not figure seriously in the literature on science teaching or teacher development. Similar comments hold for promoting aesthetic inspiration in science (famous physicists have said that if they were forced to choose between beauty and agreement with experiment, they would choose beauty, Yang, 1982, p. 39). Again the things which Beck and Frazier were seeing in their participants in cases 2 and 3 prefigure some of the moral-ethical "dangers" and "temptations" which Witz (1996) suggests scientists need to counteract in themselves. But there seems to be almost no detailed discussion of these kinds of issues and phenomena in the literature. More qualitative case studies, exploring not only the student's behavior and but also the many dimensions and levels of the teachers' struggles, are needed. But even more important would be acknowledgement and discussion of these issues in both the communities of scientists and science teacher educators.

REFERENCES

Beck, D. P. (1997). *Interpretive video analysis of children's inquiry: Fantasy and other emergent contexts at a summer science camp for elementary school children*. Unpublished doctoral dissertation, University of Illinois at Urbana-Champaign.

Bernstein, R. J. (1983). Beyond objectivism and relativism: Science, hermeneutics, and praxis. Philadelphia: University of Pennsylvania Press.

Brown, D. E,. Beck, D., and Frazier, R. (1997). *Constructive lenses for viewing and valuing students' activities during inquiry in science*. Paper presented at the annual meeting of NARST, March 1997, Chicago.

Brown, D. E. and Sinclair, M. R. (1993). Grow in science: Explorations in science, learning, and teaching. In P. L. Rubba, L. M. Campbell, and T. M. Dana (Eds.), *Excellence in science teacher education* (*p.* 191-202), (Yearbook of the Association for the Education of Teachers in Science),.

Coody, B. (1992). *Using literature with young children*. (Fourth edition). Wm. C. Brown Publishers.

Edge, D. (1985). Dominant scientific methodological views: Alternatives and their implications. In Gosling, D. and Musschenga, B. (Eds.) *Science education and ethical values* (p. 1-9*)*. Geneva: WCC Publications and Washington DC: Georgetown University Press.

Estes, T. H., and Vasquez-Levy, D. (2001). Literature as a source of information and values. *Phi Delta Kappan 82* (March), 507-512.

Frazier, R. (1996). *Ways of working, ways of being: A study of four children working in a setting of learning science*. Unpublished doctoral dissertation, University of Illinois at Urbana-Champaign.

Hargreaves, J. and Hargreaves, T. (1983). Some models of school science in British curriculum projects and their implications for STS teaching at the secondary level. *Social Studies of Science 13*(4), 1-15.

Henry, J., Pickering, J. Stevens, R., Valentine, E., and Velmans, M. (1997). Towards a psychology of experience. *The Psychologist 10* (March), 117-120.

Jurkocic, G. J. (1997). *Lost childhoods: The plight of the parentified child*. New York: Brunner/Mazel Publishers.

Lenk, H. (1986). *Zur Kritik der wissenschaftlichen Rationalität*. Freiburg: Karl Alber.

Longino, H. (1990). *Science as social knowledge: Values and objectivity in scientific inquiry.* Princeton, NJ: Princeton University Press.

MacGregor, N. (2001). *Deeper engagement: A qualitative study of multicultural fifth graders involvement with literature*. Unpublished doctoral dissertation, University of Illinois at Urbana-Champaign.

Palmer, P.J. (1998). Evoking the spirit. *Educational Leadership*, December 1998-January 1999, 6-11.

Rath, A. (1995). M*odes of engagement in hands-on science learning: A micro-analysis of elementary students relationship to the object of study*. Unpublished doctoral dissertation, University of Illinois at Urbana-Champaign.

Valentine, E. R. (1999). The possibility of a science of experience: An examination of some conceptual problems facing the study of consciousness. *British Journal of Psychology 90*, 535-542.

Van Manen, M. (1990). *Researching lived experience.* London, Ontario: SUNY Press.

Witz, K. (1996). Science with values and values for science education. *Journal of Curriculum Studies 28*(5), 597-612.

Witz, K., Goodwin, D., Hart, R. S., and Thomas, S. (2001). An essentialist methodology in education-related research using in-depth interviews. *Journal of Curriculum Studies 33*(2), 195-227.

Yang, C, N. (1982). Beauty and theoretical physics. In Curtin, D. W. (Ed.), *The aesthetic dimension of science. 1980 Nobel Conference.* New York: Philosophical Library, 25-40.

CHAPTER 9

RECOGNIZING AND SOLVING ETHICAL DILEMMAS IN DIVERSE SCIENCE CLASSROOMS

CATHLEEN C. LOVING, SUSAN W. LOWY & CORI MARTIN

INTRODUCTION

Ethics scholar Paul Wagner (1995) once said there are four great professions: medicine, law, "preachin" and "teachin." If professional preparation programs for the first three are examined, one subject is common to all – ethics. It is standard for students in these professional schools to have explicit course work that requires them to identify and solve problems requiring ethical and moral decisions. Teaching has been described as "moral by nature" (Chang, 1994, p. 81), meaning the very essence of good teaching involves the ethical and moral development of young people. Teacher preparation programs, however, do not generally include explicit instruction involving the ethical dimensions of the classroom, nor do they provide opportunities for solving ethical dilemmas (McNeel, 1994).

Perhaps those choosing the teaching profession are assumed to be moral and ethical by the fact of having chosen teaching. Unfortunately, the research suggests otherwise. In a recent study of elementary and secondary preservice teacher education students from freshmen to seniors, Cummings, Dyas, Maddux and Kochman (2001) found students seeking teaching credentials to have significantly lower moral reasoning scores than college students with other majors. The instrument used in the study, known as the Defining Issues Tests, or DIT (Rest, 1979) is a test of principled moral reasoning based on Kohlberg's theory of cognitive-moral development. Principled moral reasoning, according to Cummings et al. (2001) is required for teachers to take a " leadership role as moral agents in public schools" (p. 145). This level of moral reasoning requires the ability to shift from self-interest to concerns for equity, mutual respect and protection of rights. The

D.L. Zeidler (ed.),
The Role of Moral Reasoning on Socioscientific Issues and Discourse in Science Education, 183-194.

teacher who is able to exhibit and use principled moral reasoning provides more motivation for student learning and healthy social development (Chang, 1994).

Whether one is a special education, kindergarten or advanced placement physics teacher, research suggests there is a specialized body of knowledge known as role-specific obligations (Keefer, 2001) that must be identified and used in solving moral and ethical dilemmas associated with a profession. Keefer also found that experienced ethical reasoners "are careful to identify issues and to specify conditions under which specific professional role obligations recommend particular actions, that they elaborate conditions which would affect the moral analysis of a problem, in part through posing hypothetical variations of the problem, and that they justify resolutions in terms of those conditions which they conclude apply in the problem" (p. 385-86). To what extent is this specialized knowledge about role-specific obligations in teaching made explicit in teacher education programs? To what extent do novice or veteran teachers have experience reflecting on their profession's ethical and moral dimensions? The codes of ethics provided by state, local and professional education organizations tend to provide open-ended statements that may provide an umbrella under which teachers perform, but they are rarely cited or consulted on a day-to-day basis, thus there is need for specific strategies to confront and solve the ethical dilemmas of the classroom.

THE ROLE OF ETHICS IN A PROFESSION

The issue of how a profession prepares its future members and how it routinely applies its ethical codes has led to teaching being questioned as a true profession (Rich, 1984). When compared to law, medicine and theology, there are striking differences related to applying and enforcing ethical codes.

According to Rich (1984, p. 8-12), true professions 1) have a systematized body of knowledge that informs practice, 2) include a long period of specialized intellectual training and have an essentially intellectual focus, 3) are organized to provide a unique social service, 4) have controlled standards of entrance and exclusion, 5) include an enforced professional code of ethics that is defensible, and 6) grant a broad range of autonomy. Professions meet most of these characteristics and elementary and secondary teaching are no exception. What is missing for teachers, however, are not established codes of ethics, but explicit course work that includes instruction and practice in recognizing and solving ethical dilemmas using a variety of aids, including codes. Another concern is that the profession itself does not enforce its codes of ethics. School boards and state education associations fulfill this role. If a profession cannot regulate itself then its status is diminished. Today it is critical for teaching to maintain and advance its status as a profession, so that more quality individuals can be enticed into classrooms, and children can receive the best education possible.

Let us first explore what we mean by a professional code of ethics. Examining various codes of ethics reveals some common features. A code of ethics ensures clients that professional services will be rendered with reasonably high standards and acceptable moral conduct. It ensures the public that the professional is serving in the public interest and should continue to enjoy public trust, confidence, and support, and it provides uniform rules and behavioral standards that inform members of the profession what is acceptable behavior for the purpose of regulation. Many examples of codes of ethics can be found for teachers, but it is how these codes are used and enforced that is the most critical concern for achieving professional status. Looking at the three other professions (medicine, law and ministry) one finds established review boards made up of other professionals that deliberate and rule on ethical dilemmas in the profession. In teaching we do not have such boards. In fact certification and licensure is a state function and not a function of the profession. Membership in professional organizations is not based upon adherence to a code of ethics in teaching. In the medical profession member-ship in the professional organization can be denied for an ethical violation, which could result in loss of employment. In teaching, however, membership in a professional organization is rarely a requirement for employment, except, perhaps, in schools where collective bargaining requires membership in a teacher's union. Science teachers are not typically required to belong to organizations such as National Science Teachers Association or National Association of Biology Teachers, nor if they are members are they subject to moral or ethical oversight from that organization. Therefore, we have codes without sanctions. It is not difficult for a teacher fired in one district or state for a breach of some code of ethics to be hired in another district or state. How then can we establish public trust for our profession?

TEACHER PREPARATION IN ETHICAL DECISION-MAKING

The first step must be in the preparation of teachers. In teacher preparation programs students need experience working with moral and ethical dilemmas and developing a level of reasoning that encompasses moral and ethical classroom issues. Ethical decision-making requires practice. We believe that as a result of lack of explicit instruction in ethics, mentor teachers are often uneasy or unprepared to discuss the ethical dimensions of classrooms with preservice teachers when asked to do so. When ethical issues are discussed, often the solutions are not clearly delineated or defended and the dilemmas themselves are not always recognized as ethical dilemmas. In this chapter we suggest a process that can be used to help preservice and veteran teachers alike arrive at judicious ethical decisions in the teaching profession.

At Texas A&M University the secondary teacher preparation program includes a four-week Ethics Module (Loving, Lowy, Leunes & Riggins, 1998) that is part of a two-course block (TEFB 323 and TEFB 324) containing six modules. The modules for the two courses were designed by a collaborative of individuals from the colleges of education, liberal arts, and science on our campus and public school teachers from several districts. The collaborative group suggested the content for these two courses. Ethics was considered to be an important component for the teacher preparation program; therefore, it was developed as a module along with modules in assessment, instructional strategies, motivation, effective learning environments, and general learning strategies. The development of the ethics module gave rise to the idea of an ethical brief (adapted from Nash, 1996) to be used to help students and teachers analyze and work through ethical dilemmas to arrive at good moral decisions.

A CASE-STUDY APPROACH AND THE ETHICAL BRIEF

The ethical brief is a concise outline of the major themes and contentions of arguments in a difficult ethical dilemma. It is designed to help the individual arrive at a decision that is just, moral and appropriate for the situation, taking into account background beliefs, conflicting moral feelings, conflicting thought processes, and professional expectations. The brief is expressed in first person as if someone is actively working through an ethical dilemma in the present.

In the Ethics Module at Texas A&M, students seeking secondary credentials in various disciplines from biology to French work through sample cases of ethical dilemmas, using the steps in the brief to solve dilemmas and then create their own cases to solve. The case study approach allows students to confront real school dilemmas. An example case from Strike and Soltis (1998) involves academic freedom versus equity in assessment issues for three sophomore year history teachers from the same school whose assessment strategies are significantly different from each other, with the result of complaints from students and parents. The Texas A&M students' own cases are then developed with input from experienced classroom teachers during their three-hour-a-week field experience. Students are required to present their cases and solutions in the form of ethical briefs to their classmates at the conclusion of the module. In this way students are able to think about a wide variety of ethical dilemmas and consider how they would solve them. Students and the two instructors (one university, one public school) provide feedback during the oral presentation, which can be incorporated into the final written draft.

We believe it is this practice of thinking on a moral and ethical wavelength and providing explicit opportunities for moral and ethical discourse that is most important to the development of the ethical teacher. In addition, the use of case studies to provide rich contexts for ethical problem-solving in teaching seems essential, for preservice teachers are so new to the teacher side of the student-teacher equation.

The ethical brief has five questions that must be answered before arriving at a decision. What follows is a detailed explanation including the moral significance of each of the questions. When the steps in the brief are applied to individual cases a well thought out decision should be the result. Our brief was created by combining ideas from Nash (1996) and Strike and Soltis (1998) and is always written in the first person to constantly remind the writer whose reasoning is responsible for the final decision.

> 1. What are your immediate moral intuitions and stirrings about this case?
>
> In this section of the brief you would explain your first hunch about the case. You explore the thoughts and ideas that come spontaneously to you about what course of action to take in this decision. Intuition should be depended on to guide this thinking. Later you will apply rational thought processes to this decision, but here it is important to just let the solution be your first thought.
>
> 2. Are you experiencing any conflicting moral feelings as you think about this case?
>
> Use your primary feelings like excitement, joy, anguish, anger, disappointment, remorse, and guilt to help you carefully think about all of the morally relevant issues and people represented in the dilemma. Provide an explanation for where this thinking

leads you, so that you can better sort through the moral complexities of this case. Intuition and feelings are a part of the process that also includes reasoning.

3. What would happen if you were to make a decision first from the "consequentialist" then from the "nonconsequentialist" ethical thought processes?

If you were a "consequentialist" your decision would be based primarily on the consequences of your decision. The rightness or wrongness are in terms of who suffers or who benefits more than your obligation to obey rules, policies and even some values. You would act on the principle of benefit maximization. Your decision would be based on what provides the best benefit for the most people. If you were a "nonconsequentialist" your duty, obligations or principles would determine what is a "right" or "wrong" decision more than the consequences of the decision. This reasoning recognizes that people are ends in themselves and not means to further our own goals, therefore we must consider their welfare. We must also respect their freedom of choice even when we disagree, allowing them to function responsibly as free moral agents. Finally we recognize that people are of equal value and entitled to equal rights and opportunities. Compare and contrast these reasoning patterns while exploring your case.

4. What do you think are some of your profession's expectations regarding your decision in this case?

Incorporate the viewpoints of the teaching profession to solving this dilemma. Use national, state and local codes of ethics and policy manuals to determine what is required of you regarding this case. Sometimes the codes will be very clear about what is correct action and sometimes they will not be so clear.

5. What is your decision?

Using all of the processes outlined so far make a decision and provide an explanation for it. Here you incorporate some of your background beliefs derived from your family and community. You might also include some other sources of inspiration, like readings and discussions with other professionals.

Developing a case study of a classroom ethical dilemma and then solving it using the ethical brief is a process designed to assist teachers in making ethical decisions. It is not so much a formula as a guide to examining dilemmas from several different perspectives so that one might arrive at a satisfying solution. The goal is to have future teachers develop a level of moral and ethical reasoning, as well as a level of discourse with other professionals that results in what Strike and Soltis (1998) call "reflective equilibrium" … "We see the purpose of ethical deliberation as seeking to achieve agreement on principles that regulate human action while respecting the equal worth and the interests of all" (p. 97).

SAMPLE STUDENT-CREATED CASES – GENERIC

Through the semesters of teaching this course, some categories of ethical dilemmas have emerged from both the student contributions and those of Strike and Soltis (1998). The authors' broad categories include punishment and due process, intellectual freedom, equal treatment of students, and dealing with diversity. From these emerged student-created cases such as:

- The new teacher who finds his discipline so ineffective that he is contemplating punishing the whole class even though he knows not everyone is equally guilty of infractions. What ethical alternative does he have to improve classroom climate immediately? We have selected this scenario to provide an example of an in-depth case study (see Appendix).

- The special education student who seems to be taking advantage of special privileges given to him by his teacher. How far does his special treatment go before it is abusing the system? What ethical decisions must his teacher make?
- The teacher whose next door neighbor is a great coach, but word from her students indicates he is somewhat abusive in class and they seek her help. What would be the ethical thing for her to do in this situation?
- A veteran teacher wants to "help" a new teacher get used to her new classes by telling her as much as she can about the troublemakers ahead of time. How far can she go in telling her tales before she is guilty of biasing the teacher against students who might simply need a fresh start? What is the ethical thing to do?
- An English teacher is faced with assessing a student who has done very well on all four out-of-class written assignments, but when it comes to the four in-class themes, the student's papers are always full of errors. What options does she have in dealing equitably and ethically with this student?
- When it comes to a class participation grade, how does a teacher equitably and ethically assess a student who is painfully shy?
- Two students did not meet the extended deadline for the final project in history class. One is a very popular athlete; the other is a troubled young woman with a messy home life. Both ask for additional extensions of one week. How should they be assessed as compared to those who met the deadline? What is ethical in this case?
- A teacher is confronted with the challenge of providing reasonably authentic assessments that are in line with the way a science class is being taught. In other words, if 50% of class time is spent in inquiry-oriented activities which require hypothesizing collecting and analyzing data, and seeking best explanations for the data, what are ethical choices in testing and other assessments that will allow a teacher to assess 120 students and still get some sleep!

The Appendix contains one complete case study with an accompanying ethical brief from Cori Dacus Martin, a former student in the Ethics Module and now a contributing author. We view her work as exemplary and wanted to share it because we think it shows the power of such discourse. We hope readers will agree that the case study is full of important detail that lends credibility to the story, and that each step in the ethical brief, including the decision, is carefully reasoned.

PROPOSED CASES – SOCIOSCIENTIFIC ISSUES

In this section we propose topics for ethical dilemmas that would be appropriate for science teacher preparation. Specifically, we focus on socioscientific issues that could be developed into case studies and then solutions sought through use of the ethical brief. The same broad categories that are presented by Strike and Soltis (1998) could be used to develop ethical dilemmas along socioscientific lines. For example, in the "dealing with diversity" category, there are issues in science classes such as the evolution-creation controversy in the U.S. Some of the ethical dilemmas that might result can come from student reactions to teacher presentations, parent response to homework assignments, school board policy versus teacher views, district- selected textbook statements that may conflict with teacher beliefs of the best scientific approach and so on. The whole issue of the distinction between science and religion—what each is and is not—and the ethical stance that a teacher takes in dealing with varying views makes this category an important one for the creation of potential case studies of ethical dilemmas.

In the category "equal treatment for all students" (Strike & Soltis, 1998), we are reminded of the science education research of Lee and Fradd (1998) whose notion of "instructional congruence" (p.12, 13) serves as a powerful model to assist teachers who have diverse classes teach in a more equitable and ethical manner. Elsewhere, Lee (1999) makes an important distinction between equality, where all students are treated the same, regardless of their differences, and equity where the teacher tries to provide what is fair and just for each student before assuming equal treatment (p. 89). This is particularly critical for those with second language backgrounds and whose foreign cultures so distinct from the mainstream result in equally distinct needs in learning and teaching strategies. Creating ethical dilemmas involving equitable treatment versus equal treatment of diverse students and solving them through the ethical brief could help new teachers begin to create classroom environments where science touches people's lives more personally.

Providing teachers with opportunities to recognize and solve classroom ethical dilemmas as part of their preparation enables them not only to model ethical behavior, but it also encourages their use of ethical issues problem-solving with their students.

Suppose a community was debating the building of a Planned Parenthood facility on land that once was a family cemetery. Or, as was the case in the 1960s and 1970s, the government wanted to buy up a lot of prime private land in order to build a national seashore on Cape Cod. Other recent socioscientific examples include issues related to stem cell research, funding of very expensive basic science research, the debate over the medical use of marijuana, animal abuse and euthanasia for medical advancement, or human cloning potentials. Each of these and many other socioscientific issues could be studied and case studies could be developed that create clear and compelling ethical dilemmas for the involved citizen. Once again the ethical brief – or a modified student version – could be used to help guide the reasoning and enrich the discourse.

CONCLUSION

It is no longer acceptable to teach science in a moral vacuum. As science education colleague Randy McGinnis recently said in an informal discussion, at the 2001 annual meeting of NARST, there is a big difference between teaching in a value-free environment and teaching in a value-fair environment. The use of ethical case studies and the subsequent solving of dilemmas by going through the steps of the ethical brief force one to examine his or her intuitions and values. But the process also requires considering all conflicted feelings, the consequences of various decisions on all concerned, the moral and ethical principles as well as rules in place, and the profession's stance on the issue before a decision can be made.

We are reminded that ethics is more like the law than like mathematics or science in its degree of precision or aspirations. The purpose of ethics in life or in a profession is not to "achieve a description of the world as it is, but of how it ought to be" (Strike & Soltis, 1998, p. 97). It is probably best to call the result of the ethical brief process a decision, not a solution, since the word solution suggests a correct answer. Instead what ethical reasoning strives for is the best decision possible under the circumstances. Too many of us enter teaching unable to come to best decisions because we have had such little practice recognizing and categorizing problems, let alone trying to solve them.

Our students have given us feedback over the last three years about the value of the Ethics Module. Some found creating their own cases too difficult and wished we had provided them, and others complained about how difficult it was to draw their mentor teachers into the discussion about ethical issues (as we discussed earlier). However, the consensus of our students was that they really learned from the case study approach and the requirement to go through the various steps in the brief, especially thinking both as a consequentialist and a non-consequentialist. Typical were statements like "I haven't taught yet, but this is the real deal. We have to think about these situations… doing the ethical brief is good to help me confront what I might experience." Or, "This really made me examine my own ethics." Another realization by many was that despite their tendency to know immediately where they stand on an issue from their personal values and intuitions, the steps in the brief made clear that "ethical decisions are rarely black or white, but some shade of gray."

REFERENCES

Chang, F. Y. (1994). School teachers' moral reasoning. In J.R. Rest & D. Narvez (Eds.), *Moral development in the professions: Psychology and applied ethics* (p. 71-83). Hillsdale, NJ: Erlbaum.

Cummings, R., Dyas, L., Maddux, C. D., Kochman, A. (2001), Principled moral reasoning and behavior of presesrvice teacher education students. *American Educational Research Journal, 38*(1), 143-158.

Keefer, M.W., & Ashley, K.D. (2001). Case-based Approaches to Professional Ethics: A systematic comparison of students' and ethicists' moral reasoning. *The Journal of Moral Education, 30*(4), 377-398.

Lee, O. (1999). Equity implications based on conceptions of science achievement in major reform documents. *Review of Educational Research, 69*(1), 83-115.

Lee, O.& Fradd, S. H. (1998) . Science for all, including students from non-English language backgrounds. *Educational Researcher, 27*(4), 12-21.

Loving, C. C., Lowy, S., Leunes, J., & Riggins, B. (1998). *Ethics in teaching*. (Texas A&M, Department of Teaching, Learning and Culture Secondary Credential Program - Available from HYPERLINK "mailto:cloving@tamu.edu").

McNeel, S. P. (1994). College teaching and student moral development. In J. R. Rest & D. Narvez (Eds.), *Moral development in the professions: Psychology and applied ethics* (p. 27-49). Hillsdale, NJ: Erlbaum.

Nash, R. J. (1996). *"Real world ethics:" Frameworks for educators and human service professionals*. New York: Teachers College Press.

Rest, J. R. (1979). *Development in judging moral issues*. Minneapolis: University of Minnesota Press.

Rich, J. M. (1984). *Professional ethics in education*. Springfield, IL: Charles C. Thomas.

Strike, K. & Soltis, J. F. (1998) . *The ethics of teaching*. New York: Teachers College Press.

APPENDIX

Mr. Williams' Dilemma – A Case Study

By Cori Dacus Martin

Mr. Williams was a first year teacher at the local junior high - eighth grade math. He decided to get into teaching after working with poor innercity children as a charity service in his summer breaks during college. He grew to love working with the kids and nurtured a deep desire to help them to overcome their sizable obstacles.

His first class would test his resolve. He had 32 in his 5th period class (right after lunch), and 14 of those had lengthy discipline files. He quickly lost control of the class. It was common for students to get up and walk to the trashcan or to another student's desk in the middle of his lesson. Students would blurt out answers or unrelated questions, making it very difficult for the class to maintain the needed level of concentration. Students would begin conversations unrelated to the material, and the noise level would quickly increase as more and more students chimed in. His students were doing very poorly (over 65% were failing), and he found himself offering large extra credit projects to keep his grades from being too low. He didn't feel it was right for so many students to fail because he was unable to manage the class in such a way as to give them the opportunity for success. He found himself feeling very discouraged and incompetent; all his good intentions were for a loss.

He finally went to the school counselor for advice. She told him he should go about restoring order to the class by laying out rules that must be followed and by punishing every violation. She said it would be difficult, but that the students would learn the new standard of behavior and begin conforming to it.

The next day, Mr. Williams told the class of his new rules and informed the class that the consequences (a warning, then a detention, then a trip to the office) would be strictly enforced. However, even as he was telling the class of his new rules, about 5 or 6 students spoke without raising their hands; two other students left their desks, and a third threw a pencil at a friend (which, or course, was followed by a loud, "Mr. Williams, he threw a pencil!"). Mr. Williams could not keep up with who had violated what rules, so he gave the whole class an extra homework assignment. Three students who blurted their displeasure received detentions as well, and one especially persistent student was sent immediately to the office. Eventually, he did get the class quiet, but there was a black cloud over the class - many of the students were extremely angry, and almost all, naturally, claimed they had done nothing wrong.

After class, Mr. Williams began wondering if he had done the right thing.. He knew he had punished students who had not talked out or stood up or misbehaved at all. But what choice did he have? Class was out of control, and the students were suffering; virtually no one could learn in the environment he had allowed to persist. Still, he thought of Michael, a kid who had worked very hard, and despite the temptations, he had never engaged in any of the troublesome behavior that had been wreaking havoc on his class.

Even as these thoughts raced through Mr. Williams's mind, Michael walked into the classroom. He was very upset, almost to the point of tears, and couldn't understand why he was given any punishment. He had done nothing wrong. Mr.

Williams was tempted to tell him he didn't have to do the assignment, but he was worried that if it got out he would have many students and their parents complaining to the principal. He could not keep track of exactly which students had done what; it was chaos. All of his students would claim their innocence, and he would have no basis for punishing anyone. And even if he did remember a few of the guilty, they would all claim, " 'So and so' did it too, and you didn't do anything to them." He knew he had to get order in the class, and he felt sure that if he relented, the students would not trust his claims of punishments and order would become all the more difficult to resume. He felt he had to leave the punishment as it stood for the good of Michael, even if Michael was being improperly punished in the process.

ETHICAL BRIEF

Intuition

In this case I would be inclined to grudgingly allow the unfair punishment to stand in order to help restore the class to a manageable form. I would try to explain this to Michael, but I would not apologize for my actions - if I decided to follow that course of action, I would do it with the confidence and conviction necessary to bring about the needed change. I would continue to consult experienced professional help and would try to keep anything so chaotic and unjust from occurring again.

Conflicts

In this case I would suffer two internal conflicts. The first would be the decision between punishing the whole group and allowing an environment, which does not promote learning to continue. If I believed the situation to be such that there was no alternative, that either I punished the innocent directly by forcing them to do an extraneous assignment, or I punished them indirectly by allowing an "unsafe" environment to continue - then the conflict would indeed be great.

The second would be my temptation to not force Michael to do the assignment. I would want to reward him for his hard work and integrity, but the practical problems and risks that such an action would foster might cause me to stifle my temptation. My primary concern would be the good of the class, but does that give me the right to trample Michael's (or the other students') inherent rights as individuals?

It would seem that the two conflicts are actually only one. In both, the issue is the rights of the individual versus the collective good of the group. Do 8th graders have the same rights as adults? A parent has a right to force a child to take piano lessons, and punish them if they do not comply. Does a teacher similarly have the right to withdraw individual rights of children? What should be the primary concern? Will my action even result in the ends I desire? These are all questions that would enter my thinking.

Consequentialist Considerations

I have to consider whether such harsh action would result in bringing the class to a manageable level. Would the good of the students be served? I might believe that the students would learn that any behavior that disrupts the class will not be tolerated, and they would stop engaging in such behavior. If I believed this, then I would conclude that their scores and success would increase as their attention increased, and this would be a very compelling positive incentive to punishing the students so harshly. However, guilt-free students would be punished and a very negative atmosphere would be created, at least for a time. The atmosphere and anger might be so extreme that students might begin acting up out of anger, rebellion, or disenchantment, and their thinking and concentration might actually be disrupted by the emotional cloud. If I decided the former was the more likely outcome, that would be a compelling reason to allow the punishment to stand. If I concluded the latter was more likely, then I would contact the students and dismiss the punishments.

Nonconsequentialist Considerations

Nonconsequentialist theory suggests that moral maxim must be universal; in this case that would mean that punishing the innocent is wrong, regardless of the belief, or even the knowledge, that such action would restore the class to learning environment. Personhood is the paramount concern for the nonconsequentialist. Michael and the others like him do not deserve to be punished for something they did not do. A deeper problem for the nonconsequentialist is what to do about those that were guilty. Should they be punished even when others who were also guilty go free? Is the moral priority to bring as much justice as possible, or is it fair and equal treatment? For that matter, what is "justice" and "fair and equal treatment?" If the nonconsequentialist valued rule-keeping over fairness, they would punish only those they knew to be guilty. If they valued equal treatment to all, they would punish none, since they could not be sure who all the guilty parties were.

Professional Expectations

Principle IV of the Texas code for educators, "Ethical Conduct Toward Students" (State of Texas, 1997, p. 2), states that "the educator shall not intentionally expose the student to disparagement," and the educator shall "make reasonable effort to protect the student from conditions detrimental to learning, physical health, mental health or safety." This seems to indicate that it is an ethical breach to punish students who are not guilty, and that many forms of punishment are unethical regardless of the guilt of the student. However, it also upholds the educator's responsibility to provide an environment safe for learning. Which guideline takes precedence? By behaving questionably in the former guideline, one might help to uphold the latter. Do the ends justify the means? By not punishing the students and thereby allowing a "learning unsafe" environment to persist, am I failing to make "reasonable" effort to improve the environment? Or is it unreasonable to punish the innocent in order to promote learning?

Decision

I would find another way to fix the problem if at all possible. However, if I believed that the situation absolutely demanded a class punishment, and if I had absolute confidence that such a punishment would help to restore the order necessary to learning, then I would continue with the punishment on the theory that failing to learn is really a much more severe punishment for Michael and those like him than doing one extra assignment. “Rules cannot be seen as a means to an end, but as having direct implications for student learning” (Boostrom, 1991, p. 197). Accordingly, the veteran teachers I interviewed concerning the case study also agreed that learning must be restored to the classroom by adopting and enforcing more stringent rules. Students will be thankful next year or the following year when they realize they understand material because they were well prepared. Their next teachers will not have to start over or re-teach. Therefore, I would side with the consequentialist viewpoint - striving for the long-term good and benefit for the most involved.

REFERENCES

Boostrom, R (1991). The nature and function of classroom rules. *Curriculum Inquiry 21*, 193-216.

State of Texas (1997). *Employee standards of conduct: Code of ethics and standard practices for Texas educators*. Retrieved from http://www.tea.state.tx.us/sboe/schedule/9801/afamv.020.html

Strike, K. & Soltis, J. F. (1998). *The ethics of teaching*. (3rd ed.) New York: Teachers College Press.

CHAPTER 10

THE MORALITY OF INCLUSIVE VERSES EXCLUSIVE SETTINGS

PREPARING SCIENCE TEACHERS TO TEACH STUDENTS WITH DEVELOPMENTAL DISABILITIES

J. RANDY MCGINNIS

INTRODUCTION

At the start of the new millennium public schools in the USA are characterized as serving diverse populations. A significant portion of the student population (approaching 6 million) is identified as disabled and eligible for special services. Disabilities include physical and health impairments such as speech, hearing, motor/orthopedic, and visual difficulties, and conditions eligible for special education services such as learning disabled [LD], mental retardation [MR], autism, traumatic brain injury, and seriously emotionally disabled [EH]. Data reported by the US Department of Education (2001) indicate that the majority of students with documented disabilities are included in general education classes.

It should be noted, however, that the inclusion of students with disabilities (particularly those with developmental disabilities) in the general classroom has not always been a distinguishing characteristic of the United States' public educational system. Instead, based on a prevailing mind-set for the majority of the twentieth century, the exclusion of students with developmental disabilities in particular was the typical practice. The exclusion of students with developmental disabilities in typical US classrooms gained widespread acceptance during the first decade of the twentieth century after a campaign by the influential National Conference on Charities and Correction (NCCC) to eliminate access of the "mentally disabled" to their neighborhood public schools. The NCCC was acting on an exclusion recom-

D.L. Zeidler (ed.),
The Role of Moral Reasoning on Socioscientific Issues and Discourse in Science Education, 195-216.

mendation made by the Committee on Colonies for Segregation of Defectives (Gilhool, 1998).

After a century of advocacy by parents of children with disabilities, special educators, and influential policymakers there exists currently substantial legal support in the USA for the inclusion of students with special needs (including those with developmental disabilities) in their neighborhood schools. Specifically, P. L. 101-476 (1997) [IDEA] and Public Law 101-336 (1990) the Americans with Disabilities Act [ADA] detail the educational rights of students with disabilities. Educationally, IDEA is the most encompassing legislative victory by advocates for students with disabilities who have long fought for appropriate educational opportunities for all students in the United States school system. While there remains considerable debate (Fuchs, Fuchs & Bishop, 1992) as to the definition of "inclusion" (ranging from enrollment of all students in neighborhood schools with all necessary services being provided in the general education classroom to a more limited participation of students with disabilities that might entail separate classes in their neighborhood schools), considerable improvement in including students with disabilities in schools has transpired.

In addition to support from federal law, key science education reform documents support the inclusion initiative (McGinnis, 2000). References in the *National Science Education Standards* (National Research Council, 1996) to teaching students with disabilities unequivocally support all students' presence and participation in inquiry-based science classrooms. A central principle guiding the development of the Standards is "Science for all students" (p. 19). This is defined as a principle of "equity and excellence" (or "fairness") (p. 20) that strongly advocates science in schools for students with disabilities. In addition, all students are assumed to be included in "challenging science learning opportunities" (p. 20). This equity principle is reflected in Teaching Standard B: "Teachers of science guide and facilitate learning" (p. 32). In order to accomplish this, it is imperative that teachers: "Recognize and respond to student diversity and encourage all students to participate fully in science learning." "Students with physical disabilities might require modified equipment; students with learning disabilities might need more time to complete science activities" (p. 37).

The equity principle is also reflected in Program Standard E: "All students in the K-12 science program must have equitable access to opportunities to achieve the Standards" (p. 221). Actions to promote this include "inclusion of those who traditionally have not received encouragement and opportunity to pursue science" by "…adaptations to meet the needs of special students" (p. 221). This equity principle is further reflected in Assessment Standard D: "Assessment practices must be fair.… Assessment tasks must be appropriately modified to accommodate the needs of students with physical disabilities [and] learning disabilities" (p. 85). This is not only an ethical requirement but also a measurement requirement.

Historically, teachers inclined toward inclusion (a minority of all teachers) have identified science classes as especially suited for students with disabilities (Atwood & Oldham, 1985). These teachers identify the perceived relevance of the content, the possibility for practical experiences, and the opportunity for group learning with typical peers as the strengths of science classes for inclusion purposes (Mastropieri, Scruggs, Mantziopoulos, Sturgeon, Goodwin & Chung, 1998). However, this perspective does not mean that most contemporary teachers in science (or otherwise, see Welch, 1989) are sanguine about including students with disabilities in their classrooms. Instead, as reported recently by Norman, Caseau, and Stefanich (1998) both elementary and secondary science teachers identify teaching students with special needs as one of their primary concerns.

THE STUDY

In the context of USA society in which the science education standards support inclusion but many teachers report reluctance to include in their general classrooms students with special needs, I decided there was a need to conduct practitioner-research in an undergraduate teacher preparation program for elementary/middle level teachers. The courses investigated were a university general pedagogy course and an elementary/middle level science methods course. The focus of my study was an investigation of my prospective teachers' beliefs about and intentions for inclusive science education classroom practice, particularly for students with developmental disabilities. I was particularly interested in detecting if my students held moral considerations related to the inclusion initiative in science classrooms. Research on practice in a field setting by practitioners in that field is known as practitioner-research (Anderson & Kerr, 1999). A common focus of practitioner-research is to promote a self-reflective, systemic, and instrumental inquiry that can improve teaching practice and our understanding of practices. Practitioner-research can also take on a social justice or an emancipatory focus if the intent of the research is "to improve on the rationality and justice of their own social or educational practices, as well as their understanding of these practices" (Kemmis & McTaggart, 1988, p. 5).

I intended to use my investigation as a way to gain a deeper understanding of how my students' beliefs about inclusion/exclusion might inform their perception of culture and society and the potential progressive role of the school. With this new found understanding, I intended to craft a report in which I would document how I strive to live out my belief that as a science teacher educator I am not only a theorist but also a practitioner/teacher/parent influenced by moral considerations. This stance would permit me to engage in an autobiographical discourse advocated by curriculum theorists (Pinar, Reynolds, Slattery & Taubman, 1995) that examines interrelations of theory and pedagogy and the struggle for social justice in theory and praxis.

The two undergraduate teacher preparation courses examined in this study contained students majoring in one of two types of majors, general elementary/middle level teacher education majors and special education majors. Both majors were enrolled in the general pedagogy course; the science methods course contained only general education majors. My goal was for all of the future teachers (general and special education) to learn ways to collaborate among school professionals and to effectively teach inquiry-based science to students with disabilities (particularly those with developmental disabilities) in inclusive settings. A major goal was to foster a classroom environment that would enable me to challenge by argument (ethically and morally) the societal stigma of "mental retardation" as a reason for exclusion in the general science classroom. Being a parent of an elementary student with a developmental disability provided the impetus for this stance. Thus, I cannot feign (nor desire) objectivity in implementing this study. To lessen the potential impact of this bias, I did not reveal to my students my personal connection to the disabled community.

THEORETICAL PERSPECTIVES

I conceptualized my study as an investigation of individuals acting within a culture (Aikenhead, 1996). Therefore, I decided to use the culture construct as a mediating or explanatory variable to interpret my students' moral decision-making that resulted in the inclusion/exclusion of students with disabilities in science classrooms. Different theories have been proposed to explain the relationship between the individual and the society (Killen, McGlothin & Lee-Kim, 2001; Turiel, 1998). As an analytical construct, 'culture' has appealed to many theorists interested in understanding within a society an individual's actions and beliefs. However, since 'culture' is recognized as a multifaceted construct, it is necessary to identify the definition of culture one selects to use. I hold a definition of culture that is a diverse phenomenon with different meanings for individuals depending on the context (McGinnis & Simmons, 1999). As a result, I do not find it helpful to subscribe to macro theories of culture, in which culture is defined as a unified set of meaning systems. Instead, I conceptualize culture on the micro level. Culture is a significant source of influence on individuals. Therefore, in order to understand how cultures influence individual social judgments it is necessary to examine how different social categories contribute to an individual's evaluations of social events and interactions.

Secondly, since the premise of my argument is that there is a moral dimension (i.e., that of good/right or bad/wrong) to teachers' decision-making concerning inclusion/exclusion of students from science classrooms, I reviewed the educational literature on moral issues. For the science education research community, Zeidler (1984) and Zeidler and Schafer (1984) outlined how moral reasoning could act as a mediating variable in understanding students' judgments concerning social policy (particularly as impacting environmental issues). Zeidler and associates based much of their thinking on the works of John Dewey, Lawrence Kohlberg, and James Rest. A key assumption they held (to which I gravitate) was that "education is a social means to a social end" (Zeidler & Schafer, 1984, p. 13). As a result of this assumption, they did not limit the purpose of science education to subject matter enhancement. Instead, they expanded the purpose of science education to include consideration of moral reasoning and its critical role in achieving scientific literacy.

Within the more general education literature, my interest in the connections among culture, morals, and teaching (both in teacher education and in the practice of teaching) led me to the works of Coles (1986), Goodlad (1990), Fenstermacher (1990), Strike (1990), Rest (Rest, Narvaez, Bebeau & Thoma, 1999), Bebeau (Bebeau, Rest & Narvaez, 1999), and Killen and her associates (Killen, et. al, 2001).

Having read Coles' work, (1986) I became more sensitive to considering the moral side of teacher preparation, including: a concern with explicating its ideals and values; a yearning to discern a sense of what is right and wrong; and, a need to hear prospective teachers state their ethical and moral positions on teaching. I also found considerable inspiration in Coles' thoughts to persevere in an extended investigation that looked at science teacher education from the relatively unexplored moral perspective.

After reading Goodlad, Fenstermacher, and Strike, I gained a more multifaceted view of how educational theorists conceptualize moral considerations and teaching. I also found they supported study of curricular innovation in teacher preparation that examined moral considerations. Goodlad (1990) stated an essential connection between morals and teaching. He defined the nature of teaching as moral. As such, he asserted that teachers must act ethically. Fenstermacher (1990) both supported and extended Goodlad's premise. He argued that it is the moral nature that gives teaching its purpose. He made the argument that moral qualities (compassion, care, fairness, love, and tolerance) are learned and acquired in the course of social experience. He defined the moral dimension of teaching as directly linked to teacher modeling of moral actions. For Fenstermacher, teaching is a moral activity because "it is a human action undertaken in regard to other human beings. Thus, matters of what is fair, right, just and virtuous are always present" (p. 133). Fenstermacher asserted that teachers must draw attention to what they are doing and why, hold it up for inspection, and by suggestion and demeanor, expect learners to follow along. While examining legal considerations of morality and teaching, Strike (1990) argued for the explicit instruction of ethics in teacher preparation. He identified the moral qualities of tolerance and appreciation of appropriate diversity among learners as two desired critical characteristics of all teachers.

Although I was not drawn to Rest and associates' neo-Kohlbergian approach to investigations in moral thinking (Rest, Narvaez, Bebeau & Thoma, 1999), I gained much from their methodological analysis of research in moral issues. Their warning that total reliance on participant interview data is insufficient when the goal is to gain insight into participants' reasons for moral judgments encouraged me to seek additional data sources (e.g., lesson plans with reflective commentary). Research by Nisbett and Wilson (1977) reported by Rest and associates throws into considerable doubt the direct link between individuals' words and their moral minds. That is not to assert that interview data is not important, especially during hypothesis-generation and in collecting think-aloud commentary on individuals' processing of information, just that it is open to bias in elicitation and in interpretation. As a result, collaborating evidence is desired to accompany interview data when the intent is to draw conclusions on individuals' moral thinking.

From Bebeau and associates (Bebeau, Rest & Narvaez, 1999) I learned that current attention is being directed to research on moral education as a consequence of a resurgence of character education, first proposed in the 1930s. I also found Bebeau and associates' examination of researchable variables in moral education particularly helpful in interpreting theoreticians' selection of differing variables in moral education. Bebeau pointed out that the selection of differing variables by theorists was the result of their stance among a tripartite theoretical view of moral education. The tripartite theoretical view of moral education consisted of a psycho-dynamic psychology view (variables: guilt, shame and self-esteem), Kohlbergean/ Piagetan view (variables: stages of moral development); and a behaviorist view (variables: resistance to temptation, aggression, helping and prosocial behaviors). Bebeau and associates also reported that the tripartite view was contested, suggesting that other theoretical views might be more fruitful.

Finally, I gained a deeper level of understanding of how individuals in a culture engage in the process of determining inclusion/exclusion of persons with disabilities in school settings from my reading of the works by Killen and her associates (Killen, McGlothlin & Lee-Kim, 2001; Killen & Stangor, in press). Killen and her associates credit Minow (1990), who examined inclusion/exclusion in the context of American Law, for their theoretical view. Killen et al. (2001) view the balancing concerns of the individual and concerns of the group a common experience, part of being a member of a culture or social group. Killen and associates believe that individual and social goals vary by context, not as a function of national or social identity. Their model of moral development is domain specific and in contrast to Kohlberg's (1984) theory that characterizes development as a series of global stages or levels across all contexts. Killen and associates posit that decisions about the appropriateness of excluding learners from social groups involve two forms of social reasoning: moral beliefs about the wrongfulness of exclusion, and social-conventional beliefs about group processes and group functioning (dimensions that bear on exclusion). Moral beliefs include concepts about fairness and rights, equal treatment, and equal access (Turiel 1998). Social-conventional beliefs entail several forms of reasoning, including those that concern group functioning (Turiel, 1983 & 1998), group identity (Brown, 1989) and stereotypes about others based on their group membership (Stangor & Ruble, 1989; Stoddart & Turiel, 1985).

Research on children's reasoning about social conventions has shown that their views change with context, particularly so in terms of taking social group roles and expectations into account (Killen, 1991; Theimer, Killen & Stangor, 2001). Young children reason about social conventions in terms of social uniformity and rule systems; older children reason about social group customs in terms of societal standards and social coordination. With age, children become increasingly concerned about the nature of social groups, the norms and expectations that go along with the structure of the group, and effective group functioning. Theoretically, then, decisions about potential exclusion from social groups involve the coordination (competing) of moral judgments about the wrongfulness of exclusion with a range of social-conventional judgments about social group functioning, group identity, and group stereotypes. In their work, Killen and her associates investigate inclusion/exclusion decision-making by context. Contexts vary between a straightforward exclusion context (prototypic, based solely on social conventional reasoning), and a multifaceted context (complex, characterized by an increased cost to social conventioning, i.e., group functioning, and a decrease in the morally-relevant salience of the exclusion decision). Killen and associates reported that in multifaceted/complex situations consideration of social conventions were used to justify exclusion, such as evaluating qualifications of individuals that potentially impact group functioning. Killen (Killen, McGlothen & Lee-Kim, 2001) concluded that one way to promote change regarding exclusion is "to introduce arguments that focus on the fairness and moral dimensions of exclusion, particularly in situations involving stereotypic expectations" (p. 30). Killen and associates warned that research by Stangor and Schaller (1996) indicated that changing stereotypes held by adults is more difficult than changing those held by children.

THE CURRICULAR INNOVATION

During the two semesters that I taught both courses, I strove to engage my students in self-reflection in a public setting. Essentially, I wanted them to become moralists. Moral purpose and moral stances became my preoccupation. I wanted to explore my students' moral considerations in the context of the culture in which they lived and in which they desired to teach. I believed my students were observing me, each other, the teachers in their school placements, and were rendering moral judgments on which students should be taught science and how. My students' teacher education program was silent on formally exploring morality. Therefore, their views on the morality of teaching science to children with disabilities (particularly developmental disabilities) in inclusive settings were shaped and articulated in their teacher education program as a result of their experiences in the courses that I taught.

I resisted looking for moral accolades to advance my personal agenda to promote social justice. I hoped to encourage new moral considerations in my students who came to me resistant to inclusion while simultaneously validating the moral stances of those who already held an inclusive view. I aimed to create an environment that fostered ethical choices. For example, similar to Coles (1986), I thought new moral stances would emerge from my students as a result of considering a "new situation that holds a larger promise" (p. 35) for all learners. In addition, I avoided the use of perceived coercive fiats (such as federal laws and the science education *Standards* recommendations) in my quest to engender acceptance and perhaps even enthusiasm for the inclusion of students with disabilities (particularly those with developmental disabilities) in science classrooms. Instead, I concentrated on ways to focus attention on this socioscientific issue by explication of their beliefs concerning the inclusion/exclusion of students in science and, by argument (morally), to challenge exclusion decisions.

In both courses, I needed to create a teaching context that would permit examination of my students' inclusion/exclusion decision-making. The strategy I selected to achieve this goal was a collaborative model of inquiry-based science lesson plan development and small peer group performance. In the general education course, cooperative groups consisted of four general educators and one special educator. In the science methods course, cooperative groups consisted of only general education majors. The prospective teachers were challenged to include to the extent they felt appropriate a case study student with a developmental disability. Working together, the university special educator and I generated a scenario of a student with a developmental disability. We named her "Nina" (Appendix A contains the case study scenario). Following presentation of the lessons to their peers in class, my students were required in journal format to reflect on their inclusion/exclusion considerations and on their efforts to plan for the inclusion of a student with a developmental disability in an inquiry-based science lesson.

As a way to prepare my students to prepare and deliver inquiry-based science lessons, I modeled the cognitive/constructivist-based instructional model in a series of inquiry science lessons with them as learners that investigated the physical science topics heat and temperature. The lessons were characterized as problem-based, with an emphasis on student reflection, active student participation in data collection and reporting, and consideration of alternative methods of problem-solving and assessment. Throughout these lessons, I discussed how I would plan to include a student such as Nina in the science content lessons. I guided my discussions by use of a student handout that I crafted on research-based recommendations for inclusion of students with disabilities in science classes. Appendix B contains this handout. In particular, I put an emphasis on a combined curricular adaptation and accommodation possibility of "same activity, with adapted expectations and emphasis on embedded skills." I recommended that Nina be placed up front in the class and work in a cooperative group. I also recommended consultation with a special educator to gain pedagogical ideas on her inclusion, and my university special educator co-instructor assisted. She recommended that Nina have a buddy or an aide to assist her as needed to stay attentive and cognitively engaged. She and I both emphasized the need for Nina to develop measuring skills in the investigation and for her to practice communication skills with her peers and in written responses. We recommended that the investigation activity sheet be adapted to her reading level and enlarged for ease in decoding. Finally, we stressed how early sharing of the lesson with Nina's parents (who would be consulted as to additional suggestions) and who could prepare Nina for the activity prior to the lesson, might enhance Nina's later class participation and performance.

In contrast to my actions, the university special educator, with whom I collaboratively taught the general pedagogy course, placed her attention on an overview of the major US laws relating to special education and on formal instruction on five models of inclusion. The inclusion models she taught ranged from full inclusion to separate special education classes in a neighborhood school for students with profound disabilities. She advocated for inclusion as a legal right separate from our students' decision-making. She taught this subject matter in lecture format over a five-session sequence. She modeled direct instruction in her teaching.

In my science methods course, I continued the innovation of requiring the collaborative development and peer teaching of four lesson plans (physical, life, earth, and integrated content, respectively) that included overt adaptations and accommodations for students with disabilities. To facilitate this requirement, I used the same student scenario developed for the general education course ("Nina") and added five more scenarios of students with other disabling conditions (including physical and emotional). I also gave them the handout I crafted on research-based recommendations for inclusion of students with disabilities in science classes. In all lesson-planning activities, I encouraged my students to collaborate with the special educators who worked in the same professional development schools in which they were placed twice a week. To facilitate this collaboration, I required my students to read independently, and then to participate in a class discussion that examined in detail the journal article "Diversity, the science classroom and inclusion: A collaborative model between the science teacher and the special educator" (McGinnis & Nolet, 1996).

My aim in using the peer teaching technique in both courses was to put my students in the role of moral witnesses, to identify the aspect of the lesson that pertained to inclusion and consider it from an ethical perspective (i.e., make statements on right or wrong).

PARTICIPANT REACTIONS

Throughout both courses student self-reflection was cultivated. The preservice teachers were given ongoing opportunities to comment and reflect on the diverse strategies used in enacting the curricular and pedagogical innovation. In-class data sources consisted of participant written reflections, survey, and class discussions. Out-of-class data sources consisted of reflective journal entries and semi-structured interviews (audiotaped and transcribed).

Student reactions to the curricular innovation are presented in two sections: Reflections on planning science lessons for a student with a developmental disability and Reflections on inclusion/exclusion decision-making. I analyzed the data through the use of the qualitative technique of analytic induction to construct patterns of similarities and differences between the participants (Bogdan & Biklen, 1992; LeCompte, Millroy & Preissle, 1992). This procedure included careful reading of all the data to develop a more global perspective. In both sections students' moral considerations were detected as well as additional considerations. For heuristic purposes, categories of reflections are presented as themes (four for section one and two for section two) that are illustrated by exemplar student quotations.

SECTION ONE: PROSPECTIVE TEACHERS' REFLECTIONS ON PLANNING LESSONS FOR A STUDENT WITH A DEVELOPMENTAL DISABILITY

A pattern of response that my students (general and special education majors) expressed in their reflections on planning science lessons for a student with a developmental disability was that it was 'right' or 'fair' for my students to face this issue in their teacher education program. Their moral stance pervaded their reflections of the two courses, and prompted several unanticipated conversations during class sessions on the moral dimension of teaching. For a few general education majors, the stigma of mental retardation emerged. They expressed uncertainty in teaching a student with a developmental disability, specifically Nina (the case student who had Down syndrome), in a content area (science) they personally considered academically challenging. The majority of the majors, however, expressed optimism in attempting adaptations and accommodations for Nina in their science content lesson plans. For most of my junior and senior level general education majors, these class conversations were the first opportunities they had been given to discuss this issue with appeal to moral concerns in their teacher education program.

I found my students' journal reflections illuminating, and oftentimes encouraging in their support of my belief that the inclusion initiative in science for students with disabilities, particularly those with developmental disabilities, was intimately related to moral considerations. In regard to my students majoring in special education, I learned that while they had previous opportunities to discuss both moral and legalistic considerations regarding inclusion they were more ambivalent than were my general education majors as to the benefit of inclusion. They expressed more anxiety as to whether the inclusion educational initiative was a good or right direction for science education to take, particularly for a learner with a significant developmental disability.

A tension that emerged in the general education course between the merits of a cognitive/constructivist pedagogical perspective (favored by me and almost all of the general education majors) and behaviorism (favored by my special education co-teacher and all the special education majors) surprised me. I had not anticipated that there would be so much disagreement about the pedagogy of science instruction in inclusive classrooms based on a philosophical perspective of knowledge and principles of teaching. The opportunities for student reflection and public discourse my co-teacher and I provided in the general education course allowed the difference in perspective between the two different camps of thought to emerge and to be debated. I came to think of the difference in perspectives that we held as a "paradigm war." I decided that the most that could be accomplished in the general education course was a recognition that this major difference existed between the disciplines of science education and special education (at least at my institution). I accepted that this difference in perspectives (if it existed at other institutions) would most probably have a profound impact (as yet not understood) on a collaborative model of teaching practice in inclusive science classrooms. I also came to believe that the differing views the two majors expressed on who benefited from the curricular innovation of a combined general education course (general education and special education majors and professors) was related to that philosophical disagreement.

Theme one: *It is right/fair to make plans to include a student with a developmental disability in a general science class.*

> Exemplar voices:
>
> I never realized until this course that I might have deaf children, or children with serious emotional disorders, or even those with mental retardation such as Nina in the classes I will teach. I didn't even realize that children like Nina could actually be put in my science classroom. I've never even known any people who have Down syndrome and those round faces. I now think *it is right* [emphasis added] that they can be taught in the general education classroom (Erica, general education, general education course, class conversation)
>
> A big concern I have is that until this course, I didn't realize (and I'm a senior!), I didn't realize how much inclusion there is now in the schools-especially in science, a subject that I have found challenging! I don't think we've been told about it enough. I know I wasn't prepared. I think this is a big hindrance, because as teachers we want to reach all of our children, because that *is what is right* [emphasis added]. (Felicia, general education, general pedagogy course, end of semester interview)

Theme two: *It is right/fair to share expertise in planning instruction for students who need support in academic settings, including students with developmental disabilities in science.*

> Exemplar voices:
>
> I thought it was very helpful to be exposed to what the special education majors have learned in their course work and to provide some input in our group lesson planning. And they provided a lot of helpful information to me. And maybe there was an aspect that I had not really thought about in my science activity, but at any rate, they shed some light on it. The special education majors, they just sort of like modified things a little bit that I didn't really know how to do. They also got a taste for just sort of what a general classroom would be like and the science curriculum (Phyllis, general education major)

> I worked with Betty [a special education major], and we were doing our team teaching. She was going to use lecture to deliver science content. The two of us regular education majors with a science concentration gave her some ideas on how to have the students use science equipment to solve problems instead of just memorize some facts. And in turn, she also gave us some ideas for interacting with our case study Nina such as providing her more information. (Susan, general education major)

> Working in cooperative groups, of course, you always learn from each other, but having a special education major in the group you learn a lot more about what they've learned about special education, and they can answer questions you might have on how to apply a method, or how to teach a subject, or what to do with a student with a disability, such as mental retardation. (Carol, general education major)

> Well, I think that it is great to be in an inclusive course (regular ed and special ed majors), because we're so separate right now. It's really neat to get ideas of how they are feeling about going into inclusive classrooms and practicing making accommodations for our case study student (Nina) in the regular science class. I learned a lot about regular educators, so this type of course was really beneficial to me in my special education program. (Stacy, special education major)

> I was the only special educator in my group, and so I heard how the other three regular education majors express how they felt about preparing an inclusive science lesson. It was, like, neat to personally experience that. It was a *good thing* [emphasis added]. And it was also nice to hear them ask me questions, such as "How do I do this?" and "What should I do?" It kind of made me feel important, I guess, in a way. Like, I could help, and we kind of helped each other out a lot. (Justine, special education major)

> The two of us, when we worked together on our lesson plan, I thought it was real important because she kind of got to see where I was coming from, because I really come from a different place than she does when she's thinking of her teaching and how she wants it to go, and how I want it to go. So combining the two (special ed and general ed), I think is *right* [emphasis added]. (Angeli, special education major)

Theme three: *There exists a paradigm battle between the fields of special education (behaviorist perspective expressed in direct instruction) and general education (cognitive/constructivist perspective expressed in small group problem-solving and posing).*

Exemplar voices:

> I think it probably was good for the students majoring in special education to see other ways of teaching outside of Direct Instruction. Because, in an inclusion science or mathematics classroom when they come in and work with a general educator, they're gonna need to know how to help run a constructivist classroom based on inquiry, and not just stand up there and lecture. And that takes practice and some thinking. (Sam, general education major)

> The regular education majors just seem very content oriented. Like, you know, like "I am a science or mathematics teacher" who thinks all students should do experiments and stuff instead of like a person who wants to teach students like Nina. What we students majoring in special education bring to the course and to our collaborative micro-teaching is more of a general understanding of functioning of children with disabilities and how to structure their learning in direct ways, such as by giving clear directions and by telling the information they are expected to learn. (Michelle, special education major)

Theme four: *What benefits are there from collaborative science lesson planning for the special educator and the general educator?*

Exemplar voices:

> I think, and I'm not sure if I'm right on this, but as a regular ed majors, we're gonna be exposed to special ed, but as special educators, they're not as exposed to regular ed. So I think we're more interested in learning about special ed than they are about regular ed. It just seems like they're just starting to learn content, like science, to teach while we know the content and want to know what they know. (Pat, general education major)

> I think the special education majors have a very narrow definition of what they're going to do. I mean, anyone who goes into the Severe and Profound program is a really special individual. But I think in talking with a few of them, I think some of them think they're going to be kind of the resource teacher, a separate entity in the school. That teachers are going to come to them. I think their vision of their role in inclusion is kind of narrow. They need to see how the general education teachers teach science (and mathematics) through problems and how students who are not disabled learn. (Bill, general education major)

> One of the students majoring in special education (concentrating on the Severe and Profound), I mean, she made a joke, like, "My role is gonna be just to change diapers," or something like that. Or "give them a cookie if they're good," or something. And maybe she was joking around, but it seemed to me that she was focusing more on behavioral issues, not science content issues. She really needs this course to learn about inclusion based on the regular curriculum. (Jessica, general education major)

> As a special educator at this university, we're not trained in any one content area at all. That makes working in a content-driven inclusion class hard. However, we take courses on classroom management training that the general ed folks do not (Stacy, special education major)

SECTION TWO: PROSPECTIVE TEACHERS' REFLECTIONS ON THE INCLUSION/EXCLUSION OF STUDENTS WITH DEVELOPMENTAL DISABILITIES IN SCIENCE INCLUSIVE SETTINGS

Throughout the two courses, I was interested in promoting and listening to my students' ethical and moral considerations concerning the inclusion/exclusion of students with developmental disabilities in science. Since I gave them the case study scenario of Nina as someone to plan to include in their science lesson planning and small group presentations, I presented them with a pedagogical situation to which they had to react. Almost all of my students referred to Nina in their science lesson plans, although a few, approximately 5%, did not. When I questioned them as to this omission, the prevalent response was that they expected that any modifications for students with IEPs would need to be done by a special educator, not them. For the overwhelming majority that did refer to Nina in their plans, they were asked to comment on their inclusion attempts in a post-lesson reflection or in an end-of-the-semester interview that was audiotaped and transcribed. By reading carefully all my students' reflections and comments, I was able to detect common themes.

Two major themes explored ethical and moral considerations of inclusion/exclusion. Most of my students expressed a moral belief that it was right or fair to include students with disabilities (including those with developmental disabilities) in the general science classroom. The most prevalent reason my students provided was a commitment to an inclusive and diverse society and culture rather than to a commitment to science literacy for students with developmental disabilities. For those who felt the opposite (a number of whom were majoring in special education), that it was right or fair to exclude students with developmental disabilities from the general science classroom, the reasons varied. A few believed that the science content matter was too challenging for students with developmental disabilities; some believed the students without IEPs would be negatively impacted academically by students with developmental disabilities; a few more believed that a separate class for students with mental and other disabilities more closely matched the special educators' vision of their role; most were concerned that the needs of the students with developmental disabilities would not be met in typical classrooms. Since all of these reasons had been raised in class discussions during the courses, I was not surprised that not all students were supportive of the inclusion of students with developmental disabilities in the general science classroom. Gratifyingly, however, the number of students who ended the semester expressing exclusionary moral reasons were few compared with those who entered the courses expressing similar moral reservations.

Theme five: *It is right/fair for students of all abilities (including students with developmental disabilities) to be included in the general science classroom:*

> Exemplar voices:
>
> I think inclusion *is good* [emphasis added]. For regular ed children it teaches them social responsibility towards each other and helps them realize that everybody is different. And if they're exposed to it then they have to learn how to maturely deal with each other and understand the differences. And, I think socially it's good. They become more aware of differences that people will have in the real world, and they'll be able to deal with each other with a higher level of maturity. And for the students in special education, I think it's *good* [emphasis added] They get exposure to regular education kids and they're not in such a confined world, because when they get older and they're in the real world, it's not gonna be just their parents and their special ed instructors and their special ed friends, and so I think it exposes both in a good way. (Cline, regular education major, post-lesson reflection)
>
> I think there are different advantages of inclusion for different students which makes it the *right thing to do* [emphasis added]. For the students with special needs, they get to feel like they're actually human, which is a big plus, *a good thing* [emphasis added]. They get a chance to make friends, to develop the social aspects of the education which might be missing. I know that if they're sent to special schools, then all they interact with are their teachers and the other students with special needs, and that may stunt their development. I know that kids can be cruel, and sometimes inclusion probably backfires, but I think just having those students with special needs around the other students it makes them aware that the world is made of many different types of people (such as Nina), so I think that's a big advantage for everyone, *the right thing to do* (Pat, general education major, general course, end of semester interview)
>
> I think the whole theory behind inclusion is great, and that kids with disabilities and kids without disabilities get to work together and really learn about each other. And as far as some social aspects it seems *to be good* [emphasis added]. I worked with a student with special needs last year. At first I was really concerned about his educational needs being met. However, the other kids in the class loved him, and every time he would do anything, make one step forward, they would just cheer for him. Even yesterday, I saw a fourth grade kid who has a developmental disability (Down syndrome), and he read his book report in front of the class, and of course, his book report wasn't up to the level of the rest of the class, but he still did what they were doing on a different level, and they all just went crazy and cheered for him.. I think it is just great, you know, that they're getting out and mingling in the world and getting some of that experience. (Stephanie, special education major)

Theme six: *It is right/fair for some students to be excluded in the general science classroom.*

> Exemplar voices:
>
> I guess the constraint I see with inclusion is if the needs of the child are being met in the regular ed classroom as far as educational needs and behavioral needs. It seems like, at least from the experience that I have had, they kind of get left out. And the teacher doesn't really focus attention on them, just lets them do whatever, so they're not being worked with really. It is not a good way to go [emphasis added]. (Michelle, special education major)
>
> First, I'm very grateful to have this class, because this is the only education I will have, or at this point have had, in terms of being exposed to what I may encounter in inclusive classroom. I am a senior now. So for quite some time I was concerned about not having explored an inclusive classroom, and I have to admit that I wonder if it is right [emphasis added] to go this way in education, especially in science and mathematics–two of the harder academic subjects. (Susie, general education major, general education course, end of semester interview)
>
> I remember when we first got into our cooperative learning groups in class, one of the regular education majors said, "I don't want those kids [case study students with special needs] in my classroom." And another time, a student said she wasn't worried about the child with special needs getting her needs met. She was more worried about the children without disabilities getting their needs met when the student with a developmental disability [Nina] was in the classroom. The future teacher was worried about the distractions that student could cause and that kind of stuff. That was enough for me. It just was not right. [emphasis added] I told her, "You should be worried about meeting the needs of her [Nina], too, you know? (Justine, special education major)
>
> The regular ed major said something to the effect of, "I don't...I don't want kids like Nina in my class, they don't belong in regular science classes." And I took a deep breath, and I kind of turned my back for a minute, and then I turned back around and I said to her, "Well, I'm really sorry you feel that way. It is not right [emphasis added] to exclude kids in a blanket type of way" (Jill, special education major)
>
> Those of us majoring in special education see so clearly how little the regular education majors know about special education. When they go out into the classroom, their principal is gonna come to them and say, "Guess what? Nina whoever is going to be coming into your classroom, and she has mental retardation, and here you go." I believe at that point the regular ed teachers are going to freak out because they don't have any information (up to this point in their program) to go on, and I think that's really unfortunate for them and a disaster for the kid with the disability included in the regular classroom. (Nancy, special education)
>
> I think the inclusion initiative it has kind of changed from when I wanted to be a special ed teacher. Because when I wanted to be a special ed teacher, it was a self-contained sort of thing. I would have my own little class, my own little students. But now, with this inclusion movement, I realize that it's not going to be as self-contained as I hoped and certainly not as good for kids with disabilities as it could be. (Angeli, special education major)

PARTICIPANT ACTIONS

Because I was aware of Rest and associates' (1999) advice to obtain collaborating evidence to accompany interview data when the intent is to draw conclusions on individuals' moral thinking, I systematically collected copies of my students' science content lesson plans that they taught in micro-teaching episodes. These copies included their reflections on including Nina, who was described as "mentally retarded" in her IEP, in their science lessons. Science topics presented in the lesson plans included an array of content (physical, life, and earth/space science) recommended by the science *Standards* for grades 1 to 8.

Upon review of my students' lesson plans and the video tapes of their micro-teaching performances (a total of fifty-seven), I found it helpful to categorize in patterns the various ways my students planned to include Nina in their science lessons. I report those categories in a continuum fashion, from most to least common (refer to the Figure 1.) The most common modifications for Nina were use of a buddy system, administrative aide, and alternative assessment. I found it insightful that some of my students made no modification efforts to include Nina. They argued that their inquiry-based science lessons already included techniques that facilitated the inclusion of all students (regardless of ability): the use of small cooperative groups; the use of a problem to gain students' attention; and the use of science equipment. Very few of my students referred to collaboration with a special educator or to Nina's caregivers as sources of modification ideas.

Of special interest to me were the instances of moral considerations that my students expressed when they reflected on the inclusion/exclusion of Nina in their science lesson planning. A theme for those who made efforts to include Nina (the majority of the total) was that it was good or right to include her for two main reasons: 1) the modification process promoted the development of more effective science lessons for everyone; and 2) social justice considerations that were supported by current law. A theme for those who wanted to exclude Nina (a small minority of the total), was that it was not good or right to include her since it was assumed she would negatively impact the majority of the other students' academic performance.

Theme seven: *It is good or right to include Nina in the general science classroom.*

Exemplar voices:

> At first, I really did not like the idea of trying to make my science lesson more tailored for "Nina," even though I know it is likely that I will have to do something like this in my own classroom. In doing it, though, it caused me to think more critically about how my lesson would work in the classroom that would be better for the whole. After doing this, I now feel like because my class could only be better overall with a child, or children, with special needs that it is a good thing to do. (David, general education major, journal reflection)

> After going through the process of planning a lesson for a child with a disability [Nina], I feel that it important for children such as Nina with special needs to be a part of a regular classroom so that they can be a part of what society is filled with, people of all types. It is important that children have the opportunity to be around people different from themselves, so they do not get a closed mentality of who people are. (Sherry, general education major, journal reflection)

Theme eight: *It is not good or right to include Nina from the general science classroom because her presence will hurt the others academically.*

Exemplar voice:

> Planning my science lesson to include Nina was really hard to do. I do feel a conflict. I wonder how a teacher can possibly meet the needs of every student in a science class (particularly if it is inquiry-based and not lecture-based) if these students have such a variety of needs and abilities, such as Nina? How can a teacher take care of them at the same time? I don't think it is right to include students like Nina if it hurts the other students' academically. (Tina, general education major, journal reflection)

Figure 1. A Continuum of Ways Used by Prospective Teachers to Include a Student with a Developmental Disability in an Inquiry-based Science Lesson

Most Common ______________________________ **Least Common**

Use a buddy system.

Use an administrative aide to assist with behavior management.

Use alternative assessment.

Sit student near the front of the class.

Place the student in a cooperative group.

No modifications required due to the nature of the lesson (i.e., problem-based, use of small groups, use of equipment).

Use multiple modes of communication.

Pre-teach vocabulary

Provide the lesson plan for early review to the student's parents

DISCUSSION

Similar to Coles' (1986) conversations with younger learners, I view my curricular innovation as much larger in scope than two courses, one professor, and his students who aspired to be classroom teachers. I view it in an historical, societal scope: What is the nature of our morality in regard to establishing access to science education for students of all backgrounds and abilities, particularly by those with a developmental disability in twenty-first century schools? How inclined are prospective teachers to support inclusion of students with developmental disabilities in science classrooms? A moral challenge science educators face as a discipline operating within a society is to decide on how (and to what extent) to include students with developmental disabilities in the general science classroom. Although US law protects the educational rights (including the least restrictive placement) of students with developmental disabilities, the reality of schooling is that the role of the teacher as someone who does or does not support the inclusion of a student with a developmental disability is critical to take into consideration. Therefore, the identification of moral conflicts associated with the general and the special educators' teacher's decision-making is a critical step to accomplish.

During my extended study, I became aware of the great extent that prospective teachers (both general and special education majors) were caught between the complex and frequently contradictory worlds of their personal beliefs and the expectations of the law, the schools, and the families of children with disabilities. They were buffeted by the oftentimes conflicting educational initiatives to increase all students' science achievement on standards-based tests and to promote inclusion of all students (many of whom face significant academic challenges as measured by standardized tests) and acceptance of student differences. They were caught between learning how to teach large social groups while preparing for individual diversity. Finally, a few were faced with acknowledging a deeply held belief that involved a stigma associated with students with a developmental disability while being taught to value each and every student as a science learner. I see now how some of my students were engaged in a large moral struggle, discriminating between important and less valuable moral signals as they were challenged in their teacher preparation program to plan and implement inquiry-based science lessons.

I began my study with the intention to use my investigation as a way to gain a deeper understanding of how my students' beliefs about inclusion/exclusion might inform their perception of culture and society and the potential progressive role of the school. I learned that for most of my students moral considerations predominated in their professional decision-making concerning the cultural and societal inclusion initiative. Like Killen and her associates' (2001) study with a non-teacher preparation population, I conclude that my general education majors inclusion/ exclusion consideration for a student with a developmental disability in the general science classroom depended on the extent to which social convention considerations (i.e., group functioning) predominated. I believe that the effort I made in my courses to promote discussion and reflection of fairness and other moral dimensions of inclusion/exclusion (prompted by the use of a case study student with a developmental disability crafted to reveal stereotypic expectations in my students) was instrumental in promoting change for some regarding the exclusion decision.

I learned that my general education majors who justified an exclusion decision evaluated the qualifications of a learner with a developmental disability as impacting negatively group functioning. For my students majoring in special education, those few who supported exclusion did so out of a consideration for what they believed was right for the student with the disability, a separate environment in which they could meet their educational needs. For my students who supported inclusion, they justified their decision on a single moral consideration. They believed that all students would benefit socially from the inclusion of a student with developmental disabilities in the general science classroom. Furthermore, they believed that society would ultimately benefit from the inclusion.

Notably missing from my students' justification for the inclusion of Nina in the general science classroom was an expressed moral consideration based on the academic benefits for her in an inclusive science classroom, a focus of the science education *Standards*. An examination of the ways in which my students modified their science lessons supports this finding. In the majority of instances when my students supported the inclusion of Nina into their general science lessons, the pedagogical action they took was to have others (peers or an aide) provide her social support. It was rare for my students to use any of the shared recommended ideas to meet Nina's intellectual needs (operational and science content know-ledge).

As is often a result of practitioner research, I end my study with a new question. How can science teacher education encourage prospective teachers to reflect on their moral stance in regard to both the social *and the intellectual benefits* of inclusion for students with developmental disabilities in the general science classroom? I now believe that a first step is moral awareness of the benefits of intellectual outcomes of science education for students of all abilities. I concur with the moral theorists who state that to prepare a good teacher, one must bring problematic moral matters up to them and provide opportunities for their reaction. This is the moral work of science teacher education. As a field, science educators are in moral jeopardy without a moral perspective in making decisions on the inclusion/exclusion of students with disabilities, particularly those with developmental disabilities, in the science classroom.

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REFERENCES

Aikenhead, G.S. (1996). Science education: Border crossing into the subculture of science. *Studies in Science Education*, *27*, 1-52.

Anderson, G. L., & Kerr, K. (1999). The new paradigm wars: Is there room for rigorous practitioner knowledge in schools and universities? *Educational Researcher*, *28*(5), 12-21.

Atwood, R.K., & Oldham, B.R. (1985). Teachers' perceptions of mainstreaming in an inquiry oriented elementary science program. *Science Education*, *69*, 619-624.

Bebeau, M. J., Rest, J. R., & Narvaez, D. (1999). Beyond the promise: A perspective on research in moral education. *Educational Researcher*, *28*(4), 18-26.

Bogdan, R.C. & Biklen, S.K. (1992). *Qualitative research for education: An introduction to theory and methods*. Boston, MA: Allyn and Bacon.

Brown, B. (1989). The role of peer groups in adolescent's adjustment to secondary school. In T. Berndt & G. Ladd (Eds.), *Peer relationships in child development* (p. 188-215). New York: John Wiley & Sons.

Coles, R. (1986). *The moral life of children*. New York, NY: The Atlantic Monthly Press.

Fenstermacher, G. (1990). Some moral considerations on teaching as a profession. In J. I. Goodlad, R. Soder, & K. A. Sirontik (Eds.), *The moral dimensions of teaching* (p. 130-151).San Francisco, CA: Jossey-Bass Publishers.

Fuchs, L., Fuchs, D., & Bishop, N. (1992). Teacher planning for students with learning disabilities: Differences between general and special educators. *Learning disabilities research and practice*, *7*, 120-128.

Gilhool, T. K. (1998, November). Advocating for our children: Will it ever stop? Down Syndrome News, *22*(9), 115-120.

Goodlad, J. I. (1990). The occupation of teaching in schools. In J. I. Goodlad, R. Soder, & Sirontik, K. A. (Eds.), *The moral dimensions of teaching* (p. 3-34). San Francisco, CA: Jossey-Bass Publishers.

Goodlad, J. I., Soder, R., & Sirontik, K.A. (Eds). (1990). *The moral dimensions of teaching*. San Francisco, CA: Jossey-Bass Publishers.

Killen, M. (1991). Social and moral development in early childhood. In W. M. Kurtines & J. L. Gewirtz (Eds.), *Handbook of moral behavior and development* (Vol. 2, p. 115-138). Hillsdale, NJ: Erlbaum.

Kemmis, S., & McTaggart, R. (Eds.). (1988). *The action research planner*. Gee-long, Victoria, B.C., Canada: Deakin University Press.

Killen, M., & Stangor, C. (in press). Children's social reasoning about inclusion in gender and race group contexts. *Child Development*.

Killen, M., McGlothlin, H., & Lee-Kim, J. (2001). Between individuals and culture: Individuals' evaluations of exclusion from social groups. In H. Keller, Y. Poortinga, & Schoelmerich (Eds), Between biology and culture: Perspectives on ontogenetic development.

Kohlberg, L. (1984). *The psychology of moral development: Essays on moral development* (Vol. 2). San Francisco, California: Harper & Row.

LeCompte, M. D., Millroy, W. L., & Preissle, J. (Eds.), (1992). *The handbook of qualitative research in education*. New York: Academic Press, Inc.

Mastropieri, M., Scruggs, T. E., Mantziopoulos, P., Sturgeon, A., Goodwin, L., Chung, S. (1998). A place where living things affect and depend on each other: Qualitative and quantitative outcomes associated with inclusive science teaching. *Science Education, 82*, 163-179.

McGinnis, J. R. (2000). Teaching science as inquiry for students with disabilities. In J. Minstrell & E. van Zee (Eds*.), Inquiring into inquiry learning and teaching in science* (p. 425-433). Washington, DC: American Association for the Advancement of Science.

McGinnis, J. R. (2001, March). The morality of inclusive verses exclusive settings: Preparing teachers to teach students with developmental disabilities in science. In D. Zeidler (Chair*), The role of moral reasoning on socio-scientific issues and discourse in science education*. Symposium conducted at the meeting of the National Association for Research in Science Teaching, St. Louis, Missouri.

McGinnis, J. R,, & Nolet, V. W. (1995). Diversity, the science classroom and inclusion: A collaborative model between the science teacher and the special educator. *Journal of Science for Persons with Disabilities*, *3*, 31-35.

McGinnis, J. R., & Simmons, P. (1999). Teachers' perspectives of teaching science-technology-society in local cultures: A socio-cultural analysis. *Science Education, 83*, 179-211.

Minow, M. (1990). *Making all the difference: Inclusion, exclusion, and American law*. Ithaca, New York: Cornell University.

National Research Council (1996). *National Science Education Standards*. Washington, DC: National Academy Press.

Norman, K., Caseau, D., & Stefanich, G. (1998). Teaching students with disabilities in inclusive science classrooms: Survey results. *Science Education*, *82*,127-146.

Piaget, J. (1948). *The moral development of the child*. Glencoe, IL: Free Press (originally published, 1932).

Pinar, W., Reynolds, W., Slattery, P., & Taubman, P. (Eds.), (1995). *Understanding curriculum*. New York: Peter Lang.

Rest, J. , Narvaex, D., Bebeau, M.J., & Thoma, S. J. (1999). *Postconventional moral thinking*: *A neo-Kohlbergian approach*. Mahwah, New Jersey: Lawrence Erlbaum Associates, Publishers.

Stangor, C., & Ruble, D. N. (1989). Differential influences of gender schemata and gender constancy on children's information processing behavior. *Social Cognition*, 7, 353-372.

Stangor, C., & Schaller, M. (1996). Stereotypes as individual and collective representations. In C. N. Macrae, C. Stangor, M. Hewstone (Eds.), *Stereotypes and stereotyping* (p. 3-37). New York: Guilford Press.

Strike, K. (1990). Legal and moral responsibilities of teachers. In J. I. Goodlad, R. Soder, & Sirontik, K. A. (Eds.), *The moral dimensions of teaching* (p. 130-151). San Francisco, CA: Jossey-Bass Publishers.

Stoddart, T., & Turiel, E. (1985). Children's concepts of cross-gender activities. *Child Development*, 56, 1241-1252.

Theimer, C. E., Killen, M., & Stangor, C. (2001). Young children's evaluation of exclusion in gender-stereotypic peer contexts. *Developmental Psychology*, *37*(1), 18-27.

Turiel, E. (1983). *The development of social knowledge: Morality and convention*. Cambridge, England: Cambridge University Press.

Turiel, E. (1998). The development of morality. In W. Damon (Ed.), *Handbook of child psychology:Social, emotional and personality development 5th Ed., Vol. 3* (N. Eisenberg, Volume Ed.) (p. 863-932). New York: Wiley.

US Department of Education (2001). *Twenty-second annual report to Congress on the implementation of the Education of the Individuals with Disabilities Act.* Washington, DC: US Government Printing Office.

Welch, M. (1989). A cultural perspective and the second wave of educational reform. *Journal of Learning Disabilities*, *22*, 537-540, 560.

Wright, H. K. (2000). Nailing Jello-O to the Wall: Pinpointing aspects of state-of-the-art curriculum theorizing. *Educational Researcher*, *29*(5), 4-13.

Zeidler, D. (1984). Moral issues and social policy in science education: Closing the literacy gap. *Science Education*, *68*(4), 411-419.

Zeidler, D. & Schafer, L. (1984). Identifying mediating factors of moral reasoning in science education: *Journal of Research in Science Teaching*, *21*(1), 1-15.

APPENDIX A

A CASE STUDY OF A STUDENT (NINA) WITH A DEVELOPMENTAL DISABILITY

Nina is a student who needs support in an academic setting. Nina has Down syndrome and is eligible for additional resources as described by her Individualized Education Plan (IEP). According to USA federal eligibility guidelines, she is classified as having "mental retardation" and is eligible for special education services. Nina has a moderate hearing loss. Her hearing loss has affected her language acquisition since she has had difficulty hearing the language around her. Some classmates find her difficult to understand because of her difficulty with expressive language.

Nina enjoys social settings and is typically friendly to her classmates and school personnel. Nina communicates through vocalizations as well as some simple sign language. This is the first year Nina has ever been in general classroom education setting for science. She is used to being in classrooms populated only by students with disabilities. She is excited about being in the general education classroom.

APPENDIX B

CLASS HANDOUT ON IDEAS TO INCLUDE STUDENTS WITH DISABILITIES IN SCIENCE CLASSES

Key insights from the literature

1. The manner in which a student with a disability participates in a science lesson will vary with the style of the lesson as well as the content area.
2. There is never just one way to involve successfully a student with a disability in a science lesson.
3. A collaborative model of instruction that draws on the expertise of general and special educator classroom teachers offers much promise in meeting the needs of students with disabilities.

General Recommendations for the Classroom Teacher

Make adaptations and accommodations to include students with disabilities according to these four possibilities (ranging from the most preferred to the least) based on the ability of the student:

1. Same activity with adapted materials or expectations.
2. Same activity with focus on embedded skills.
3. With the group, yet working on a different activity for a different purpose.
4. Working in another part of the room on a different activity.

Specific Adaptations to Use (as Needed with a Particular Student)

Classroom Environment. Assign preferential sitting. Alter physical arrangement of the room. Reduce or minimize distractions. Have present a special education teacher or aide in the classroom. Use behavioral contracts.

Presentation of subject material. Pre-teach vocabulary. Use manipulatives. Demonstrate concepts. Tape lectures for playback. Use small group instruction. Use a multi-modal teaching approach that includes auditory, visual, and tactile modes. Use a parallel curriculum. Check often for understanding. Have student repeat directions.

Assignments. Adapt readings and activity sheets to match the reading/ comprehension level of the student. Use written backup for oral directions. Shorten the assignment. Give directions in small, distinct steps. Read the directions to the student. Use a school/home assignment sheet. Use an alternative assignment.

Assessment. Modify format. Shorten test length. Require only selected test items be answered. Allow student to answer orally. Modify grading system as appropriate to match the student's individual educational plan.

RECOMMENDED READINGS

Holahan, C., McFarland J., & Piccollo,B. A. (1994). Elementary school science for students with disabilities. *Remedial and Special Education*, *15*(2), 86-93.

Keller, Jr., E.C., Keefer, R.A., & Keller, E.C. (1994, Spring). A historical overview of literature concerning science and math curricula for students with disabilities. *Journal of Science for Persons with Disabilities*, *2*(1), 16-24.

Mastropieri, M. A., & Scruggs, T. E. (1992). Science for students with disabilities. *Review of Educational Research*, *62*(4), 377-412.

Mastropieri, M., Scruggs, T. E., Mantziopoulos, P., Sturgeon, A., Goodwin, L., Chung, S. (1998). "A place where living things affect and depend on each other": Qualitative and quantitative outcomes associated with inclusive science teaching. *Science Education*, *82*, 163-179.

McGinnis, J. R,, & Nolet, V. W. (1995). Diversity, the science classroom and inclusion: A collaborative model between the science teacher and the special educator. *Journal of Science for Persons with Disabilities*, *3*, 31-35.

Norman, K., & Caseau, D. (1994, March). Integrating students with learning disabilities into regular education science classrooms: Recommended instructional models and adaptations. Paper presented at the Working Conference on Science for Persons with Disabilities, Anaheim, California.

Scruggs, T. E., & Mastropieri, M. A. (1993, January/February). Current approaches to science education: Implications for mainstream instruction of students with disabilities. *Remedial and Special Education*, *14*(1), 15-24.

SECTION V: SCIENCE-TECHNOLOGY-SOCIETY-ENVIRONMENT SOCIAL AND CASE-BASED ISSUES

CHAPTER 11

TEACHING SCIENCE, TECHNOLOGY, SOCIETY AND ENVIRONMENT (STSE) EDUCATION

PRESERVICE TEACHERS' PHILOSOPHICAL AND PEDAGOGICAL LANDSCAPES

ERMINIA PEDRETTI

INTRODUCTION

> If ever we are to be governed by intelligence, not by things and by words, science must have something to say about *what* we do, and not merely *how* we do it most easily and economically. (Dewey, 1938)

Proponents of science, technology, society and environment (STSE) education advocate a literacy grounded in the context of ethical, individual and social responsibility (Aikenhead, 1994; Kumar & Chubin, 2000; Pedretti, 1999; Solomon, 1993). Accordingly, STSE programs and themes have been designed and developed in an effort to interpret science and technology as complex socially embedded enterprises, and to promote the development of a critical, scientifically and technologically literate citizenry capable of understanding STSE issues, empowered to make informed and responsible decisions, and able to act upon those decisions.

STSE is a desirable and clearly defensible goal, however in practice it is often fraught with difficulties and marginalized (Hughes, 2000; Pedretti, 1997). Dilemmas often arise when educators begin to seriously address issues of power, knowledge, decision-making, moral reasoning and responsible action in the science curriculum. This chapter therefore addresses STSE in the context of its theory and practice. I begin by providing a framework for STSE education that identifies social responsibility as its primary goal, and inherently includes critical thinking, decision-making, moral and ethical reasoning, and action. The second part of the chapter

D.L. Zeidler (ed.),
The Role of Moral Reasoning on Socioscientific Issues and Discourse in Science Education, 219-239.

examines philosophical and pedagogical challenges that emerged when a group of preservice teachers, participating in a longitudinal research project, set out to plan and practice STSE education. In particular, the marginalization of STSE education becomes evident in the context of what was espoused by these beginning teachers in contrast to what was practiced. The chapter concludes with implications for teacher educators.

STSE EDUCATION: MOVING TOWARD A RATIONAL RATIONALE OF SCIENCE EDUCATION

Typically, secondary school science is presented as a corpus of knowledge to be mastered, memorized and occasionally applied to the real world. Little is done to convey to students that science is a human/social activity laden with values, beliefs and conventions, situated in a particular time, context and culture (Aikenhead, 1994; Hodson, 1994; Pedretti, 2002; Smith & Scharmann, 1999), and little is done with respect to critiquing the institution and practice of science (Pedretti, McLaughlin, Macdonald & Gitari, 2001). For example, what becomes 'deemed' as scientific knowledge? How? By whom? For whom? How are science and technology used? Whose interests are being served? Unproblematic accounts and portrayals of science, are indeed problematic, and do little to promote principles calling for informed, responsible citizenry.

Conventional teaching strategies also seem to reflect a clean and rather sterile view of science. This in part is probably due to the fact that many teachers emphasize science as a body of knowledge to be transmitted to their students (Aikenhead, 1994; Hodson, 1998). There is little consideration of the 'messiness' of science, the politics of science, or moral and ethical dimensions. How then, can science be portrayed as authentic and contextualized for students? One avenue presents itself through the adoption of an STSE approach.

In general, STSE places science in a larger social, cultural and political context. Solomon's (1993) framework characterizes STSE education as including: 1) an understanding of the environmental threats, including global ones, to the quality of life; 2) the economic and industrial aspects of technology; 3) some understanding of the fallible, tentative nature of science; 4) discussion of personal opinion and values, as well as democratic action; and 5) a multi-cultural dimension. A model developed by the author includes similar guiding principles for STSE education (see Figure 1).

One way of achieving the challenging goals proffered by STSE advocates is through the exploration of socioscientific issues (Pedretti, 1997; Ramsey, 1993; Watts, Alsop, Zylbersztajn & Maria de Silva, 1997). Issues, when utilized as a context for instruction, carry the potential for capturing the dynamic interplay of science, technology, society and environment (Ramsey, 1993). Issues might include; genetically modified foods, cloning, nuclear power, ozone depletion, dietary advice, endemic disease, poverty, transgenic food, genetic engineering, biotechnology, advances in medical science, reproductive technologies, pollution, space exploration and the list goes on. In particular, socioscientific issues used as

Figure 1: Components of STSE Education

Sustainable Development	STSE education involves systematic study and utilization of resources and the consideration of human long term needs in an effort to maintain a life-giving and life-sustaining environment.
Decision-making	This includes a clear understanding of how decisions are made at the local, provincial and national government levels, and within the private and industrial sectors.
Ethics & Moral Reasoning	STSE education attempts to re-couple science and values education. Such a perspective departs from the more traditional presentation of science as a value-free, objective enterprise, and explicitly considers moral and ethical reasoning.
Personal & Political Dimensions	An STSE curriculum includes discussion of politics and science. STSE education not only addresses the traditional question of whether the science is good science but also who benefits and who loses.
Critical Social Reconstruction	STSE education allows people to exercise both intellectual and ethical skills in determining the pros and cons of any scientific or technological development, to examine potential benefits and costs, and to recognize that underlying political and social forces drive the development and distribution of scientific and technological knowledge and artifacts.
Action	Action ideally empowers people, leading to personal and social change, and prepares citizens to function responsibly and effectively. Not only is it sufficient to develop the potential to act, but the disposition to do so. Those who act are those who have a deep personal understanding of the issues and their human implications and feel some sense of ownership and empowerment.
Nature of Science Emphasis	Recognition that scientific knowledge is tentative (subject to change), empirically based (based on and/or derived from observations of the natural world), subjective (theory laden), partly the product of human inference, imagination and creativity, and socially and culturally embedded.

organizers for science education present many advantages; issues present a point of departure for developing and exploring further inquiry, provide a rationale for the search for information, and more accurately reflect the multi-disciplined nature, discourse, and activities of the scientific pursuit. Other strategies might include the use of historical case studies, debates, town meetings, simulations, and role-play.

Finally, it would be a mistake to assume that STSE is a single, coherent, well-articulated approach to science education, nor should it be. If the spirit of STSE education is to explore the relationships among science, technology, society and environment, then we cannot hope to capture this complexity in a neat unencumbered package. Allowances must be made for multiple interpretations, non-prescriptive curriculum and teaching methods, and the opportunity to develop curriculum around local and global issues. Only then, can students be engaged in activities that allow for critical reflection, intellectual independence (Aikenhead,

1994) and personal meaning making (Hodson, 1998). Hence, the rationale, with these preservice teachers, to introduce them to the theory *and* practice of STSE education.

STSE AND SCIENCE EDUCATION REFORM: THE CANADIAN CONTEXT

During the past twenty-five years or so, the science, technology, society and environment STS[E][1] movement has become a part of science education discourse, curriculum documents and policies worldwide (Kumar & Chubin, 2000; Pedretti, 1999; Pedretti & Hodson, 1995; Ramsey, 1993; Solomon & Aikenhead, 1994). This section provides a brief overview of STSE education in the Canadian context, focusing on Ontario. Situating STSE assists in understanding the curriculum demands and ideological bents that teachers' face in their daily practice.

In 1997, the Canadian Council of Ministers of Education distributed a document entitled: *Common Framework of Science Learning Outcomes: Pan-Canadian Protocol for Collaboration on School Curriculum.* This national document was disseminated to all provinces to be used as a guide for provincial curriculum design and development, and states that "the STSE perspective must be a major driving force in science education, to make student learning relevant and meaningful" (p. 258).

In many ways, the Pan Canadian Framework contains the strongest endorsement of STSE education and provides the most hope for significant change. Unlike its predecessors, this document boldly places STSE perspectives along side (in fact before) the traditional knowledge, skills and attitude outcomes. Furthermore, it describes STSE education as including the "nature of science and technology, relationships between science and technology, and social and environmental contexts of science and technology education" (p. iv).

At the provincial level the Ontario Curricula, describes specific expectations in terms of: understanding basic concepts; developing skills of inquiry and communication; and relating science to technology, society and the environment. Treatment of STSE education in the Grades 9 and 10 Science (1999) document is even more explicit:

> The newer aspects of the science curriculum – especially those that focus on science, technology, society, and the environment (STSE) – call for students to deal with the impacts of science on society, and this requirement brings in issues that relate to human values. Science can therefore not be viewed as merely a matter of "facts"; rather, it is a subject in which students learn to weigh the complex combinations of fact and value that developments in science and technology have given rise to in modern society.... Science is approached in all courses not only as an intellectual pursuit but also as an activity-based enterprise operating within a social context (Ministry of Education and Training, p. 5).

Unfortunately, at the provincial level, the STSE emphasis seems to have lost its central position, lagging far behind concept attainment, and developing skills of inquiry, design and communication. As written (and often practiced), a hierarchy

[1] Early references describe the emphasis as STS education, while more recent work often includes science, technology, society *and* environment perspectives – STSE.

exists. Again, it appears that STSE expectations or outcomes, although heralded as fundamental to science education, have taken a peripheral position in the curriculum (due in part to the special set of challenges that STSE presents to educators). However, the language and spirit of STSE education remain, and provide incentive to continue to teach what many believe to be the critically important outcomes of science education; that is, citizenship, decision-making skills, consideration of science and ethics, and issues of sustainability. It is from this premise that the study evolved with a group of preservice secondary science teachers.

THE PRACTICE OF STSE EDUCATION

Teacher Beliefs and Classroom Practice

"A growing body of research indicates that the relationship between teachers' conceptions and their classroom practice is far from being direct or simple" (Abd-El-Khalick et.al., 1998, p. 419). To assume that actions follow directly from beliefs (i.e., beliefs as knowledge, attitudes, personal convictions) is naive. A web of factors exert subtle (and sometimes not so subtle) pressures to create a tapestry of teaching praxis that is rich and varied. A number of variables have a strong influence on the content and context of science teaching: learning environment and physical milieu, student needs, motivation, and internal and external constraints. Materials (i.e., textbooks, lab-books) are often heavily content-laden and prescribed, and communicate implicit messages about the nature of science (Gallagher, 1991, Tobin & McRobbie, 1997). In addition, the text often becomes the source of class work (Gallagher, 1991), laboratory work, homework activities, and assessment and evaluation tools that perpetuate a content approach to science. Gess-Newsome and Lederman (1995) identify six variables that impact on the relationship between teachers' beliefs and classroom practice: teacher intentions, content knowledge, pedagogical knowledge, students' needs, teacher autonomy, and time. These factors are also discussed elsewhere in the literature (i.e., see Brickhouse & Bodner, 1992; Kagan & Tippins, 1991; McRobbie & Tobin, 1995; Meichtry, 1993; Tobin & McRobbie, 1997), and support the assumption that teachers' beliefs do not necessarily translate directly to the enacted curriculum. It is this assumption of incongruity and mismatch between beliefs and practices that help guide this research and provide a lens through which preservice students' ideas and experiences about STSE are explored.

Marginalization of Socioscientific Material

In addition to the myriad of factors that impact on teachers' beliefs and practices, STSE education presents a particular set of challenges. Many teachers fear that extensive coverage of socioscientific issues devalues the curriculum, alienates traditional science students, and jeopardizes their own status as gatekeepers of scientific knowledge (Hughes, 2000; Roth, McGinn & Bowen, 1996). Inclusion of socioscientific content raises questions about teachers revealing political bias (Pedretti, 1997; Rudduck, 1986; Ziman, 1980), and the role and appropriateness of action in the context of science education. Frequently, teachers are specialized, and do not have the background in sociology, politics, ethics, and economics that socioscientific debate warrants, and resources are scarce or patchy. In addition, teachers can face unfamiliarity when dealing with controversial material, where multiple viewpoints require careful consideration, empathy, and moral reasoning (Reiss, 1999). Given these forces, it is not surprising that although STSE has gained considerable recognition it has made far less strides in practice, often leading to its marginalization in the curriculum.

A PRESERVICE SECONDARY SCIENCE CASE STUDY

This naturalistic (Lincoln & Guba, 1988) case study examines twenty-four secondary science preservice teachers' beliefs and practices about the nature and institution of science through STSE education. Phase one of the study was conducted in the context of beginning teachers' experiences in a Bachelor of Education program. Phase two of the project occurred the following year, with 15 of the 24 students (12 female, 3 male) as they began their first year of teaching. These beginning teachers agreed to be interviewed and visited at intervals during their first professional teaching year. Those who did not continue in the study cited the following reasons; they moved out of the city, they were teaching something other than science, or their schedules were too hectic to take on anything 'extra.'

Participants and Program Context

Of the 24 students in the program, 19 were female and 6 were male. The class was ethnically diverse, with representation from Asian, East Indian and Caucasian cultures. Each of the participants had already earned a Bachelor of Science degree, with three of the students having earned M.Sc. degrees in their respective disciplines before entering the program.

The context for this study is a one-year (September to April) Curriculum and Instruction Methods course in secondary science education at a large Canadian university. In this program, students take 2 two-hour blocks of science per week (except during the 3 three-week practice teaching rounds interspersed throughout the year). The methods course is designed to introduce students to the methodology, pedagogy and principles of teaching and learning science. Some of the topics in the course include; constructivism, lab work (and safety in the classroom), use of multimedia technologies in science, lesson design, demonstrations in science, assessment and evaluation, alternative conceptions, cooperative learning, equity and diversity in the classroom, and STSE education.

With respect to STSE education, the author developed a module that includes a few key articles in the field, activities to promote STSE perspectives, and a modest list of resources that students can later draw upon. This module was used during the course to introduce STSE education to students. Beginning teachers (as a class) also visited the Ontario Science Centre, specifically an exhibition entitled *A Question of Truth*. *A Question of Truth*, unlike the usual phenomenon exhibits found in science centres explores the sensitive (and often contentious) themes of: frames of reference, bias in science and society, and science and race (see Pedretti, 2002; Pedretti et al., 2001). The exhibition is designed to examine several questions about the nature of science, how ideas are formed and how cultural and political conditions affect the actions of individual scientists. The notion of bias in science is demonstrated by examining various episodes in the history and practice of science. This exhibit effectively illustrates many of the principles and practices of STSE education, and prompted much discussion in class. My intention in presenting these perspectives and experiences was to challenge preservice students to critique science, and to explore the possibilities of STSE education in their own teaching.

Data Collection and Analysis

Multiple data sources were used in an effort to understand more fully, participants' perspectives, and to corroborate findings. The most intensive data collection occurred during the year that students were enrolled in the program. At the beginning of the term, preservice students participated in a thirty-minute interview aimed at collecting demographic information, understanding their views about teaching science, and exploring their views of the nature of science. They also completed a shortened version of the VOST (Views on Science and Technology) instrument (Ryan & Aikenhead, 1992) and the Nature of Science instrument developed by Nott and Wellington (1993) to further ascertain their incoming views about the nature of science, and the relationship amongst science, technology, society and environment. While on practicum, preservice students were visited, and copious field notes were taken to reflect the activities of their class. At the end of the year, each student was interviewed again, for approximately thirty to forty minutes. However, capturing the theory and practice of STSE education, also necessitates observing STSE embedded within an enacted curriculum over time. Consequently, I chose to enhance findings from questionnaires and surveys with rich contextual data, field notes, and extensive interviews as teachers began their careers.

The following year, the subset of teachers (fifteen) were interviewed in the context of their first year of professional teaching. Interviews were designed to encourage these novice teachers to reflect and comment on their practice, particularly in the context of STSE perspectives. I augmented the third set of interviews by asking participants to complete the Nott and Wellington (1993) Nature of Science survey once again. Inquiry into their understanding of the nature of science and STSE education was also explored and integrated through collaborative inquiry into classroom practice. Graduate students assisted with data collection.

All interview data were transcribed for analysis. The VOST and NOS survey data were analyzed for trends across the entire group, and also provided profiles for individual student teachers. NOS and VOST items clustered around the following larger themes:

- science for social good and reconstruction,
- science as a human endeavour,
- science and its social/cultural context, and
- science as tentative and empirically based.

The following sections reflect these emergent themes across the group, over time, supported by representative preservice teachers' comments. A detailed analysis of findings is beyond the scope of this chapter.

STSE EDUCATION: PHILOSOPHICAL AND PEDAGOGICAL LANDSCAPES

Attempting to chart the philosophical and pedagogical landscapes of STSE education, as experienced by these preservice teachers, has been daunting. Below, by way of summary, I provide a snapshot of findings to convey to the reader a sense of the teacher candidate's philosophical and epistemological positions early in his/her career. In general, students in the program had surprisingly sophisticated and contemporary views of the nature of STSE education, and the nature of science. However, within these rather progressive views, considerable inconsistencies arose echoing what Palmquist and Finley (1997) call a "mixed view." At times, students held a combination of traditional and contemporary views, although there was a marked increase for the majority of students in their understanding of STSE over the two-year period, as would be expected.

Science for social good and social reconstruction

Science was viewed mainly (by 92%) as a way of exploring the unknown, discovering new things about our world and universe, and transmitting that information to others – essentially a 'cultural transmission view.' Only 18% of the students endorsed a view (in response to a VOST item) that science is mainly "finding and using knowledge to make this world a better place to live in (for example, curing diseases, solving pollution and improving agriculture)" – a 'science for social reconstruction view.' However, in response to specific items about science and its *potential* to resolve social problems such as poverty, crime, unemployment, overpopulation, and the threat of nuclear war, 85% of the students viewed science as providing possible solutions to these issues. No one saw science as exclusively the source of these problems, although 35% of the 85% stated that science and technology do contribute to social problems. An important difference cited was that science and technology in and of themselves cannot solve the problems, rather it is a question of people using science and technology wisely. Therefore, informed and responsible decision-making becomes part of the goal of science for social good and progress. As some students commented:

> The issue around responsibility… Is science responsible to and for environmental issues, technological developments and advancements? I think this is the STSE portion. It is about being able to assess in our changing world, scientific developments or technological developments, being able to look at these and say, how is this going to impact on us as a society, and what role does society have in influencing science, and determining what science does? (Judy, interview 2)

> I do think that in all relative science teaching we need to do a great deal more to emphasize the individual moral responsibility of each person in society. In a democracy for one thing, but in any society, everybody is implicated in one way or another into what that society becomes. And I do believe that science and science education divorces itself much too easily from those issues. They're difficult to teach. (David, interview1)

A distinction seems to be made between school science as teaching about the formal institutional discipline of science (a 'cultural transmission view') and the utility and purpose of science (a 'science for social reconstruction view'). Science, in their view, should be about both.

Science as a Human Endeavour

There was overwhelming evidence that preservice students viewed science as a human endeavour, and as such, subject to the vision and vagaries of the human spirit. Human emotions, imagination and intuition play important roles in the creation of scientific knowledge. For example, students felt that scientists try to be honest in the work they do, but may succumb to funding pressures, competition, and ambition:

> Sometimes you get influenced in a certain way. For instance, research is funded by government or by industry and say a manufacturer of a specific drug is funding your research, of course, your research is not going to contradict benefits of using this drug because otherwise your funding is cut right there, and there goes your career. So although you're aiming to find the truth it's not one and the same. (Helena, interview 1)

> I think people would like to believe that science is extremely objective and that human emotions play no part in it but I'm all too aware that this is not the case. (John, interview 1)

Beginning teachers (80%) also commented that generalizations about the character of a 'scientist' (i.e. open-minded, logical, unbiased, objective, subjective) were impossible to make, because scientists are individuals like any other member of society:

> Their [scientists'] bias is there just from their upbringing, from who they are, the way they see things, the way their brain works. (Cindy, interview 1)

What is clear from the data is the preservice students' beliefs that scientists possess a range of qualities, agendas and biases, that play themselves out in what they do, how they conduct their research, how they interpret their data, and what they report.

Social-Cultural Context

The social-cultural context of scientists was identified as playing a significant role in their work. David, a particularly articulate and reflective student commented with the following:

> I think we need to recognize that as much as it [science] claims to be objective, it is a particular culture's creation, a particular culture's construct and a way of viewing the universe. (David, interview 1)

Eighty-five per cent of the preservice students felt that religious or ethical views and beliefs could make a difference in what scientists pursue, observe, and the kinds of problems they choose to work on. Science was not viewed as divorced from moral and ethical considerations. Only 10% endorsed a view that religious or ethical views do not make a difference, suggesting that science and the scientific practice transcends culture and values. The remaining 5% did not answer these items on the surveys. Preservice teacher comments during interviews included:

> I am sure the cultural situation and the country that you're in does influence the type of progress and the work you do in science. (Jan, interview 1)

> I think science is affected by the views of a particular culture, in terms of subjects, experiments conducted and what you should investigate. For example the issue of using fetal tissue from aborted fetuses… it's okay in some cultures and not in others. (Helena, interview 2)

Take for example the Native Indians, they see nature as part of whom they are and they are one with it. Other cultures might say, okay, nature is there and since we're at the top of the chain we can do what we want. (Ram, interview 2)

> Oh yes, science deals with moral and ethical issues. If you think about the sheep Dolly, in terms of cloning… how far do we go? (Samina, interview 1)

Ninety-two per cent of the respondents also agreed with the claim that scientific research is economically and politically determined. Again, this was further supported by their comments during interviews:

> Scientists get their money from companies, you get your money from the government and if they view it as being valid you get funding. So I think there's some political motivation behind there for sure. (Jan, interview 1)

> Governments certainly have agendas of their own. I think a lot of technological advances that we have, have been in particular, politically determined. (Tina, interview 2)

Science as Tentative and Empirically Based

The majority (79%) of students' comments and responses reflected the notion that science is a way of knowing; one way among many possible ways. However, this particular way of knowing is empirically based, functions within the criteria defined by scientific communities, and is essentially characterized by the methods and processes it uses. Most of the participants described scientific knowledge as tentative in nature, negotiated and always changing. Infallibility of science seemed to be a non-issue. In support of the belief that science is a way of knowing, these students disagreed with the premise that scientific knowledge deserves higher status than other kinds of knowledge.

Only 5% of students endorsed or articulated a view that science represents nature as it really is, or that models are true copies of an external, knowable reality. At best, scientific models and explanations are approximations that are helpful in explaining and predicting phenomenon. According to this group of preservice teachers, it cannot be expected that scientists will eventually fully reveal reality nor do scientific theories describe a real external world, which is independent of human perception. As David said: "There are many truths and science is certainly one way to truth and to a kind of truth" (interview 1).

STSE: THE INTENDED AND ENACTED CURRICULUM

This section examines preservice teachers' intentions to teach some STSE education (i.e., the intended curriculum), followed by some of the difficulties and challenges encountered in actual classroom practice (i.e., the enacted curriculum). What is striking about their comments is the tension they experience between what it is they believe they 'ought' to do in the interest of science education and the students they teach, and what they 'actually' did. Why the gap between pre-students' beliefs and what they value as important in science education, and their actual classroom practice? Their comments shed light on the difficulties of being a new teacher, and generate important reminders to teacher educators committed to teaching about STSE perspectives.

The Intended Curriculum

All of the preservice students interviewed spoke with conviction that STSE education was integral to teaching science, and that they intended to adopt these perspectives and appropriate strategies into their own teaching. Justification for STSE education included: making science more meaningful, relevant, interesting, and connecting science to real world experiences. Beginning teachers also referred to notions of literacy, understanding the importance of socioscientific issues, and engendering confidence about science and technology.

> *There are ethical issues, there are environmental issues that have to be looked at, how we're going to look after our environment, how we're going to treat people and things like that. There are a lot of social issues surrounding science. (Ram, interview 2)*

> *For all of us possibly, we need to have some kind of personal connection to what we're learning about or as teachers be able to make some kind of personal connection. And so I think a lot of that can be made through some STSE - by taking science out of the textbook. (Judy, interview 2)*

> *We need to get away from the idea that science is just information. There are too many issues within science that don't always get talked about because you just stick to the content. (Tina, interview 2)*

Such comments reflect an enlightened view of science education as more than a collection of facts, or a body of knowledge to be transmitted by the teacher and subsequently memorized by the students.

Many students related stories about their practicum experiences and the opportunities they had to teach or collaborate with an associate teacher around issues such as genetic engineering, cloning, environmental degradation etc.

> In my practica I was teaching genetics so I brought up the ethical considerations of genetic engineering and all that. But I feel that it wasn't adequately addressed. (Helena, interview 2)

Enthusiasm for STSE continued:

> I was always amazed at things like global education and environment education that actually had a name. I mean they were just part of what constituted an interesting lesson. I think that science without those types of applications is really dull…. A good teacher would incorporate that. STSE is really to enhance your lessons. (Alexandra, interview 2)

Finally, it should be noted that some of the students (about 8%) came away after one year in the program, with the notion that STSE is simply about ‘applications’, echoing the kinds of superficial connections that have been in curriculum for decades (i.e., car batteries, industrial applications):

> We’re balancing an equation and I might just happen to mention, ‘oh this, well this is what you use for nail polish, and this is what’s in your gas tank when you drive.’ Just little things like that. (Jane, interview 1)

A critique of science and the recognition of complex connections among science, technology, society and the environment seemed to be lacking in this group’s accounts of STSE education, in spite of the fact that they acknowledged political, social and cultural contexts of science.

The Enacted Curriculum

What happened the following year? In spite of preservice students’ rather sophisticated views about the nature and practice of science, and strong endorsements of STSE education, very little materialized by way of practice during their first year of teaching. Similar results have been reported elsewhere (Abd-El-Khalick et. al., 1998; Hodson, 1993; Lederman, 1992; Pedretti, 1996; Smith & Scharmann, 1999).

A sampling of teachers’ second year interview comments include: “I don’t have time this year,” “I can barely keep up with everything else,” “I’d love to [do some STSE], but it seems impossible right now, I won’t even get through the science curriculum as it is,” “STSE shows up a little, but not too much in detail – you know we might discuss in class, controversy around cloning,” “if you’re going to incorporate it you have to do it from scratch. There is no book of global or STSE education but maybe eventually it will get that way so there’ll be lots of resources and it will be easier to do.” These sentiments were more or less echoed by most of the first year teachers. One teacher did recount their class trip to the Ontario Science Centre: “I took my class to the exhibit A Question of Truth – it was great, but I’m not sure that I did enough to make those STSE connections.”

In summary, a number of barriers hindered and in some cases, marginalized STSE practice for these teachers. Reasons they cited include issues related to: decision-making, social responsibility and moral reasoning, values education and the role of the teacher, nature of action, nature of science, pupil readiness, content and context, assessment, confidence, resources, and induction into teaching. What follows is a discussion around each of these issues and the implications for science teacher educators.

STSE: MEETING THE CHALLENGE AND MIMINIZING MARGINALIZATION

Decision-Making

Informed decision-making is often highlighted as one of the attributes of STSE education (Aikenhead, 1994; Pedretti, 1997; Ramsey, 1993; Zoller, 1987). However, all acknowledge the complexity of decision-making and the difficulty of providing both theoretical and practical models to guide instruction. This is true not only for the science students we teach, but also for teachers in teacher education programmes. Many times preservice students would say to me, "*yes, decision-making is important in STSE…but how do we do it?*" Ratcliffe (1997) provides a useful set of criteria to guide the decision-making process in the context of socioscientific issues. Although her list is meant to elucidate pupil decision-making, it can at the same time serve preservice candidates who seek useful decision-making models for their growing repertoire and pedagogical knowledge. Ratcliffe's (1997, p. 169) framework includes the following:

1) Options (list or identify the possible alternative courses of action in considering the problem or issue).
2) Criteria (Develop or identify suitable criteria for comparing these alternative courses of action. The nature of these criteria is left open to discussion).
3) Information (Clarify the information known about possible alternatives, with particular reference to the criteria identified and to any scientific knowledge or evidence).
4) Survey (Evaluate the advantages and disadvantages of each alternative against the criteria identified).
5) Choice (Choose an alternative based on the analysis undertaken).
6) Review (Evaluate the decision-making process undertaken, identifying any possible improvements).

Decision-making is an inherently complex process, encumbered by multiple possibilities and agendas. Many viewpoints play themselves out, and frustration in trying to resolve issues can mount. Expertise in decision-making is difficult to script. Experts can be found to support a number of different decisions and perspectives stemming from a single issue. However, this should not preclude educators from attempting to teach decision-making (Aikenhead, 1994, Piel, 1993). Rather, it points to the need to provide students with critical thinking and doing skills that assist them in understanding and reaching informed decisions while participating as citizens in a democratic society.

Social Responsibility and Moral Reasoning

Science and technology cannot be divorced from their social purposes and responsibilities; to do so is to err on the side of presenting science as a value-free, abstract, and objective pursuit. Rather, science should be portrayed as a human activity, acknowledging the strengths of science and technology (usually referred to as 'progress,' 'better standards of living,' 'improved quality of life') but also the limitations. Therefore, encouraging a "critical thinking disposition" (Aikenhead, 1990, p. 127) would allow citizens to exercise both intellectual and ethical skills in investigating the pros and cons of any scientific and technological development, examine potential benefits and costs, and perceive any underlying political and social forces driving the development. Reiss (1999) posits that teaching ethics in science can: heighten the ethical sensitivity of participants, increase the ethical knowledge of students, improve the ethical judgement of students, and most ambitiously, might make students better people in the sense of making them more virtuous or otherwise more likely to implement normatively right choices. With this view in mind, spaces can be created for students to discuss and practice what is right, just, or good, moving toward action guided by principles of social reconstruction and social good.

STSE insists that we speak to notions of social responsibility and moral reasoning. However, very little time is typically devoted to the development of moral and ethical reasoning in the curriculum. And yet, this 'skill' is inherent to STSE education. An understanding of children's moral development is most helpful here, particularly the work of Noddings (1984) and Solomon (1994). Accordingly, children's moral development includes ways of being and acting, such as being 'good,' learning to 'care' for other individuals and things (Noddings, 1984), and reflective understanding of disembodied notions such as 'justice' and 'rights' (Solomon, 1994). Solomon extends these ways of reasoning with the use of "broad, contextual and personal statements" (p. 149) as categories of moral reasoning. These categories provided a framework for making sense of student dialogue in the context of a socioscientific issue, and for thinking about resolution to controversy. Broad statements comment on the problem or issue from a decontextualized position, personal statements reflect strong feelings of empathy and personal connection with people, and contextual statements take account of the situations of the people and events and integrate comments based on people's experience or understanding of similar situations.

In general, science teachers lack confidence in teaching ethics. Discourse about, and practice with, moral reasoning frameworks may potentially equip and empower beginning teachers to assist their own pupils in working through complex issues. In situations in which there are alternative courses of action, a number of frameworks can be considered. For example, a utilitarian approach (the desirable i.e., right action, is the one which leads to the greatest net increase in good), or a deontological approach (certain actions are considered right and others wrong in themselves, i.e., intrinsically, regardless of the consequences) (Reis, 1999). According to Reiss (1999, p. 129): "the safest conclusion, as far as science education is concerned, is that students need to look both at the consequences of any proposed course of action and at relevant intrinsic considerations before reaching any ethical conclusion".

Values Education and the Role of the Teacher

The addition of a values component to a science education program caused some difficulty for many of the novice teachers. We live in an increasingly plural society, and within most countries there is no longer a single shared set of moral values. Moral and ethical perspectives take into account alternative cultural perceptions, customs and values. Therefore, STSE needs to be sensitive to the range of values and ideologies present. Conceptual ideologies about progress, sustainability, democracy and educational purposes continually shift. STSE educators, particularly when dealing with controversial value issues, face the challenge of recognizing relativism, biases and indoctrination, while simultaneously taking account of alternative values. How do we teach about science and values? Is this a mandate in science education? How do we accommodate diverse views, cultural contexts and ways of thinking about the world and our relationship to it? What is the role of the teacher?

Epistemological debate about teachers revealing political ideologies has been addressed in the literature (Hughes, 2000; Ziman, 1980). Rudduck (1986) for example, writes that teachers must aspire to be neutral on controversial issues, although she acknowledges a number of concerns that may emerge in adopting the position of 'neutral chairperson'. By not expressing a personal view on the discussion, teachers might be perceived by pupils as not caring about the issues. Therefore, teachers should explain why they have adopted procedural neutrality. Other teachers may feel that they are failing students and parents if pupils are not given positive advice. On the other hand, a neutral stance helps to ensure that their 'authority' as teachers does not lead students automatically to accept their view as the right one. Many of the preservice teachers worried about the extent to which they might influence their students' decision-making, while a smaller group of preservice students felt quite at ease in articulating their particular value positions. Issues related to values clarification and decision-making formed the basis of further group discussion as we attempted to understand our positions and contextual teaching situations.

The Nature of Action

STSE speaks to developing a science curriculum that politicizes students and promotes empowerment through civic participation, decision-making and action (Hodson, 1998; Pedretti, 1997). If we accept the premise that science is rooted in social reconstruction, then issues of politicization, values and action become inextricably bound together.

> In short, we must transform rhetoric into action. Thus STSE is dynamic; it not only educates students but provides them with the necessary skills to take action on issues of personal and societal importance (Smith et. al., 1993, p. 27).

This is clearly a post-positivist vision of science education – and can engender some tensions for practitioners. Action moves beyond the passive comprehension of scientific and technological principles, and the decision-making processes. However, the degree to which teachers and their students should take action becomes subject to debate and raises some pedagogical issues. Indeed, these beginning teachers wrestled with the extent to which decision-making and action are legitimate activities and principles to foster in the science classroom. The role and the degree of action in STSE education were problematic, and entailed a certain amount of risk-taking. For example, to what extent do we encourage action, and to what extent can STSE education engender meaningful action and politicization? The call for 'responsible' action begs further analysis. Who decides what is deemed as responsible action? What are the criteria for making choices? Philosophically and pragmatically, these are difficult questions, value-laden and replete with ramifications. There are no simple solutions to such complex questions. As educators we need to be sensitive to diverse values and beliefs, while simultaneously encouraging critical reflection and thoughtful action.

Addressing Nature of Science Goals

A significant amount of research literature purports that Nature of Science perspectives can be difficult, arduous, and challenging to implement in the classroom (Abd-El-Khalick et. al., 1998; Eflin, Glennan & Reisch, 1999; Lederman, 1995; Matthews, 1998; McComas, 1998). We are reminded that teachers themselves are the products of an old curriculum, and that often they have developed unexamined and uncritiqued views about science. "If teachers are going to teach children about the nature of science, most will need first to re-examine their own understandings" (Bentley & Fleury, 1998, p. 277). However, STSE can be a conduit for attaining those goals, and therefore offers a promising solution. Bentley and Fleury (1998) for example, describe teaching the nature of science through STSE courses. They provide course outlines, sample course assignments and resources. Again, what is abundantly clear is the need to provide explicit and carefully thought out experiences for preservice teachers to re-examine their beliefs about the nature and practice of science.

Pupil Readiness

Are students, particularly our younger ones, ready to engage in STSE education? This notion of readiness emerged in interviews and discussions with preservice teachers. Indeed, it can be argued that young children might not fully appreciate or be able to engage in activities that require empathy and understanding of multiple view-points, and complicated relationships. However, studies (Cheek, 1993; Pedretti, 1997 & 1999; Solomon, 1993; Torney-Purta, 1983) suggest that children's and adolescents' views of social institutions, democratic life, and social inequalities, although different, are accessible and operational. This speaks clearly to the need to engage our youngest pupils in STSE education: "complex notions of social cohesion and responsibility which will later be drawn out through STS[E] education, must rest upon a solid foundation of the simpler but basic moral and social notions constructed during this early vital phase of education" (Solomon, 1993, p. 20).

Many will argue that young children lack the cognitive competence to engage in decision-making and values education. Such an exaggerated commitment to sequential development (i.e., Piagetian theory) may lead some teachers to abandon probing the young child's grasp of controversial issues (Short, 1988). However, constructing an atmosphere of natural inquiry, critical thinking and decision-making about science and technology and the links to the world they encounter at an early age is important for young children: "This will stand the child in good stead in later life should some health or environmental problem threaten the quality of life, and some scientific knowledge becomes necessary for combating its real or imagined effects" (Solomon, 1993, p.28).

Content and Context

Busy and hectic schedules often discouraged these beginning teachers from designing and implementing STSE perspectives. Activities such as debates, simulations, and role-play take time to plan and implement. Also, given that the curriculum is heavily content-laden, beginning teachers were reluctant to spend the time on STSE education, for fear of not getting through the curriculum. In other words, ‘science’ (as a discipline) would be lost. This is a common criticism leveled against STSE education. However, many have argued that the “science’ in STSE is not in jeopardy. Solomon (1993, p. 37) argues: “There is absolutely no conflict between teaching orthodox conceptual science for understanding, and teaching STS[E].” She suggests that it would be absurd first to teach something we identify as ‘science’ or ‘technology’ in a way that makes no contact with peoples’ lives, and then teach STS[E] incorporating personal or fallible dimensions. Similarly Aikenhead, (1994) posits that traditional science content is not watered down in STSE teaching, but rather embedded in a social-technological context, and therefore students learn the content by constantly linking it with their everyday world.

Assessment Strategies

Many of the preservice students felt inadequately prepared to assess STSE competently. Assessment resources are scarce (Aikenhead, 1994; Cheek, 1993; Reiss 1999) and require much more than standardized testing instruments. If for example, we are to understand a child’s process of coming to understand a socioscientific issue that is steeped in controversy, moral and ethical reasoning, and decision-making, then the ticking of boxes, the grading of examinations and the administration of pre and post tests are inadequate: “They would omit the necessary ethnographic description of the students’ experiences, as well as our own grounded explanation or theory of learning by which to analyze and illuminate the steps of the learning process” (Solomon, 1994, p. 148). A range of assessment practices need to be in place to capture the complexity of STSE education; i.e., use of portfolios, writing, reflection, performance assessment, peer and self assessment, journals, laboratory work, tests, and quizzes. Such assessment strategies need to be tied directly to preservice STSE education in both theoretical and concrete ways.

Confidence, Comfort and Resources

Many reported that they felt uncomfortable teaching about the complexities of STSE education. Discomfort and lack of confidence stemmed mainly from the multi-disciplinary nature of STSE education, and their lack of background in the history and philosophy of science. Understanding for example, the political, cultural, ethical, social and historical perspectives in a given topic required further study and a working knowledge (i.e. both content knowledge and pedagogical content knowledge) of many disciplines. In addition, pressures of time, curriculum demands and lack of resources contributed to their unease.

Induction into Teaching

Teacher induction was one of the most powerful themes to emerge. As beginning teachers, much of their time and energy was consumed in enculturating themselves into the profession, the school, and generally 'learning the ropes.' STSE in the context of science education was viewed as an 'extra.'

In summary, there are many factors that obviate moving beyond the usual way of conducting science classes. Criticisms include too heavy a reliance on textbook orientated activities, exclusive representation of theories, emphasis on memorization and regurgitation rather than inquiry processes, as well as transmissive modes of delivery (Driver & Leach, 1993; Loving, 1997). Excessive curriculum content demands and corresponding lack of time and resources, and uncertainty among some novice teachers about STSE pedagogical content knowledge, contribute to the theory/practice gap. Strategies, such as town meetings, debates, simulations, historical case studies, and issues (central to STSE education) are given very little space in the traditional science class or lab, *and* little time (I would argue) in most teacher education programs. Yet these strategies most clearly and authentically convey to students something about the real practice and nature of science.

IMPLICATIONS FOR TEACHER EDUCATION

> Our society simply cannot afford teachers who fail to understand and assume the moral burden that goes with developing human individuals within the context of a political democracy. Teacher-preparing institutions share the moral burden. (Goodlad, 1990, p. 21)

If STSE education is to become a reality in schools, and if we indeed are striving to widen the moral community, then teacher educators need to assist preservice teachers in significant and meaningful ways. Although the rhetoric of STSE education has gained some force, as evidenced by novice teachers' beliefs and articulations, the practice of STSE education does not necessarily follow from such strong endorsements. Teacher education programs no doubt, play a critical role in helping prospective teachers understand and teach about STSE education (Clough, 1997; Matthews, 1998), moving beyond transmissive orientations to teaching science. However, these beginning teachers' experiences suggest that their teacher education program did not do enough in preparing them to meet the goals of STSE. At a time when STSE education is gaining momentum in Canada, it seems appropriate to revisit instructional and pedagogical practices in preservice science education. Recommendations to enhance preservice science experiences in the context of STSE education include:

1) Reconceptualizing science education programs so that STSE becomes infused across an entire program. A module dedicated to STSE education is inadequate. Integrating STSE would also parallel the philosophy that STSE education should permeate science teaching as opposed to being considered an 'add on' or an 'extra.'
2) Helping students develop a strong, theoretical underpinning and justification for adopting an STSE orientation.
3) Providing students with concrete teaching ideas, resources, and a repertoire of strategies to bring STSE to life in the classroom.
4) Engaging students in discussion and practice of ethics and moral reasoning through the use of case studies, socioscientific issues, and appropriate frameworks.
5) Familiarizing students with decision-making frameworks and providing practice.

6) Providing students with concrete teaching practice, i.e., the opportunity to design, implement and assess STSE practices in collaboration with associate teachers during their practicum placements. This should be augmented with debriefing sessions and sharing with peers back at the faculty.

7) Creating opportunities for students to discuss and practice principles of sustainability.

8) Establishing on-going support (i.e., into the first years of teaching) and creating STSE networks, so that beginning teachers are provided with mentoring and a sense of community.

In conclusion, most pervasive in this study, are the external and institutional restraints, and 'cultural myths' (i.e., there is no time, STSE is only an extra) that impede alternative approaches to teaching and learning science. Unless these restraints are alleviated, conventional science teaching with its heavily transmissive orientation will continue to be the norm. STSE education will continue to be marginalized, particularly when it is presented as a subordinate form of knowledge. It is not enough to teach about STSE implicitly, with the hope that principles of decision-making, action, and moral reasoning, will come to fruition in subsequent classroom praxis. Beginning teachers need to feel empowered, pedagogically equipped and enabled to explore alternative post positivist visions of science education. For ultimately, it is teachers and their students who bring the 'what' and 'how' of STSE curriculum and instruction to life.

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REFERENCES

Abd-El-Khalick, F., Bell, R. L. & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education*, *82*(4), 417-436.

Aikenhead, G. S. (1990). Scientific/technological literacy: Critical reasoning, classroom practice. In L. Phillips and S. Norris (Eds.), *Foundations of literacy policy in Canada* (p. 127-145). Calgary, Alberta: Detselig.

Aikenhead, G. S. (1994). What is STS science teaching? In J. Solomon and G. Aikenhead (Eds.), *STS education: International perspectives in reform*. (p. 47-59). New York: Teachers College Press.

Bentley, M., & Fleury, S. (1998). Of starting points and destinations: Teacher education and the nature of science. In W. McComas (Ed.), *The nature of science in science education: Rationales and strategies* (p. 277-291). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Brickhouse , N. W. & Bodner, G. M. (1992). The beginning science teacher: Classroom narratives of convictions and constraints. *Journal of Research in Science Teaching, 29*, 471-485.

Cheek, D. (1993). A constructivist view of learning: Children's conceptions of the social sciences and social institutions. In R. Yager (Ed.), *What research says to the science teacher: Vol. vii, The science, technology, society movement*. (p. 97-102*)*. Washington, DC: National Science Teachers' Association.

Clough, M. (1997). Strategies and activities for initiating and maintaining pressure on students' naïve views concerning the nature of science. *Interchange*, *28*(2&3), 1191-204.

Councils of Minister of Education, Canada. (1997). *Common framework of science learning outcomes: Pan-Canadian protocol for collaboration on school curriculum.* Toronto: Author.

Dewey, J. (1938). *Democracy and education*. Toronto: Maxwell MacMillan Inc.

Driver, R. & Leach, J. (1993). A constructivist view of learning: Children's conceptions and the nature of science. In R. Yager (Ed.), *What research says to the science teacher: Vol. VII, The science, technology, society movement* (p. 103-112). Washington, DC: National Science Teachers' Association..

Eflin, J., Glennan, S. & Reisch, G. (1999). The nature of science: A perspective from the philosophy of science. *Journal of Research in Science Teaching*, *36*(1), 107-116.

Gallagher, J. (1991). Prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science. *Science Education, 75*(1), 121-133.

Gess-Newsome, J., & Lederman, N. (1995). Biology teachers' perceptions of subject matter structure and its relationship to classroom practice. *Journal of Research in Science Teaching, 32*, 301-325.

Goodlad, J. (1990). The occupation of teaching in schools. In J. Goodlad, R. Soder, & K. Sirotnik (Eds.), *The moral dimensions of teaching* (p. 3-35). San Franciso: Jossey-Bass Publishers.

Hodson, D. (1993). Philosophic stance of secondary school science teachers, curriculum experiences, and children's understanding of science: Some preliminary findings. *Interchange, 24*, 41-52.

Hodson, D. (1994). Seeking direction for change: The personalisation and politicization of science education. *Curriculum Studies*, *2*, 71-98.

Hodson, D. (1998). *Teaching and learning science: Towards a personalized approach.* Philadelphia: Open University Press.

Hughes, G. (2000). Marginalization of socioscientific material in science-technology-society science curricula: Some implications for gender inclusivity and curriculum reform. *Journal of Research in Science Teaching, 37*(5), 426-440.

Kagan, D. & Tippins, D. (1991). How teachers' classroom cases express their pedagogical beliefs. *Journal of Teacher Education, 281-291.*

Kumar, D., and Chubin, D. (2000). Science, technology, and society: A sourcebook on research and practice. London: Kluwer Academic Publishers.

Lederman, N. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching*, *29*(4), 331-359.

Lederman, N. (1995). Suchting on the nature of scientific thought: Are we anchoring curricula in quicksand? *Science & Education*, *4*, 371-377.

Lincoln, Y. S. & Guba, E. (1988). *Naturalistic inquiry*. Beverly Hills, CA: Sage.

Loving, C. (1997). From the summit of truth to its slippery slopes: Science education's journey through positivist-post-modern territory. *American Educational Research Journal, 34*(3), 421-452.

Matthews, M. (1998). In defense of modest goals when teaching about the nature of science. *Journal of Research in Science Teaching*, *35*(2), 161-174.

McComas, W. F. (1998). *The nature of science in science education: Rationales and strategies.* Dordrecht, The Netherlands: Kluwer Academic Publishers.

McRobbie, C. J., & Tobin, K., (1995). Restraints to reform: The congruence of teacher and student actions in a chemistry classroom. *Journal of Research in Science Teaching, 30*, 429-443.

Meichtry, Y. J. (1993). The impact of science curricula on student views about the nature of science. *Journal of Research in Science Teaching, 30*, 429-443.

Ministry of Education and Training, (1999). The Ontario Curriculum, Grades 9 and 10, Science. Toronto: Queen's Printer for Ontario.

Noddings, N. (1984). *Caring.* Berkeley, CA: University of California Press.

Nott , M. & Wellington, J. (1993). Your nature of science profile: An activity for science teachers. *School Science Review, 75*, 109-112.

Palmquist, B. & Finley, F. (1997). Preservice teachers' views of the nature of science during a postbaccalaureate science teaching program. *Journal of Research in Science Teaching, 34*(6), 595-616.

Pedretti, E. (1997). Septic tank crisis: A case study of science, technology and society education in an elementary school *International Journal of Science Education, 19*(10), 1211-1230.

Pedretti, E. (1999). Decision-making and STS education: Exploring scientific knowledge and social responsibility in schools and science centres through an issues-based approach. *School Science and Mathematics*, *99*(4), 174-181.

Pedretti, E. (2002). T. Kuhn meets T. Rex: Critical conversations and new directions in science centres and science museums. *Studies in Science Education, 36*, 1-42.

Pedretti, E., & Hodson, D. (1995). From rhetoric to action: Implementing STS education through action research. *Journal of Research in Science teaching, 32*(5) 463-486.

Pedretti, E., McLaughlin, H. Macdonald, R. & Gitari, W. (2001). Visitor perspectives on the nature and practice of science: Challenging beliefs through a question of truth. *Canadian Journal of Science, Mathematics and Technology Education, 1*(4), 399-418.

Piel, E.J. (1993). Decision-making: A goal of STS. In R. Yager (Ed.), *What research says to the science teacher: Vol. vii, The science, technology, society movement* (p. 147-152). Washington, DC: National Science Teachers' Association..

Ramsey, J. (1993). The science education reform movement: Implications for social responsibility. *Science Education*, *77*(2), 235-258.

Ratcliffe, M. (1997). Pupil decision-making about socioscientific issues within the science curriculum. *International Journal of Science Education, 19*(2), 167-182.

Reiss, M.J., (1999). Teaching ethics in science. *Studies in Science Education, 34*, 115-139.

Roth, W.M., McGinn, M., & Bowen, G. (1996). Applications of science and technology studies: Effecting change in science education. *Science, Technology, & Human Values, 21*, 454-484.

Rudduck, J. (1986). A strategy for handling controversial issues in the secondary school. In J. J. Wellington (Ed.), *Controversial issues in the curriculum* (p. 6-18). Oxford: Blackwell.

Ryan, A.G. & Aikenhead, G.S. (1992). Students' preconceptions about the epistemology of science. *Science Education, 76*(6), 559-580.

Short, G. (1988). Children's grasp of controversial issues. In B. Carrington & B. Troyna (Eds.), *Children and controversial issues* (p. 11-28). New York: The Falmer Press.

Smith, B., Pedretti, E., Boulding, A., & MacGregor, S. (1993). Rhetoric to reality: Development of a model for STS education through action research. *Crucible, 24*(4), 25-28.

Smith, M. & Scharmann, L. (1999). Defining versus describing the nature of science: A pragmatic analysis for classroom teachers and science educators. *Science Education*, *83*(4), 493-509.

Solomon, J. (1993). *Teaching science, technology and society*. Philadelphia, PA: Open University Press.

Solomon, J. (1994). Learning STS and judgments in the classroom: Do boys and girls differ? *STS education: International perspectives in reform* (p. 141-154). New York: Teachers' College Press.

Solomon, J. & Aikenhead, G. (1994). *STS education: International perspectives in reform.* New York: Teachers' College Press.

Tobin, K., & McRobbie, C. J. (1997). Beliefs about the nature of science and the enacted science curriculum. *Science & Education*, *6*, 355-371.

Torney-Purta, J. (1983). The development of views about the role of social institutions in redressing inequality and promoting human rights. In R. L. Leahy (Ed.), *The child's construction of social inequality* (p.289-310). New York: Academic Press.

Watts, M., Alsop, S., Zylbersztajn, A., & Maria de Silva, S. (1997). Event-Centred-Learning: An approach to teaching science technology and societal issues in two countries. *International Journal of Science Education*, *19*(3) 341-351.

Ziman, J. (1980). *Teaching and learning about science and society*. Cambridge: Cambridge University Press.

Zoller, R. (1987). Problem-solving and decision-making in science-technology-environment-society (STES) education. In K. Riqarts (Ed.), *Science and technology education and the quality of life*, vol. 2 (p. 562-569). Kiel: IPN.

CHAPTER 12

MORAL REASONING AND CASE-BASED APPROACHES TO ETHICAL INSTRUCTION IN SCIENCE

MATTHEW KEEFER

INTRODUCTION

In this chapter, I would like to explore and expand upon a conception of moral reasoning with moral cases that follows a classical conception of moral thinking (outlined briefly in the introduction).

The classical account is founded on a unified conception of practical reason or practical rationality. Accordingly, a rational action is action undertaken for a reason, and reasons carry normative force when they support or explain actions as good or valuable in some aspect or to some degree. It follows then, that moral responses, or for that matter any sort of practical resolution of a values' conflict, is deemed rational to the extent that it is responsive to reason. On the surface, this view may not seem so much different from commonsense notions, yet I will argue that it differs fundamentally from all of our most influential and recent philosophical and psychological conceptions. Moreover, this view holds important pedagogical implications for the development and implementation of case-based approaches to ethical instruction in science and science education. This chapter will present four sections which will: 1) Contrast modern and classical approaches to moral reasoning and moral cases; 2) Present a unified conception of reasoning with moral cases; 3) Provide empirical support for the classical conception; and 4) Consider implications for case-based approaches to science and science education.

D.L. Zeidler (ed.),
The Role of Moral Reasoning on Socioscientific Issues and Discourse in Science Education, 241-259.

SECTION I: MORAL REASONING AND MORAL CASES – CONTRASTING MODERN AND CLASSICAL APPROACHES

The lynchpin of classical view of moral reasoning with moral cases is its connection to rationality. Reason is rational from the ground up – since all our choices and actions are based on reasons, what is most reasonable for us to do is also, characteristically, what we should or are most obliged to do.[1]

> What we want to do, be, or have, we want for reasons. The questions 'What should we want most?' and 'What do we want most?' are normally one and the same question. When we reason about what we want most, we reason about what we have most reason to want. Since the value or the goodness of things and options constitutes the reason for having them or for doing them, their value or goodness is also the reason for wanting to have them or to do them. Normally when we deliberate about what we want most, we deliberate about what it would be best for us to want because it would be best for us to have or to do. (Raz, 1998; pp 52-53)

The action guiding quality of moral judgment (a focus of the practical view) is a function of action being responsive to reason in this way (Foote, 2001).[2] Such a view, as it works out practically, has considerable implications for how we understand moral reasoning with cases. What the classical conception of practical reason opens up is a closer connection between *the agent's* reasons, choices, and our actions. What we do, we do for reasons, what makes an action or course of action intelligible, is also what justifies it or provides the basis for its evaluation. That means, what is good or best for us to do, is also what we are most justified in doing.

As stated in the introduction, this classical conception of practical reason is markedly different from the Kohlbergian view that has dominated the field. There we described how Kohlberg's understanding of the moral domain provides for a highly abstract and justificatory conception of practical reason, a conception that produces a narrow view of the moral domain. It can also be argued that this view moral reasoning has had a limiting effect on our understanding of moral cases. Not only does Kohlberg rely greatly on rules and principles to define the moral domain, but Kohlberg's use of dilemmas in the measurement of moral judgment requires subjects to focus almost exclusively on the justification of moral actions, usually at the expense of more practical prospective considerations. In other words, this justificatory bent toward principle and rule overshadows the nuances and complexities of context-dependent practical activity.

From the perspective of practical rationality, one of Gilligan's great contributions was to bring to attention the importance of appreciating a prospective, practical response in resolving moral cases (Gilligan, 1982; Gilligan & Wiggans, 1987). First-rate responses to moral conflicts could now include resolutions that focused on the 'messier' problems of practical deliberation, i.e., what is the best course of action available to the agent in the particular context of action. Thanks to her analyses and possibly even more to her feminist critique, such responses to

[1] In the classic view, that we have a want or desire for a particular action or activity, is in no way a reason for performing it. Only that which can be conceived as in some sense or in some way valuable can be desired (Raz, 1998, Foote, 2001, and Wiland, 2001).

[2] Since value and not desire is the only basis for determining what it is rational (or moral) to do, it is not true that whenever we rationally choose to do X rather than Y we do so because we are motivated by a desire to do it (Raz, 1998; p. 54).

moral cases could came to be appreciated as legitimate *moral* responses to hard cases.

While Gilligan's contribution constitutes a clear advance, especially in terms of widening our conception of the moral domain, there are, I believe, certain costs that attach to the manner in which she accomplished that advance. The cost stems, ironically I will argue, from Gilligan's acceptance of the justificatory conception of moral rules. For both Gilligan and Kohlberg the application of a rule or principle indicates a deontic orientation of justice. This acceptance provides the basis for the "justice" and "care" approach to the psychology of moral reasoning and, I will argue, posits an unrealistic bifurcation of the moral domain. Such a division not only conflicts with our commonsense understanding and applications of moral thinking, but it also runs counter to the classical conception of the unity of practical reason. Concerning the treatment of moral cases, it has led to the somewhat implausible view that when presented with moral conflicts, subjects *generally* are likely to adopt either a "justice" or a "care" orientation in their strategies of problem resolution. According to Gilligan, women are more likely to adopt the care orientation, and men the justice orientation.

Interestingly, Kohlberg also accepted the bifurcation, but believed it occurs as the product of the sphere or domain in which a moral conflict transpires, rather than the "moral orientation" of the individual confronting the conflict. That is, Kohlberg endorses the bifurcation when he came to describe his stage theory as accounting only for structures of "justice" reasoning, and then acknowledged that there may be other more "private" spheres of value, where other forms of reasoning may be more appropriate. While care reasoning may be adequate when facing problems of a private or personal nature, when confronted with conflicts of justice in the public sphere, the only appropriate response is to apply the structures of deontological justice reasoning. According to Kohlberg, two senses of the meaning of the word moral are captured by the distinctions that many Americans make between the sphere of personal moral dilemmas and choices and the sphere of moral choice that is not considered personal, that is, the sphere captured by our justice dilemmas. The spheres of kinship, love, friendship, and gender, all eliciting considerations of care, are usually understood to be the spheres of personal decision-making, as are, for instance, the problems of marriage and divorce (Kohlberg, 1984). `Kohlberg, of course, did not follow Gilligan in accepting a gender-based conception of moral thinking.

In section II of this chapter, I will attempt to first outline an alternate conception of reasoning with moral cases that avoids bifurcation, yet can still make sense of both Kohlberg's and Gilligan's arguments and claims. In section III, I will describe some empirical support for this alternate framework. The next two sections will be more practically oriented. Section IV will outline an alternative conception of case-based reasoning in the moral domain, and in the final section, I will discuss some of the practical and educational implications for teaching and for science education.

SECTION II TOWARD A UNIFIED CONCEPTION OF REASONING WITH MORAL CASES:

In the introduction, we described the classical conception of rules as they function in their role of resolving moral conflicts. Rules, according to Raz, are "metaphorically speaking, expressions of compromises, of judgments about the outcome of conflicts" (Raz, 1990, p. 187). Rules constitute compromises or generalizations of previous practical resolutions of conflicts. They preempt the need for protracted deliberation in each particular case (Nussbaum 1989; Raz 1990, 1986). Rules, as exclusionary reasons, not only provide a reason for performing an action the rule recommends, but also constitutes a means of resolving practical conflicts by excluding conflicting reasons (Raz, 1990). In the introduction, we noted how a this practical conception of rules operates in, for example, guidelines for research on human subjects, experimentation with animals, and in professional codes such as in science and medicine.

Tough moral cases often involve conflicts between competing or conflicting rules. They are generally of the character that the action, goal, or value supported by a conflicting rule will be completely frustrated if the course of action supported by the norm or rule is chosen. However, in actual practical conflicts this is often not the case. Raz (1990) refers to situations in which the conflicting reasons are *not* completely frustrated as *partial conflicts.* The significance of partial conflicts is that they temper the importance of *moral justification* in situations of moral conflict. These are cases, according to Raz, "in which judgments that one reason overrides another rests on an assessment of possible alternatives in partial conflicts" (Raz, 1990, p. 188). Moral dilemmas, of course, often deny just this possibility. Yet, it may be the case that, when confronted with what they perceive as an irresolvable moral conflict, some subjects might wish to re-construe the dilemma as a partial conflict and search for alternative courses of action, rather than appeal to a rule or a norm as decisive.

According to this conceptualization, *all* moral reasoning will or should include *all* the relevant set of norms or rules that apply to each particular case, but the conditions for applying the norm or rule (the *ceteris paribus* conditions) may or may not be met. If they are, one could expect norm, or rule-based judgments; if they are not, one could expect attempted reconciliation, or an effort to comply with both norms.

We may now appreciate how the classical account of the use of rules in a moral conflict has implications for Gilligan's proposal to link contextual or narrative reasoning to a substantive ethical orientation (i.e., the ethic of care). Rules, which rule out other considerations, also have *ceteris paribus* conditions, which may or may not be met. In the world of practical action one could argue that they are never all met. If they are not, even exclusionary reasons may fail a challenge and fail to overrule these considerations (including in some cases, a lower order rule).[3] For example, these exclusions might include relevant facts and social knowledge that render an act supported by the ought conclusion ineffectual or frustrated (see Raz,

[3]For example, that you may steal in order to save a life is an exception (for some) to the rule to always uphold the law.

1990, p 187). A case in point, taken from Kohlberg's Heinz dilemma, is that although “life is to be valued over property” is treated as an exclusionary reason, the *ceteris paribus* conditions may not be met, that is, all things may not be considered equal in the particular case. For example, some subjects argue that if stealing the drug would only secure a single dose of the drug, or if Heinz were to get caught and imprisoned, then the exclusionary rule may not justify the conduct and other avenues ought to be sought (i.e., hence a more protracted or deliberative strategy is adopted).

Hence, we are now in a position to appreciate how the classical view can provide an alternate explanation for why persons might choose to provide a more protracted deliberative response to moral cases, yet one that does not assume the existence of an independent moral orientation. The explanation may be described as a *deliberative* and a *justificatory* approach to the resolution of moral cases. The deliberative approach is concerned with prospective problems of practical action. It uses knowledge and processes relevant to *choosing one particular course of action over another,* employing narrative descriptions and interactive plans (e.g., to pressure a druggist to lower his price by public appeal or boycott). According to the proposal offered above, it is undertaken when the application of a norm or rule is seen as having the side effect of undermining the effective pursuit of other important goals or values, or as it was put it above, violate the *ceteris paribus* conditions of the rule or norm. The justificatory approach focuses on the retrospective evaluation of moral actions by assimilating the action(s) to a general moral norm or rule (e.g., to steal a drug because the right to life is more important than the right to property). It uses the knowledge and processes relevant to *accepting or rejecting a moral judgment about a particular course of action*.[4] Adopting a justificatory approach requires simply the judgment that there is, all things considered, a best or most justified option. In such cases, subjects accept the norm or principle as *decisive*, excluding consideration of the conflicting reasons that may support alternative courses of action. Hence, this conceptual framework can provide an alternate explanation for “justice” and “care” reasoning that does not assume two distinct “orientations” of moral thinking.

In a series of studies reported in Keefer and Olson (1995), I attempted to provide some empirical support for the claim that this classical conception of practical reason provides a more complete or accurate account of how subjects reason when confronted with case-conflicts. The argument to support this claim came in two distinct steps. The stratagem was to confront subjects of both genders with cases that would produce results consistent with the classical approach but inconsistent, or at least, partially inconsistent with *both* Gilligan’s and Kohlberg’s theoretical claims and explanations.

[4]This distinction (i.e., deliberative and justificatory) is similar to the distinction that Hampshire (1983) applied to the history of philosophical ethics. Hampshire’s contrasts classical agentive approaches where the focus is from the perspective of the moral agent and what is to be done, from modern approaches that address cases from the perspective of the moral judge or critic.

SECTION III EMPIRICAL SUPPORT FOR THE CLASSICAL CONCEPTION:

In the first step, I designed a study using the Heinz dilemma that appeared to support Gilligan's claims regarding both gender and moral orientation hypothesis. A second study was conducted using a new dilemma that produced findings that contradicted Gilligan's gender hypothesis but appeared to support Kohlberg's domain argument.

Any *empirical test* of the orientation hypothesis must meet two requirements. The first requirement is to provide an explanation of *why* any subject chooses a particular strategy of reasoning. This requirement was met above in section II. The second requirement is met by creating a more precise methodology that can distinguish the strategies of reasoning from the content of moral concerns.

The first study is an attempt to validate the classical conceptual framework and an alternate methodology (described below), and to assess its relatedness to Gilligan's orientation construct. The second study provides a test for the alternative explanation of why different genders prefer different strategies given different problems.

In the first study was comprised of 32 graduate students (16 male and 16 female) selected on volunteer basis using a quasi-random procedure. The subjects were from a diverse variety of cultural backgrounds with ages ranging from 24 to 55. The experimenter presented subjects with the Heinz dilemma and asked three questions. In Kohlberg's Moral Judgment Interview (Colby & Kohlberg, 1987b) subjects are asked, "Should Heinz steal the drug?" The structured interview requires that the yes or no answer to this question be followed by the question "Why?" or "Why not?" As this procedure encourages subjects towards a justificatory resolution, the strategy employed in this study was to first ask a practical question: "What should Heinz do?" This requires the subject to generate a course of action they consider suitable for solving the problem without an expectation that it will be necessary to defend it. Secondly, they were asked to justify the course of action.[5]

The method devised to analyze deliberative and justificatory strategies was a semantic phrase-structure grammar, a methodology informed by techniques of discourse analysis (Bruce, 1980; Bruce & Newman, 1978; Backus, 1959). All of the subjects' responses were first segmented into independent syntactic clauses, using Winograd's specification of the structure of English clauses (Winograd, 1983) and then analyzed using a newly devised Moral Reasoning Grammar (MRG). The grammar defines rules that specify how a structure corresponding to a rule name may be formed by applying other rules. This methodology (similar to recursive phrase structure rules used in psycholinguistics) allows for the identification of lower-level discrete knowledge structures (i.e., such as enabling conditions, goals,

[5] We have noted that Kohlberg's conceptual and methodological approach to the study of moral reasoning is decidedly justificatory in its emphasis. Here it is important to note that the question to subjects in Kohlberg's Moral Judgment Interview (MJI) is also clearly justificatory in emphasis For example, the interviewer using the MJI must first ask the quite narrow practical question "Should Heinz Steal the Drug?" which requires a simple binary option between two simple action plans. The MJI then requires the justificatory follow up query, "Why or Why not?" When Walker (1987 & 1989) reports no significant differences in gender orientation using the Heinz dilemma he is applying (I believe consistently) Kohlberg's MJI. This format certainly "pulls" for a more justificatory approach. In contrast, when subjects are asked more simply, "What should Heinz do?" the possibility for more protracted deliberative responses is encouraged.

and outcomes) as well as an opportunity to uncover how such entities are used by subjects in higher level structures that are characteristic of the two orientations. The higher-level structures are of most interest here. These included, for the justice orientation, the specification of rules, principles, and rationales and, for care orientation, narrative episodes, including interactive plans and social episodes (Bruce, 1980; Bruce & Newman, 1978).

In the MRG it is the top-level rule that best differentiates the two moral orientations. This rule defines a Moral Solution as requiring a Course of Action rule with an optional and iterative call for a Justification rule. While all subjects must specify, at least minimally, a practical Course of Action (e.g., steal the drug), the requirement to justify their solution is optional. The Course of Action may take the form of a simple Action; a single actor plan; an Interactive plan; or the enactment of a Social Episode (that includes interacting plans). We scored a subject's response as exhibiting a justification strategy if at any point in the protocol the subject generated a simple Action or single actor Plan followed by a Justification (such as a principle or rationale). We scored a protocol as deliberation if at any point the subject used an interactive planning structure (either a Interactive Plan or a Social Episode).

Following is an example of a Deliberation protocol using an interactive planning structure:

> Q What should Heinz do? ....
>
> Umm, He could try elsewhere or he could probably approach this druggist and tell him well if his wife were cured well, that would be the best advertisement for his drug. So that he would be able to make something out of that too. Because the drug maker would profit from having known one case was cured So he could ask even more money from the next people who would be interested in the drug.

Following is an example of Justification protocol using a principle.

> Q. If you were required to support the course of action that you have chosen for Heinz, how would you do it?
>
> Well I would say that he is right in valuing his wife's life over respecting the right for someone else to ah withhold their property from him. In other words his wife's life is worth more that ah the pharmacists right to withhold the property from him. Life is more valuable than property. I think he could (inaudible) persuade the druggist to have a solution that would be profitable for everybody.

In order to assess the relationship between these alternate strategies and Gilligan's "justice" and "care" orientations, both studies were designed to compare the coding of these strategies with independent coding of justice and care reasoning using Lyons's method.[6] It was hypothesized and we found that protocols identified as exhibiting a deliberation or justification strategy would demonstrate a high degree

[6]Lyons's method is not the only measure to assess moral orientation. An alternate method has been used (Brown, Tappan, Gilligan, Miller & Argyris, 1989), that allows for the identification of five different "voices" of human relationship (one of which includes a moral voice). The methodology is based on a "hermeneutic" approach, both in terms of its conceptual basis as well as in regard to the actual coding of protocols. The extent to which the new methodology represents a theoretical departure on Gilligan's part is difficult to judge. For the reader who holds that the newer method does represent a significant change, the generalization of the findings reported in these studies must be qualified.

of association with the same protocols scored for either justice or care reasoning using Lyons' (1983) methodology.

Identification of Moral Orientation Strategies and Comparison of the Gilligan and MRG Methodologies.

Analyses conducted to assess the relationship between gender and *the moral orientation strategies* identified by the MRG are presented in Table 1. Comparisons were made on the basis of coded responses to the first two questions. Using the criteria 25 of 32 protocols were identified as Deliberation or Justification strategies, while none of these 25 exhibited both.

Table 1. Number of Subjects by Gender for Justification and Deliberation Strategy for Subjects' Responses to the Heinz Dilemma (MRG) N=25

Gender	Justification Approach	Deliberation Approach
Men	11	1
Women	5	8

A 2 by 2 (Gender X Deliberative and Justificatory Strategy) chi-square test was significant, X = 5.531, df=1, $p<.02$ indicating that men in this sample showed a greater use of the justificatory moral strategy than women, while women tended toward greater use of the deliberative strategy in their responses than men. The extent to which the Justice-Care distinction overlapped with the Justification-Deliberation distinction was assessed using Cohen's Kappa Statistic. This analysis returned a value of Kappa of 0.68 indicating strong agreement ($p < .001$) between these two independent measures of orientation reasoning. This was also reflected in the observation that only 4 of 25 responses did not agree in the predicted manner.

This study provides support for Gilligan's hypothesis that women are more likely to respond to this dilemma as a problem for calling for practical action chosen by deliberation, while men are more likely to respond by appeal to norm or principle on the basis of the "logic of justification." The former utilized narrative descriptions (such as interactive plans and social episodes), while the latter made use of principles and rationales in defense of their chosen solution. Furthermore, the argument that this alternate account of the moral orientation hypothesis accounts for the same data as Gilligan's (1982) description of justice and care reasoning, is supported by the high degree of association between the justification and deliberation strategies identified by the MRG, and those identified as either justice or care orientations using Lyons (1982) measure. In sum, the findings from these case analyses would appear to support Gilligan's notion that there may be different moral orientations (i.e., different subjects or genders indeed differ in terms of their moral orientation) over Kohlberg's suggestion that there are different spheres or values that might pull for different types or orientations of moral thinking.

Two hypotheses come under scrutiny in the second study. The first is that reasoning with rules is common to all moral reasoning and, hence, to both genders. The second is that a set of values perhaps associated with gender will have the effect of determining whether a rule is treated as exclusionary. Manipulating the content or value, I argue, will determine the choice of a rule; whether or not it is treated as exclusionary will depend upon whether the case is seen as clearly violating the *ceteris paribus* conditions assumed by the rule. To test this conjecture what is required is a dilemma in which the action, justified by an exclusionary norm or rule, is seen as entailing significant damage to other values and pursuits, which are more important to one gender than the other. These conditions may have been met for most women subjects in the Heinz dilemma as the action of stealing the drug and justifying it by appeal to the rule “life over property” entails potentially unacceptable risks to the value of relationship (e.g., *sustaining* Heinz and his wife's personal relationship, as well as maintaining a relationship with the pharmacist). Thus, women may tend to reject the rule because in their view the *ceteris paribus* conditions are not met. Consequently, they are led to search for alternate solutions. The reason the *ceteris paribus* clause is rejected corresponds to Gilligan's claim that women are more sensitive to issues pertaining to special or intimate relationship. Gilligan's explanation why women use “relational” or cooperative problem-solving in their responses to the Heinz dilemma is that they conceive moral dilemmas, generally, in terms of the "“parameters of connection.” This, presumably, fits with the traditional roles of men and women; women being more occupied with maintaining the family, etc, while men are more preoccupied with, and in some case have exclusive access to, issues pertaining the public sphere. While there is little evidence to support this second conjecture, it may be that men would be more concerned with ruptures or potential problems in public or civic relations than would women.

A second dilemma, written to exploit this possibility, brings into conflict family obligations and political responsibilities and ideals. The problem revolves around a long unemployed carpenter, Michael, who is in desperate financial straits with a large family to feed. He is offered employment on condition that he nominates a political adversary as council chair. The adversary, in this case, is the personnel manager for the town's only contracting business. Unfortunately, the councilman's social policies, including as they do severe cuts in social spending, etc., are morally repugnant to Michael. The problem posed to subjects is whether or not Michael should nominate the councilman. Pilot data indicate that the content of value or concern in this dilemma is experienced differently by the two genders. Many women perceived the conflict as a clash between duty to family (others) and duty to one's own personal/political ideals (self). Many men, on the other hand, viewed the conflict as a clash between duty to one's community (others) and duty to one's personal or private including family responsibilities (self).

The dilemma was written to invite the application of the norm or rule for maintaining (intimate or personal) relationships as an exclusionary rule. But here, treating the rule as exclusionary entails accepting the *ceteris paribus* clause, that is, it requires that one ignore the potential risk to the “greater” public and civic well-being. If women have a concern for the maintenance of relationships (Gilligan's care orientation) they may adopt as exclusionary this rule as it supports these values. That is, they may be prepared to overlook other considerations, such as civic well-being. If this occurs, it would suggest that application of a norm or rule is not tied to gender but, rather, domains of concern.

In order to facilitate comparisons in orientation reasoning, all subjects in this second study were tested on both the Heinz and Michael dilemmas.

Following is an example of a justification response to the Michael dilemma where the subject resolves the dilemma by appeal to a rule or principle:

> Q What should Michael do?
>
> Well my first intuition is to say swallow your lofty ideals and nominate him because when you have a family you have a responsibility.
>
> OK. If you were required to justify the course of action that you have chosen for Michael how would you do it?
>
> I think I have already said that: Family responsibilities. When you have a family you have made a commitment to look out for others, other than just your own ideals. If you want to do it alone and you wanna do just what you think and what your ideals are then sure. But you have other people that depend on you.

Following is an example of a deliberation response where the subject applies interactive planning structures and a social episode in their resolution of the dilemma:

> Q What should Michael do?
>
> Uh, I think he would have to... I mean it's not a straightforward answer, saying that, uh, he should go against his political views to just get the money an' all, just to support his family, although that is possibly one of the largest concerns probably he has in his life.
>
> I think maybe he should find some way around it, uh, if he finds that this is the only solution, but, what are some of the other solutions around it, possibly to, uh, get other members in the community involved in what's going on.
>
> .... if other members in the community become aware of this, it could possibly, they could possibly understand Michael's situation and help him out in other ways; in getting him a job in another area, uh, if they know the situation.

Forty Georgetown University undergraduates participated in the study. Subjects were selected on a volunteer basis, mostly on the basis of classroom announcements. The undergraduates that participated in this study were of somewhat younger age than the subjects in the previous study. Georgetown University is a relatively prestigious, private American University and, so, these subjects may be assumed to come from middle to upper class backgrounds. Table 2 presents the relationship between subject's gender and moral orientation strategy on the Heinz dilemma. Scores are based on coded responses to the first two questions using an adaptation of the procedure outlined previously. Using these criteria 32 subjects were identified as exhibiting a deliberation or justification strategy. Twenty percent of the subjects (N=8) responding to this dilemma used a non-moral strategy.

A 2 by 2 (Gender X Deliberative and Justificatory Strategy) chi-square test was significant, X = 6.036, df=1, $p<.01$ indicating that men in this sample showed a greater use of the justificatory moral strategy than men, while women tended toward use of the deliberative strategy in their responses to Kohlberg's Heinz dilemma than men. These findings replicated those of first study.

Table 2. The Heinz Dilemma. Number of Subjects by Gender for Justification and Deliberation Strategy N=32

Gender	Justification	Deliberation
Men	14	3
Women	5	10

The relationship between subject's gender and moral orientation strategy on the Michael dilemma are presented in Table 3. Scores are based on coded responses to the first two questions using the procedure outlined above. In this analysis 29 subjects were identified as exhibiting a Deliberation or Justification strategies. Twenty seven percent of the subjects (N=11) responding to this dilemma used a non-moral or pragmatic strategy. As predicted a very different result obtained in responses to this dilemma.

Table 3. Michael Dilemma. Number of Subjects by Gender for Justification and Deliberation Strategy N=29

Gender	Justification	Deliberation
Men	7	7
Women	13	1

A 2 by 2 (Gender X Deliberative and Justificatory Strategy) chi-square test was also significant, X = 5.222, df=1, p<.02 indicating that women in this sample showed a greater tendency to adduce a principle or norm in support of their solutions than men. Whereas, men were more likely to use a deliberative strategy in their responses to this dilemma than were women.

The results reported in this second study support the classical view that reasoning with norms and rules is common to all moral reasoning and to both genders, and it is independent of any effect due to the influence of moral ‘spheres’. Both women and men use rules in their solutions to certain types of moral conflict and both women and men are also, under certain conditions, willing to adopt a more protracted deliberative strategy. The gender differences reported in this study indicate that it is a set of values associated with gender that will determine whether or not a rule is treated as exclusionary. The manipulation of values determined the choice of a rule; whether or not it was treated as exclusionary depended upon whether the case was seen as clearly violating the *ceteris paribus* conditions assumed by the rule.

Specifically, in response to the Heinz dilemma, many women rejected the justification for stealing the drug by appeal to the rule “life over property” because it entailed unacceptable risks to the value of relationship (e.g., *sustaining* Heinz's and his wife's personal relationship as well as maintaining a relationship with the pharmacist). They attempted to minimize the potential for collateral damage to this value by using interactive planning structures in their search for alternate solutions. This account of why the norm or rule was rejected also supports Gilligan's claim that women are more sensitive to values pertaining to special or intimate relationship.

Taking the two studies together, we see that different subjects appear to use either approach or "orientation" strategy in either the public or the private sphere. Indeed, subjects' perception of the kind of sphere the case-conflict represents itself appears to be an object for interpretation or construction.

Specifically, in response to the Michael dilemma, many men *rejected* the justification for nominating the Councilman by appeal to a rule like "family responsibilities over personal ideals" because it entailed unacceptable risks to the value of the "greater" public welfare. They also attempted to minimize the potential for collateral damage to this value by using interactive planning structures in their search for alternate solutions.

This account of why the norm or rule was rejected supports the claim that men are more sensitive to values pertaining to public or civic well-being. These results, taken together, support the general hypothesis that rule application is not tied to gender but rather to values or domains of concern. In the Michael dilemma, male subjects' appear to apply narrative structures in defense of a threat to values perceived to be constitutive of the public sphere, whereas women apply principles in defense of values explicitly interpreted as "private" in their constitution. In conclusion, these results suggest that, contra Gilligan, neither gender nor a general disposition for a particular moral orientation will account for differences in kind of reasoning subjects apply to moral cases. Contra Kohlberg, the results suggest that neither the value sphere or content of the moral conflict will determine the type of orientation reasoning suitable to the resolution of moral cases.

Most important, these results considered together do not support a conception of reasoning with moral cases that posits two different and independent orientations of moral thinking.

SECTION IV: THE IMPORTANT ROLE OF PRACTICAL AND PROFESSIONAL ETHICS.

What are the practical lessons that we have learned from more basic research in the psychology of moral reasoning? One concern is that a focus on theoretical foundations in our psychological models of moral thinking can produce somewhat distorted characterizations of practical moral deliberation. It suggests that psychological and philosophical theories would benefit from exposure to and comparison with the reality of practical moral experience. Case-based approaches provide a useful means to evaluate whether our theoretical models of moral thinking pass muster in tackling the practical exigencies of moral deliberation.

To take a rather famous example, one of the major reasons that Gilligan's was able to challenge the narrowness of justificatory approaches to moral thinking was that she listened attentively to what women were saying when they confronted realistic case examples. Similarly, in the field of philosophical ethics, Jonsen and Toulmin (1990) note sharp differences in theoretical perspectives in ethics amongst philosophers. However, they also note that when professional ethicists and philosophers focus first is on discussion of tough moral cases in professional contexts, differences in theoretical orientation appear far less relevant. Therefore, while consensus may be elusive if not impossible when the spotlight is on theoretical justification, a shift to the practical challenge of determining what *to do*, allows moral consensus to become a realizable objective.[7]

A similar transition appears in my own professional experience. In the earlier work I described above, theoretical issues provided the motive for designing studies that challenge prevailing conceptions of moral reasoning. In later work, further additions and revisions to the model became necessary when attempting to meet the challenge of analyzing mature ethical case responses in professional contexts. The later model Kevin Ashley and I developed comprises seven basic components. Whether one can:

(1) identify the moral issue at stake,

(2) identify the relevant knowledge and unknown facts in a problem,

(3) offer a resolution,

(4) provide a justification,

(5) consider alternative scenarios that argue for different conclusions,

(6) Identify and evaluate moral consequences and

(7) offer alternative resolutions.

What we subsequently noticed, is that the model we derived empirically, bears a close resemblance to moral analyses and heuristics recommended by ethicists involved in professional ethics instruction in engineering and medicine (see Ashley & Keefer, 1996). What these approaches have in common is a commitment to teaching ethics using analyses of moral decision-making in practical contexts, usually in the form of realistic case examples (e.g., Whitbeck, 1998; Arras, 1991; Griffin, 1988). Many of these approaches employ a casuist model of practical ethical decision-making as found in Strong (1988), Jonsen (1991), Jonsen and Toulmin (1990) and especially those found in a text like *Engineering Ethics: Concepts and Cases* (Harris, Pritchard & Rabins, 1999).

This research has important pedagogical implications for both undergraduate and graduate science education. For example, the case examples in *Engineering Ethics* are presented to students in an interesting way. Often, the authors organize a series cases around a principle drawn from common morality such as "it is wrong to steal or to commit theft" and from an engineering ethics code as in "Engineers shall not disclose confidential information concerning the business affairs or technical processes of any present or former client or employer without his consent ([NPSE code] III.4)" (Harris et al., 1999, p. 126). The analysis presents a series of examples along a spectrum from clear positive to clear negative (e.g., the "line-drawing" method in Harris et al., 1999, p. 131). Each successive case represents an addition of or a change in the salience of some morally relevant factor that makes the application of middle-level moral principles more or less necessary (Harris, et al., 1999, p. 131).

[7] Note further, that the classical conception of reasoning with rules provides us with a theoretical explanation of this result. As exclusionary reasons, rules constitute solutions to practical problems and provide a "middle-level" of justification for moral actions (Raz, 1990; Nussbaum, 1986). That is, the appeal to middle-level norms and rules can provide for the resolution of practical conflict by appeal to a level of justification that may not be available at the deeper more theoretical level.

Similarly, we wrote the case examples in our study with the aim of promoting explicit case comparison in the manner of the casuist or “line-drawing” approach outlined in *Engineering Ethics*. While explicit reference to earlier cases was quite rare, many of the analyses and explanations that our more experienced ethical thinkers used closely modeled those employed by the authors of *Engineering Ethics*. For example, whereas the text's analysis might include a series of clear positive and negative examples (intentionally varied to obtain pedagogical goals), some of our subjects spontaneously generated the same strategies in order to explain or justify their resolutions of the dilemma (component 5).

To use one of our own case examples, a dilemma describes a 73 year old woman with Alzheimer's disease. The woman's son tells the physician that he is no longer able to care for his mother (due to other responsibilities), and wishes his mother to enter a nursing home. The son further requests the physician not tell his mother about her condition “since it would only scare her.” The question to our students is whether the physician should honor the son's request. One of the graduate students enrolled in a professional ethics program responded as follows:

It is not clear why the doctor is communicating with the son, and not the patient, in the first place. That issue aside, the doctor should tell his patient that she has Alzheimer's disease, unless he has reason to believe she is suicidal and will react badly to the information, or that she is demented so that she will not understand the information conveyed. Unless these extreme circumstances obtain, there is no reason to override the prevailing assumption that patients should be given accurate and complete information about their conditions. If the son is concerned about “scaring” her, he should realize that she is likely aware of her condition, and will realize upon being put in a nursing home that something is wrong, both of which are “scary” issues too. The patient should participate as much as possible in the planning about the nursing home.

This student strategy bears a close similarity to the example of a line-drawing or graduated response that is described in *Engineering Ethics* (Harris et al., 1999, p. 130). Here the subject establishes a negative paradigm or reference case for the purpose of a comparison that shows the (extreme) conditions, which would need to be in place to honor the son's wish and to override the physician's obligation to inform the patient of their condition. In the protocol analysis that was used in our study, part of this response was coded as a counter-factual case comparison. That is, it was scored as a justification, which poses hypothetical situations or extreme cases, in order to show whether a relevant moral principle clearly would or would not apply.

While this response may seem too highly advanced or sophisticated to constitute a realistic objective for undergraduate or graduate instruction in the sciences, our experience suggests otherwise. Additional ingredients are required however. These would appear to include in addition to realistic case examples, the opportunity for dialog and engagement with mature ethical thinking and case analyses. In a recent study (see Keefer & Ashley, 2001), we provided undergraduate engineering students with the opportunity to benefit from both exposure to realistic case examples as well as analyses of these cases by experienced professionals and ethicists.[8] We found that a large number of these students were able to reason and dialog with the ethicists at levels that some would find surprising.

For example, one of our case examples describes a dilemma in which XYZ Company contracts ABC Company to supply custom parts for one of their products. After the agreement is signed, but before production of the part begins, an ABC R&D scientist, Christine Carsten, determines that a much less expensive metal alloy can be used that only slightly compromises the integrity of the part. When Christine informs management, her boss asks her whether "anyone would know the difference". When Christine answers that it would be unlikely the client could detect the switch, her boss decides to substitute the part without informing the client. The question to our undergraduate engineering students was "What should Christine do?"

> Christine's actions should be based on the exact effect of using the less expensive alloy. If it would alter the product sufficiently to in any way violate the specifications given when XYZ signed the contract, then her best course of action would be to press for XYZ to be informed of this. If they receive parts which do not last as long as they expected them to, not only could they investigate more fully and discover the changed alloy, they could also cease to do business with ABC. If the specifications will not be met, the customer must be informed and allowed to make a decision on the matter. On the other hand, if it can be shown that the change in alloy will not deviate from specifications, then there is no absolute need to inform XYZ. It would however, in the interest of professional business practices, probably be a good idea to let them know (and perhaps save them some money). This way, everyone wins, and it will most likely enhance the relationship between the two companies.

What this response shows pedagogically, is a developing sensitivity on the part of a student to context and the importance of professional knowledge that would appear unusual for someone who does not yet have any practical experience. In particular, it shows the necessity to attend to the relevant specialized professional knowledge needed to identify moral issues and especially the requirement to identify the knowledge not provided but that also bears on the identification of moral issues and assessment of moral responsibility.

Nor does this type of casuist or line-drawing strategy exhaust the kinds of reasoning that we have found students find useful in ethical problem-solving in the practical sciences. For example, other cases in Engineering Ethics are presented organized around conflicting middle-level code principles such as engineers should "hold paramount the safety, health, welfare, of the public in the performance of their professional duties" versus "act in professional matters for each employer or client as faithful agents or trustees" (Harris et al., 1999, p. 139). Cases that are presented as calling for "hard choices" between conflicting principles are also annotated by the authors with a range of optional actions the protagonist could take (referred to as creative middle-way solutions) that are organized by the extent to which they serve

[8] We had intended to collect cases and commentaries from ethicists and professionals (in engineering) but were pleased to discover that Michael Pritchard, Charles Harris, and Michael Rabins had already assembled a fine set of cases and commentaries (some of which ultimately appeared in their textbook, *Engineering Ethics*). These authors asked the ethicists and professionals in their study to write detailed commentaries on several ethical cases involving an engineering context. We were very fortunate when Michael Pritchard graciously made them available to us.

each of the conflicting principles. This strategy turned out to be empirically identical with the deliberative strategy outlined in section II & III above and is captured by component 7 in our revised model.

We also found other important parallels in the manner our experienced thinkers' responses applied professional knowledge and the pedagogical strategies promoted in *Engineering Ethics*. For example, virtually all of our graduate students were careful to specify the knowledge issues and conditions (whether stated in the dilemma or inferred as hypothetical) that support the application of principles or recommend actions. That is, we found that experienced ethical thinkers and many students were better able to specify the knowledge conditions under which specific professional role obligations, the kind of obligations described in professional ethics codes, recommend particular actions. In terms of application to K-12 science education, this finding argues strongly in favour of those who would like a close connection between ethics instruction and the knowledge and actual curricular content of science instruction.

The following response is an example of specifying the content of conditions necessary for a paradigm/case to override the patient's autonomy. The response was to a case in which a physician, Diana, is considering whether or not to “deceive” her patient, whom she suspects is addicted to narcotics, by administering a placebo in place of her medication for pain. Note that most of the conditions specified presuppose some expert knowledge of special obligations of medical practice:

> It may be that Diana is justified in “deceiving” her patient, provided that the following questions are affirmatively answered: (1) does Diana have sufficient reason to believe her patient is addicted; (2) is the patient's current dosage of painkillers sufficient for other patients in similar circumstances; (3) is the patient likely to recover so that addiction is undesirable for future life plans; (4) has Diana attempted to provide [refer the patient for] psychiatric, support group or pain relief care which is non-medicinal; (5) has Diana attempted to communicate her concerns directly to the patient?

In addition, this protocol shows another important and characteristic case-based strategy referred to creative middle-way solutions in *Engineering Ethics* or what we called “rewrites” of the dilemma (our component 7). We defined these as instances where subjects generate a practical solution that satisfies all, or most, of the moral issues at risk in the dilemma. In the Diana example, our subject specifies some possible “middle-way” solutions that ought to be attempted prior to making a hard choice (e.g., the students’ points listed as 4 and 5). This is the same strategy was shown to be empirically associated with Gilligan’s care reasoning (see section X above).

CONCLUSION AND EDUCATIONAL IMPLICATIONS

To summarize, in both these later studies we compared the practical complexity of the experienced and more novice students’ responses to realistic case examples. What we found is that more experienced thinkers and some students clearly employ more complex and more contextually sensitive ethical strategies. While almost all of our ethicists and students used moral principles to justify their responses, the experienced thinkers (and some students) were much more likely to also specify the context and conditions under which specific professional role obligations recommend actions, and/or, to consider their consequences in light of these. In some cases, students also appeal to hypothetical situations or alternate cases and/or generate creative middle way solutions to protect threatened values and fulfill obligations (Ashley & Keefer, 1996; Keefer & Ashley, 2001).

What do these important findings tell us about K-12 science instruction? I believe that the characterization of mature case-based ethical reasoning provided in this chapter has much in common with recent advances in pedagogical theory and instructional design, particularly in the area of inquiry and problem-based learning.

For example, recent interest in problem-based learning (PBL) includes an understanding of how effective knowledge and thinking emerges from social and institutional contexts, so that understanding the purpose or function of knowledge requires considering carefully its role in those contexts that have produced it (Resnick & Wirk, 1996; Salomon, 1993; Lave & Wenger, 1991). What have emerged from these theoretical advances are important practical instructional principles that dovetail nicely with the complexities of case-based ethical thinking described above. Some key principles include: Anchoring curriculum and instruction within contexts that include authentic problems and case examples (Bereiter, 1992; CTGV, 1992 & 1993); Helping students to appreciate and respond to complex problems that require multiple steps with different possible solutions (Bereiter & Scardamalia, 1989; CTGV, 1992 & 1993); Challenging students to assess, revise and reflect on their own thinking and provide them with multiple opportunities to have their thinking challenged by other students, the teacher, or other outside resources (Keefer, in press); Connecting learning outcomes to relevant problems or cases that require products or performances from students that demonstrate knowledge, (HPL, 2000; Brown & Campione, 1996; Savery & Duffy, 1995); And finally, there are several classroom activities derived from cognitive research that include new strategies for facilitating collaborative learning and discussion, strategies that are clearly well suited for both ethical and scientific investigation (McGilly, 1994; Bereiter & Scardamalia, 1989; Brown & Palinscar, 1989; Brown & Campione, 1994; Resnick & Collins, 1994; Resnick, Bill, Leer & Reams, 1992; Keefer, Resnick & Zeitz, 2000).

As the reflections and findings presented in this chapter indicate, it is clear that ethical instruction is most successful when it is introduced and integrated into authentic contexts, those same contexts within which it will subsequently need to be practiced and understood.[9] I believe that the parallels between the emerging fields of PBL and case-based ethical instruction offer unique, though as yet largely unrealized, opportunities for integration of ethical content in K-12 inquiry science instruction.

To conclude, what I have attempted to show in this chapter is that first; there is still urgent need to broaden our theoretical understanding of the complexity of mature case-based ethical reasoning. Second, there is considerable benefit in using realistic cases and case analyses when teaching professional ethics in the applied sciences. Third, there exists a great opportunity to infuse inquiry based science

[99] Indeed, one of the reasons why ethical reasoning has been so easily ignored in our schools relates to difficulties encountered in the attempt to include one additional subject into the curriculum. I believe that such attempts are ill advised for both theoretical and practical reasons.

instructional programs with realistic and informed case-based ethical instruction at the K-12 level.

REFERENCES

Arras, J. D. (1991). Getting down to cases: The revival of casuistry in bioethics, *Journal of Medicine and Philosophy 16*, 29-51.

Ashley, K. D. and Keefer, M. W. (1996). Ethical reasoning strategies and their relation to case-based instruction: Some preliminary results. *Proceedings of the Eighteenth Annual Conference of the Cognitive Science Society*, 483-488.

Backus, J. W., (1959). The syntax and semantics of the proposed international algebraic language of the Zurich ACM-GAMM conference. *Proceedings of the International Conference on Information Processing*, 123-132.

Bereiter, C. (1992). Referent-centered and problem-centered knowledge: Elements of an educational epistemology. *Interchange, Vol. 23/4*, 337-361.

Bereiter, C. & Scardamalia, M. (1989) Intentional learning as a goal of instruction. In L.B. Resnick, (Ed.), *Knowing, learning and instruction: Essays in honor of Robert Glaser* (p. 361-392). Hillsdale, NJ: Lawrence, Erlbaum Associates.

Brown, A. L., & Palincsar, A. S. (1989). Guided, cooperative learning and individual knowledge acquisition. In L. B. Resnick (Ed.), *Knowing, learning and instruction: Essays in honor of Robert Glaser* (p. 393-451). Hillsdale, NJ: Lawrence Erlbaum Associates.

Brown, A. L., & Campione, J. C. (1994). Guided discovery in a community of learners. In K. McGilly (Ed.), *Classroom lessons: Integrating cognitive theory and classroom practice* (p. 229-272). Cambridge, MA: MIT Press.

Brown, A. L., & Campione, J. C. (1996). Psychological theory and the design of innovative learning environments: On procedures, principles, and systems. In L. Schauble & R. Glaser (Eds.), *Innovations in learning: New environments for education* (p. 289-325). Mahwah, NJ: Lawrence Erlbaum Associates.

Bruce, B. C. (1984). Plans and social action. In. R. J. Spiro, B. C. Bruce, & W. F. Brewer (Eds.), *Theoretical issues in reading comprehension: perspectives from cognitive psychology. Linguistics, artificial intelligence and education*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Bruce, B. C., & Newman, D. (1978). Interacting plans. *Cognitive Science, 2*, 195-233.

Bruer, John T. (1993). *Schools for thought: A science of learning in the classroom*. Cambridge, MA: MIT Press.

Cognition and Technology Group at Vanderbilt. (1992). The Jasper experiment: An exploration of issues in learning and instructional design. *Educational Technology Research and* Development, *40*, 65-80.

Cognition and Technology Group at Vanderbilt. (1993). Designing learning environments that support thinking: The Jasper series as a case study. In T. M. Duffy, J. Lowyck, & D. H. Jonassen (Eds.), *Designing environments for constructive learning* (p. 9-36). NY: Springer-Verlag.

Cognition and Technology Group at Vanderbilt. (1994). From visual word problems to learning communities: Changing conceptions of cognitive research. In K. McGilly (Ed.), *Classroom lessons: Integrating cognitive theory and classroom practice* (p. 157-200). Cambridge, MA: MIT Press.

Colby, A., & Kohlberg, L. (1987). *The measurement of moral judgment. Vol. 2: Standard issue scoring manual.* New York: Cambridge University Press.

Gilligan, C. (1982). *In a different voice: Psychological theory and women's development*. Cambridge, MA: Harvard University Press.

Gilligan, C., & Wiggans, G. (1987). The origin of morality in early childhood relationships. J. Kagan, & S. Lamb (Eds.), *The emergence of morality in young children*. Chicago: University of Chicago Press.

Griffin, N. (1988). Using “Ethics in teaching” in teaching in ethics: Student views on the case studies. *Teaching Philosophy, 11*(2), p. 116-127

Hampshire, S. (1983). Fallacies in moral reasoning. In A. MacIntyre, & S. Hauerwas (Eds.*), Changing perspectives in moral philosophy*. Notre Dame, IN: Notre Dame University Press.

Harris, C., Pritchard, M., and Rabins, M. 2nd Ed. (1999). *Engineering ethics.* Belmont, CA: Wadsworth.

Jonsen A. R. and Toulmin S. (1990). The abuse of casuistry: A history of moral reasoning. Berkeley, CA: University of CA Press.

Jonsen, A. R. (1991). Casuistry as methodology in clinical ethics. *Theoretical Medicine*, 12, p. 295-

307.

Keefer, M. W. (In Press). Designing reflections on practice: Helping teachers apply cognitive learning principles in an SFT - inquiry-based learning program. *Interchange: A Quarterly Review of Education.*

Keefer, M. W., Olson, D. (1995). Moral reasoning and moral concern: An alternative to Gilligan's gender based hypothesis. *Canadian Journal of Behavioral Sciences, 27*(4), p. 420-437

Keefer, M. W., (1996) The inseparability of morality and personal well being: The duty/ virtue debate in moral education - revisited. *The Journal of Moral Education*, *25*(3), p. 277-290.

Keefer, M. W., Zeitz, C. M., & Resnick, L. B (2000). Judging the quality of peer-led student dialogues, *Cognition and Instruction*, *18*(1), p. 55-83

Keefer, M. W., & Ashley, K. D. (2001). Case-based approaches to professional ethics: A systematic comparison of students' and ethicists' moral reasoning. *The Journal of Moral Education Vol. 30*(4), 377-398.

Kohlberg, L.(1984). The psychology of moral development: The nature and validity of moral stages. In L. Kohlberg.(Ed.), *Essays on moral development: Vol. 2: The philosophy of moral development*. San Francisco:

Lave, J., & Wenger, E. (Eds.), (1991). *Situated learning:Legitimate peripheral participation.* New York: Cambridge University Press.

Lyons, N. (1983). Two perspectives: On self relationships and morality. *Harvard Education Review, 53*(2), 125-45.

McGilly, K. (1994). *Classroom lessons: Integrating cognitive theory and classroom practice*. Cambridge, MA: MIT Press.

National Research Council, (2000). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press.

Nussbaum, M. (1986) *The fragility of goodness: Luck and ethics in Greek tragedy and philosophy,* Cambridge: Cambridge University Press.

Raz, J. (1990). *Practical reason and norms*. Princeton, NJ: Princeton University Press.

Raz, J. (1986) *The morality of freedom.* Oxford: Clarendon Press.

Raz, J. (1998) *Engaging reason: On the theory of value and action*. Oxford: Clarendon Press.

Resnick, L. B., Bill, V. L., Leer M. N., & Reams, L. E. (1992). From cupcakes to equations: The structure of discourse in a primary mathematics classroom. *Verbum 1-2,* 63-85.

Resnick L. B., & Collins, A. (1994). Cognition and learning. In T. Husen & T. N. Postlethwaite (Eds.), *International encyclopedia of education* (2nd ed.), (p. 835-838). Oxford: Pergamon.

Resnick, L B. & Wirt, J G., (1996) (Eds.) *Linking school and work: roles for standards and assessment.* San Francisco: Jossey-Bass Publishers.

Savery, J. R. & Duffy, T.M., (1995). Problem based learning: An instructional model and its constructivist framework. *Educational Technology,* September/October, 31-38.

Strong, C. (1988). Justification in ethics. In B. A. Brody, (Ed.), *Moral theory and moral judgments in medical ethics (*p. 193-211). Dordrecht: Kluwer Academic Publishers.

Walker, L., DeVries, B., & Trecethan, S. (1987). Moral stages and moral orientation. *Child Development, 58*, 842-858.

Walker, L., (1989). A longitudinal study of moral reasoning. *Child Development*, *60*, 157-166.

Whitbeck, C. (1998). *Ethics in engineering practice and research*. Cambridge: Cambridge University Press.

CHAPTER 13

SCIENTIFIC ERRORS, ATROCITIES AND BLUNDERS

USING CASES TO PROMOTE MORAL REASONING

TROY D. SADLER & DANA L. ZEIDLER

INTRODUCTION

Morality, authority and power are central concepts embedded in the life-blood of the polis. While it has always been tempting to compare modern society to Greek and Roman antiquity, scholars understand that the images we see are through "modern" lenses (De Coulanges, 1873). Having said that, however, scholars are left with recorded deeds and verse that hint at vestiges of behavior and practices that reveal something about the collective practices we strive for or submit to in present day society. The relationships between beliefs and social practices are found in seminal sociological concepts like those mentioned above, and tell us something about the collective morality of a group or culture (Arendt, 1958; Berger, 1969; Nisbet, 1966; and Trilling, 1972).

The distinction between power and authority lies not so much in the testimonies or actions of (one in) authority, but in the prevailing attitude held by those who are influenced by the authority, those who have bequeathed authority, and those who may have the presence of authority. Authority is exercised over those who voluntarily accept it; it will not affect those who do not recognize it as legitimate unless those who respect the authority coerce those who do not. By placing ourselves in the hands of (an) authority, we make a moral commitment and expect that it will be honored. We are lulled into doing whatever is deemed best by the authority simply because we ought to. Politically, authority means the right to act. Morally, it is the duty to do so. This is the de facto implication of our relationship to authority, which arises out of the de jure. As long as the people respect the legitimacy of the authority, the de facto state is ever present.

D.L. Zeidler (ed.),
The Role of Moral Reasoning on Socioscientific Issues and Discourse in Science Education, 261-285.

It should not be surprising that complacency among a public in the form of the philosopher's "naturalistic fallacy" (just because something has x, x must be good) is a self-perpetuating norm within a society. But the more firmly rooted in established traditions an authority is, the more it depends on its own continued success than the support of the people – more so if the people have become complacent.

This becomes a powerful lesson for our students to grapple with: we are the authors of authority. We are influenced and affected by institutionalised authority (church, government, school systems, science) and individual authorities (pastors, senators, teachers, scientists) to the extent we trust them with guiding and somehow enhancing our social existence. By accepting "what is", we have consented to be dominated (or at the very least – become complacent); we have accepted the *power* of the authority.

How can our students or an entire society move beyond blind acceptance of authority that may lead to the abuse of power? The agents that grant authority, members of the society from which the authority springs, must have the ability to evaluate the actions of authority. More specifically, citizens must inquire about the rights and duties of the agencies that are granted authority. Does a particular agency have the right to commit the actions in which it engages? Has that agency moved beyond the rights afforded to it by the people? Not only is it important to consider how extensively power is applied, it is equally appropriate to consider cases in which authority fails to apply its power. Has the agency fulfilled its duty? Has the agency accomplished that which it is morally bound to undertake? Failure to uphold duty as well as overextension of rights marks a breach in the moral commitment formed when citizens granted authority.

Evaluating the issues that surround authority and power, rights and duties involves moral reasoning. Lawrence Kohlberg, arguably the most instrumental theorist in moral development and education, posits that the primary aim of education should be the development of moral reasoning (Kohlberg & Mayer, 1973). In the Kohlbergian model, individuals progress through a series of six, sequential and invariant stages that define the processes by which people consider moral situations (see chapter 1 in this volume for a more complete discussion). Accordingly, the optimal way to facilitate students in evaluating authority would be to promote moral stage progression, that is, provide an educational environment that encourages development of post conventional reasoning. More recent theorists note the importance of factors other than reasoning on morality. Rest, Narvaez, Bebeau, and Thoma (1999) propose a four-component model that adds moral sensitivity, moral motivation, and moral character to moral judgment, a category built upon Kohlbergian moral reasoning. Berkowitz (1997) offers another taxonomy termed moral anatomy; it subsumes some of the ideas presented in the four-component model as well as other aspects. Moral anatomy consists of moral behavior, moral character, moral values, moral reason, moral emotion, moral identity, and meta-moral characteristics. Both models imply that moral decision-making and behavior are contingent on factors beyond reason; therefore, development of post conventional reasoning should be one of many aims for an education program that seeks to arm citizens with the skills needed to evaluate authority.

The impact that science has had on society cannot be overstated. The fact that science has led to the acceptance of specific epistemological and methodological belief systems – or social paradigms of thought as it relates to research traditions has been well described in the literature (Giere, 1988; Gould, 1995; Gould, 1996; Kuhn, 1970; Lakatos & Musgrave, 1970; Lakatos, 1978; Laudan, 1977). Students tend to view science as a monolithic authority lulled into accepting the power of its authority because of its firm foothold on the established traditions of its past successes, and because it has become interwoven into the fabric of our daily lives. Science epitomizes knowledge – and what school-aged child has not had that catchall phrase drummed into their psyche by good intentioned educators – that "knowledge is power!" Threats, browbeating, propaganda and ostracism ("get with the program!") are ways of exercising power. Power is exercised most efficiently when people conform to power because they fear not the penalty itself, but the potential to enforce it – the "power of suggestion!" That science tends to be seen as a foremost authority suggests to unwitting students, and many adults, that knowledge generated by the scientific enterprise must have importance and, therefore, it or its utility must be good.

Challenging the monolithic authority of science falls under the province of science education. To understand the interactions of science, technology and society and the nature of science, as prescribed by standards documents emanating from science education organizations around the world (see chapter 1), students need to appreciate the authority they grant. As described earlier in this section, the evaluation of authority and power requires moral skills. Therefore, to satisfy the aims of science education, science educators must address moral issues and attend to the developing morality of their students. One method to accomplish these goals is discussing historical instances when the power of science was over-used or abused, cases in which the authority of science should have been challenged.

In an effort to highlight appropriate examples, three areas of bad science are identified from the 19^{th} and 20^{th} centuries that crack the pillars of established science and its institutional authority. They are Cultural Prejudice Based on Scientific Errors, Unethical Science by Business and Government, and Unwitting Errors. Specific cases are selected because of the magnitude of their impact on the collective morality of our lives in terms of how we view culture, accept power, authority and governance, and are impacted by the interdependence of science and society. The cases have also been selected because of their pedagogical potential in developing critical reasoning skills, stimulating discussion, and inspiring critical inquiry. In each case a description of the salient features surrounding the event is presented, followed by a discussion of the basic error committed and the fallacious reasoning involved (which we operationalize for the purposes of this chapter as "bad science"). The social impact such errors in reasoning have, and have had, on our personal, social or political beliefs are also examined.

CRACKS IN THE PILLARS

Cultural Prejudice Based on Scientific Errors

Case: Phrenology and Craniology

Numerous cases exist in which cultural biases have impacted the scientific enterprise, and the scientific community produced results that, not surprisingly, reflected and confirmed the prevailing Zeitgeist. Scientific theories tend to be "contextualized", i.e. consistent with the prevailing norms of both the scientific community and of the greater society (Kuhn, 1970; Hubbard, 1990; Harding, 1993). Political agendas that fuse science with political and economic power have clearly been identified in contemporary literature (Callon, 1995; Cozzens, 1990; Gieryn, 1995). However, the case of phrenology offers both historical and contemporary lessons that are illustrative and instructive in terms of understanding sociological factors that may lead to bad science.

The notion that overt appearances in body type, facial and cranial features (craniology), and even body adornment (i.e., tattoos) are directly linked to race, criminal temperament, and intelligence is a by-product of the "science" of phrenology. The impetus of phrenology can be traced to the late 19th and early 20th centuries, and to early advocates such as Cesare Lambroso, Bernard Hollander, and Paul Bouts. Arguably, it was Lambroso's scientific study and political discourse (1895, 1911) that had the most impact on producing cultural biases inasmuch as their bases of support were built upon evolutionary theory and anthropometrical data consisting of objectively measured body features. Since phrenology stressed precise quantitative measurements of facial features it was deemed as an objective science and political decisions to oppress individuals, groups or cultures were implemented and justified based on objectivity and data-driven information. It was, for example, used by the British to justify its racial policies in the colonization of black tribes of Africa, as well as in its dominance over the Irish. In both cases, measurements of the jaw in relation to the mandible were said to be more similar to apes, monkeys or Cro-Magnon humanoids than to Anglo-Saxon people of Europe and thus constituted "inferior races." Extensions of phrenology included measuring convicted criminals' crania and body features to build a profile of innate social deviant characteristics. That some convicted murderers had pronounced jaws and pickpockets long hands and scanty beards provided a sufficient profile to convict others charged with similar offences well into the 1930's. Even more startling, since Lombroso's "anthropometric data" of criminal traits held the status of an evolutionary theory, heredity and criminal destiny were causally linked; hence, people could be convicted of crimes independent of evidence as long as their anatomy fit particular taxonomies. Consider for instance the case of describing the "prehensile" foot features of prostitutes as revealing atavistic anomalies.

Another "quantitative" study further revealed genetic destiny: Lombroso formed typologies of criminals based on the content of their tattoos. Typologies were subsequently formed that coded criminals into groups like "lawless" or "unlucky." One can only imagine how a tattoo that read "Long live France and french fried potatoes" was used by English investigators to code for atavistic traits (Gould, 1996, p.162)!

Similar scientific classifications based upon evidence of Arian and non-Arian features (or the degree of Arian or non-Arian blood from mixed marriages) were used by anthropologists sympathetic to Nazi politics to select individuals that would be relegated to death camps (Gould, 1995). Infuse bad science with systemic anti-Semitic (Nazi) education—typified by curriculum chapters like: "The heredity of physical and spiritual characteristics of the German race; Sorting out people [Jews] plagued with hereditary diseases; Keeping the blood pure"–and an authority is doubly reinforced to advance doctrine and laws for the "racial health" and survival of their people (Wegner, 1991, p.198). Racist policies become more palatable to a given culture if the oppressed are viewed as something less than human.

It is tempting to view phrenology (and its related forms) as an interesting but anachronistic phase in the evolution of scientific knowledge. However, one only has to survey current literature (Colbert, 1997; Cooper & Cooper, 1983; Cooper & Childs, 1997; Hedderly, 1970; Leek, 1970) and Internet sites (e.g., Van den Bossche, 2000a & 2000b) to realize that such practices are still advocated in the name of "true science." With the aid of a phrenology chart, a practitioner can supposedly ascertain personality traits from observing, measuring, or reading the shape of the bumps, ridges, and bones of the subject's head. Benevolence, for example, is said to be located in the upper part of the forehead; a convex forehead indicates the presence of this trait, whereas a slanted forehead signals its absence. The more obvious the protuberances located halfway down the forehead, the greater the capacity for causality (abstract, logical thinking). And so it goes for other faculties such as perception, morality, destructiveness, firmness, constructiveness, veneration, hope, etc. Modern proponents of this science have attempted to gussy it up by distancing it from a checkered past and suggest it can be used to serve humanity. "New Age" advocates of phrenology claim that human resource management counsellors may help direct people into their proper fields since arts or trades such as law, medicine, divinity, journalism, mechanical arts, and fine arts, among others, demand requisite skills that can be matched to genetically endowed personality traits, which can be determined by phrenological methods. In other words, phrenology claims to have the ability to predict whether an individual will succeed in a given profession. They do however offer a disclaimer. It is comforting to know that contemporary phrenological practitioners recognize that errors of interpretation might occur in the "diagnosis" of clients if the phrenological examination of the skull is incomplete or the observer is misled by the subject's hairstyle!

The basic errors of phrenology and craniology stem from a combination of fallacious reasoning and incomplete attention to disconfirming evidence. In the case of contemporary phrenology, it is easy to detect the ill-fated logic, in the form of circular reasoning evident in the following premise:

> Starting from the measurements made on a subject's skull, it is possible to state which character faculties are more or less developed. The combination of these faculties yields an overview of the subject's character and personality. These are the innate propensities of the subject, the real foundations of the personality, which may be adjusted but not

> changed by external factors like environment and education. … Phrenological analysis describes a person's naked body, external factors provide the clothes, which, even when influencing exterior appearance, will never change the body itself. (Van den Bossche, 2000b)

The premise presented is that measurements of a subject's skull are equated with innate personality characteristics, which reveal innate propensities of the subject. The conclusion is that this indicates the "real" foundations of personality. This is a fallacious argument inasmuch as the conclusion is already contained within the premise providing a circular argument.

Whether used to weed out inferior races, identify moral character flaws, or counsel individuals into professions best suited to their genetic endowment, phrenology and its related offshoots evoke the power of quantification and objectivity and use its methods, whether implicitly or explicitly, as a form of social control. Its appeal is to (pseudo)scientific techniques, advanced cultural stereotypes and prejudices based a deterministic view of human behavior.

Case: Intelligence Testing and Reification

Few areas of the social sciences have been the subject of as much contention as that of intelligence testing. Arguments about how to conceptualize and operationalize this construct have existed since antiquity. For the Egyptians, thought resided in the heart and judgment in the head or kidneys; for Plato the "mind" resided in the "brain"; while scholars during the Middle Ages gauged intelligence by the degree of quadrivium (arithmetic, geometry, music, astronomy) and trivium (grammar dialectic, rhetoric) that the educated person had mastered (Gardner, 1993a). In the 20th and now the 21st centuries, debate and discussions have centered on whether intelligence is best viewed as a unitary and stable construct (Jensen, 1992; Weiner, 1986; Graham 1991) or pluralistic and dynamic (Guilford, 1967; Gardner, 1993b; Sternberg, 1984, 1985).

The manner in which scientists view intelligence necessarily impacts their choice of methodological approaches. Where research on intelligence intersects with race, one finds conflicting genres of research, pitting "hermeneutical" approaches, which emphasize textual, historical, and political factors, with "race-realist" approaches, which stress quantitative psychometric approaches.

> The race-realist viewpoint is descriptive and typically avoids prescribing policy. To their opposite numbers, hermeneuticists come across as muddled, heated, and politically committed to 'antiracism'; the race-realists come across to their opponents as cold, detached, and suspect of hiding a 'racist agenda'. (Rushton, 1997, p.78)

The historical development of intelligence and testing is beyond the scope of this section and has been discussed elsewhere (Gould, 1996; Rushton, 1997). What is important to the present analysis is to understand how the interpretation of scores on various empirical measures of intelligence are imbued with human judgments by the scientists who analyze the data. Factor analysis is one pervasive method used in the social sciences to analyze multiple variables from various measures of intelligence for simultaneous relationships. This is a statistical technique in which large data sets with many variables can be examined for "patterned variation" and reduced to smaller subsets of variables that share common mathematical patterns (factors). Each variable in a cluster is said to "load" on that factor, which is to say it may be correlated in some way and to some extent with that factor. Scientists can make a priori or post hoc decisions as to how the data might be analyzed and how factors might be displayed and subsequently interpreted. Whether factor analysis is used as an exploratory or (theoretically) confirmatory technique, it is a powerful tool for scientists attempting to identify mathematical patterns among clusters of statistically related variables that are potentially interesting to explore.

Even the novice scientist realizes that correlation does not necessarily imply causation. And at the heart of factor analysis lies what is essentially a highbrow set of correlation procedures. But it is easy to fall prey to the seductiveness of such sophisticated statistical procedures and lose sight of the context (theoretical and real) under which those procedures are invoked. Where there is smoke it is easy to infer fire – and scientists have sometimes been lulled into assigning causal physical properties to abstract mathematical entities – the error of reification (Gould, 1996). Mathematical entities (patterned variation reflected in factors) are not necessarily isomorphic with the corresponding physical entities they purport to measure. Yet, the history of intelligence testing is replete with claims of this nature (Spearman, 1904, 1939a, 1939b; Burt, 1909, 1940, 1961; Jensen, 1979; Herrnstein & Murray, 1994). So prevailing is this error that Gould (1996) uses history to evoke a quote from John Stuart Mill not once, but twice in the same book warning scientists of this fallacy:

> The tendency has always been strong to believe that whatever received a name must be an entity or being, having an independent existence of its own. And if no real entity answering to the name could be found, men did not for that reason suppose that none existed, but imagined that it was something particularly abstruse and mysterious. (p. 350 & 378)

The moment intelligence tests are viewed as an absolute measure of a person's innate potential, society and its institutions risk falling prey to a sense of biological determinism. Once intelligence scores become reified as "things" that define the capabilities, talents and defects of an individual, paternalistic arguments may be advanced by those in authority and by those who wield power on "behalf" of those who lack the ability or inclination to advance claims for themselves. Such judgments might lead to institutionalized normative expectations in terms of what kind of performance is acceptable or desirable, as in the case of tracking in school systems. If intelligence scores are true reflections of what resides in the heads of students it is not difficult to understand how Pygmalion effects (Cooper & Good, 1983) take root in those of authority and expectations of individuals (or groups) are communicated explicitly or implicitly in ways that may lead to self-fulfilling prophesy. It is prudent to remember one central caveat that often gets muddled in many paternalistic judgments about human performance: "…norms are statistical artifacts; they are not biological realities. Biology is not committed to bell-shaped curves" (Lewontin, Rose & Kamin, 1984, p. 93).

Historically, the kind of scientific reductionism that has led to unwavering confidence in measuring the intellect "proper" has led to hereditarian theories of intelligence that resulted in racial and cultural stereotyping (Terman, 1906 &

1919; Yerkes, 1921 & 1941). More recently, theories advanced in the name of Sociobiology (Dawkins, 1976 & 1981; Wilson, 1975 & 1980) have resurrected the claim that our genes determine our destiny. At the core of this modern reductionist view is the argument that our genes dictate epigenetic biochemical and developmental pathways that determine rules for semantic networks, which govern cultural and social relationships. The "human condition," in other words, is viewed as a biological product (Wilson, 1996 & 2000). Even the philosopher's free will is rendered questionable at best, or an illusion at worst, under this mechanistic genetic view of biological determinism. Moreover, the evolution of ethics and morality is said to be determined by underlying genes and occurs only if the ethical principles or moral actions contribute to the evolutionary fitness of the individuals displaying these traits or their close relatives.

Biology, in and of itself, does not define destiny. The fallacy at the heart of the matter is the misconception that heritability is analogous to unchangeability. The extension of this view is that biological determinism implies cultural determinism. This view rules out any form of social evolution and free will. Once again, Lewontin et al. (1984) reminds us: "All human phenomena are simultaneously social and biological, just as they are simultaneously chemical and physical. Holistic and reductionist accounts of phenomena are not 'causes' of those phenomena but merely 'descriptions' of them at particular levels, in particular scientific languages" (p. 282). Sadly, the lingering effects of cultural prejudice rooted in "objective" science are still with us in the new millennium.

Unethical Science by Business and Government

Case: Tuskegee Syphilis Experiments

In the early 1930's, a philanthropic organization, in conjunction with the Public Health Service (PHS), began the Wasserman Survey, a project to diagnose and treat syphilis sufferers in Macon County, Alabama, which includes the town of Tuskegee. Macon County had long been an economically depressed area; as late as 1970, about half of residents lived below the poverty level. Conditions during the Wasserman Surveys were even worse. African Americans, most of whom barely earned a living as sharecroppers, comprised 82% of the population. Whereas national syphilis rates for African Americans were just under 1% (twice as high as Whites), 36% of Blacks in Macon County suffered from the disease. At the conclusion of the Wasserman Surveys, the PHS envisioned a new study to investigate the long-term effects of syphilis on African Americans. A similar nontherapeutic experiment had been conducted in Norway on a series of white patients, but the prevailing sentiment maintained that syphilis manifested itself differently in different races. In 1932, the PHS began screening for syphilitic African American males who had carried the disease for at least five years but had not received treatment. The project sought to study the physiological impacts of syphilis' third stage, the final and most severe disease stage, when left unchecked by medical treatment. At the study's inception, drugs existed to treat symptoms, and prolonged treatments cured some cases of the disease; however, the citizens of Macon County had no access to the treatments. PHS officials reasoned that their study subjects would suffer from the disease despite their actions so they might as well gain some insight about the disease process (Jones, 1993; Fourtner, Fourtner & Hereid, 1994).

The PHS originally intended the investigation to last for six to eight months. After nine months, the program's director retired and the study probably would have ended, but the PHS Division of Venereal Diseases' new director was interested in continuing the study. Dr. Raymond Vonderlehr had served as a field doctor for the study and when he became Director decided to prolong the study and add to the body of scientific knowledge that he had worked so hard to amass. Vonderlehr realized that blood tests, physical exams, spinal taps and x-rays on live patients could produce only a limited amount of information about the disease's pathology. By extending the study indefinitely, he would be able to autopsy the subjects and gain a much more detailed picture of syphilis' progression. By 1934, the PHS had a list of 204 Black male controls and 412 Black male syphilitics who would be monitored without treatment and autopsied upon death. The PHS proceeded unimpeded for forty years using the same protocol of passive examination and eventual autopsy (Jones, 1993). Although information on the study was publicly available, no one took notice until 1972, when a law student named Peter Buxton aroused the attention of the press. Buxton had encountered Tuskegee study reports when he worked for the PHS as an infectious disease investigator. He seemed to be the only individual disturbed by the ongoing experiments. Having failed to elicit concern from within the agency, Buxton alerted the Associated Press after leaving the PHS for law school. Associated Press reporter Jean Heller cast the Tuskegee study into the national spotlight on July 25, 1972. Public and congressional attention and outrage triggered the study's immediate termination (Fourtner et al., 1994).

The very premise of the Tuskegee study was flawed. By the 1930's, scientific studies had shown that syphilis affected Blacks and Whites in the same manner. Clinicians treated the disease exactly the same in both races. Norwegian scientists had completed a less controlled, but equally informative experiment on white patients at the turn of the century. The PHS conducted the Tuskegee experiments because of racial ignorance and prejudice (Fourtner et al., 1994). The investigator's unfounded views on race prevented them from appreciating the futility of a study that would withhold treatment from several hundred suffering patients.

The most obvious flaw in the Tuskegee study was a lack of respect for medical ethics. The PHS violated ethical norms for behavior by withholding treatment from patients. The original justification offered by the PHS, which stated that no consistently effective treatments existed and the Tuskegee patients lacked access anyway, might have satisfied some early observers. However, the medical community learned that penicillin cured syphilis in the 1940's, and by the early 1950's, penicillin was commonly available. Even as patients' bodies were ravaged by the disease, the PHS continued to deny readily available treatment for over twenty years.

Why did the individual syphilis sufferers remain in the research study for four decades? Simply put, the participants were deceived into believing that they were receiving legitimate medical attention. The subjects were mostly very poor and uneducated, and few understood the severity or nature of their conditions.

Most thought that the PHS experiments were just an extension of the Wasserman Survey, which provided the men with medical advice and temporary treatments. The PHS also offered the impoverished participants attractive incentives such as free examinations, meals on examination days, free treatment for minor problems, and burial stipends to be paid to their families. When the PHS first started working in rural Macon County, they learned that the locals referred to syphilis as bad blood, so doctors used that phrase rather than mentioning syphilis. PHS officials did not understand that the subjects referred to any ailment as bad blood and so doctor-patient communication was obscured for the entire length of the study. A study survivor made the following statement at the experiment's conclusion, "All I knew was that they just kept saying I had the bad blood- they never mentioned syphilis to me, not even once" (Jones, 1993, p.6). The subjects were also confused about the nature of the study. Most assumed that because they were seeing a doctor, they were being treated, and information provided to them perpetuated this idea. The subjects had no idea that a potential cure was being withheld. PHS not only failed to attain patient consent, it actively deceived its subjects.

At least 28 and probably as many as 100 men died as a direct result of syphilitic complications because of the Tuskegee experiments. The 300 or more other subjects suffered from tumors, skin ulcers, bone deterioration, liver damage, vascular disease and neurological disorders (Jones, 1993). Clearly what did emerge from the Tuskegee study was the illumination of dangers inherent when science objectifies humans. After the study, research institutions, hospitals and government agencies were encouraged to seek the advice of ethicists in the plan and implementation of studies involving humans and the U.S. Congress created a permanent committee to monitor and regulate all federally funded human research.

The Tuskegee Experiments caused less immediate consequences as well. When the public learned that the U.S. government had subjected 400 of its own people to this disastrous experiment, mistrust understandably evolved. The African American community, in particular, grew distrustful of the government. When the AIDS crisis surfaced in the 1980s and 90's, some African Americans questioned the role of the U.S. government. A 1990 survey of black church members reported that 35% believed AIDS was the government's attempt at genocide (Jones, 1993). Public health providers and researchers have consistently noted the impact of the Tuskegee Experiments on perpetuating AIDS conspiracy theories among Black communities (Thomas & Quinn, 1991). Members of the homosexual community have also expressed concerns over the government's role in perpetuating or even starting the disease (Jones, 1993). The deliberate misuse of science by those in charge of the Tuskegee experiments has left individual families in disarray and many groups distrusting government officials and medical authorities.

Case: Big Tobacco.

Starting in the late 1920's, biological and health researchers began investigating the effects of tobacco, and early conclusions suggested high toxicity. One researcher, employed by the industry, gauged toxicity by placing tobacco-smoke extract on rabbits' eyes. He terminated the experiment prematurely because a single drop was potent enough to cause immediate sores and the eventual loss of the entire eye. In a report that landed on several executives' desks, this scientist claimed that tobacco was the most toxic substance he had ever seen. In 1953, a research group from the Sloan Kettering Institute published a report describing the formation of cancerous tumors on the skin of mice exposed to cigarette smoke condensate. In an unpublicized meeting, top executives from the major tobacco companies (Philip Morris, R.J. Reynolds, Brown and Williamson, American Tobacco, U.S. Tobacco, and Benson and Hedges) met to address the attacks against their industry and affirm they could produce "comprehensive and authoritative scientific material which completely refutes the health charges" (Hilts, 1996, p.6). A plan emerged from the meeting for the industry to invest large sums of money to prevent scientists and public health officials from discouraging cigarette usage.

The industry sought scientists sympathetic to their cause and new mission. They awarded research grants to scientists investigating alternative cancer causation. Great efforts were made not only to sponsor research that would not produce damaging information, but would also keep undesirable results submerged. The industry began reviewing and, when necessary, censoring scientific reports prior to publication. Many experiments were simply buried so that their findings would never reach the public. In a confidential report, an industry scientist wrote, "There are biologically active materials present in cigarette tobacco. These are a) cancer-causing b) cancer-promoting c) poisonous d) stimulating, pleasurable, and flavorful (Hilts, 1996, p.25)." Damaging research, linking tobacco to many types of cancer, coronary diseases, and pulmonary problems, continued to mount throughout the 1960s and 70s. Recognizing that the "authoritative scientific material" sought by the industry did not exist, industry-funded labs charged with proving that tobacco was safe began closing down (Hilts, 1996).

It is also interesting to note that tobacco companies began investigating nicotine, the active agent in cigarettes. Industry scientists quickly showed that nicotine was addictive and without nicotine the industry would crumble. However, executives continued to claim that nicotine's sole purpose in a cigarette was to add taste. The research and manufacturing processes told a different story. Companies used specific tobacco blending protocols in order to ensure nicotine content. They also added ammonia which doubled the amount of nicotine ingested because it frees chemically bound nicotine that otherwise would not be available to the smoker. Publicly, the industry reported that nicotine content was a function of the tobacco leaves used in manufacturing. However, informants claimed that companies monitored and controlled the amount of nicotine in their cigarettes by adding the substance during the manufacturing process. Philip Morris documents indicated that nicotine content on production lines was determined hourly and, if necessary, nicotine extract was added. Some companies went so far as to study psychological profiles and nicotine affinity in order to design cigarettes that met the "nicotine needs" of customers and potential consumers (Glantz, Slade, Bero, Hanauer & Barnes, 1996; Hilts, 1996).

Many individuals find the story of Big Tobacco distasteful if not appalling, but why is this bad science? The industry has misused science in an attempt to prove the efficacy of its product when the data clearly showed that its product was dangerous. It then concealed but used information gained through science to prey on an unsuspecting public. One only has to refer to popular magazines from the 1940s and 50s to find evidence of ad campaigns by Big Tobacco that appealed to scientific authority in an effort to convey that our nation's most educated and trusted leaders wholly endorsed the use of tobacco products. Consider, for example, the advertisement R.J. Reynolds Tobacco Company ran in LIFE Magazine in 1946 that portrayed a Norman Rockwellian-like scene with a smiling family doctor standing on a sidewalk by a white picket fence lined with flowering shrubs, dressed in a white suit and fedora, wire-rimmed glasses, black bow tie, medical bag in tow, reaching out to greet and pat on the head a dimple-faced little boy, his dog and approving mother. The following words accompany this heart-warming, slice of American-Pie scene:

> The doctor makes his rounds: Where he goes, he is welcome... his life is dedicated to serving others. Not all his calls are associated with illness. He is often friend and counsellor... he is present when life begins, watches it flourish and develop. His satisfactions in life are reflected in the smiling faces of youngsters like this one [in the ad] below, and of countless others whom he has long attended. Yes, the doctor represents an honored profession...his reputation and his record of service are cherished possessions... According to a recent Nationwide survey, MORE DOCTORS SMOKE CAMELS THAN ANY OTHER CIGARETTE... If you're a Camel smoker, this definite preference for Camels among physicians will not surprise you. If not, then by all means try Camels. Try them for taste... for your throat. That's the 'T-Zone' test.... For only your taste and your throat can decide which cigarette tastes best to you...and how it affects your throat. (LIFE, August 19, 1946, p. 39)

Fifty years later, the industry continued to propagate falsities. In 1994, Philip Morris ran a full page newspaper ad making the following claim: "A large U.S. study published in the American Journal of Public Health, found no overall statistically significant link between second-hand smoke and lung cancer" (Hilts, 1996, p.106). In fact, the article claimed a small but significant increase in the incidence of lung cancer due to second-hand smoke. For many public observers, "scientific claims" carry merit just because they are "scientific." Therefore, individuals making claims under the auspices of science should adhere to one of its central tenets: full disclosure.

Deception continued as tobacco spokespeople denied the health risks associated with smoking despite overwhelming evidence produced in their own labs. Tobacco companies not only lied to the public, they used information about the potency of nicotine to exploit the physical addictions of their customers. Presenting partial truths or complete inaccuracies is a violation of scientific ethics. Big Tobacco used the name of science to give their propaganda instant value without adhering to the guidelines of the scientific enterprise.

The Tobacco Industry has produced approximately 48 million adult smokers in the US with the aid of unethical scientific practices. Between 1990 and 1994, cigarettes caused the death of 430,700 people. During this time, one out of every

5 deaths in the country was a cigarette-related death. Males that smoke are 23 times more likely to contract lung cancer than non-smokers and female smokers are 13 times more susceptible to cancer (American Cancer Society, 2000). Smoking also contributes to cancers of the mouth, throat, reproductive and urinary systems as well as a litany of cardiovascular and pulmonary diseases (Hilts, 1996). From an economic vantage, the tobacco industry has been equally devastating. It is estimated that health costs and loss of productivity have drained $100 billion from the US economy (American Cancer Society, 2000). Big Tobacco has made billions of dollars by misrepresenting scientific information and influencing public opinion as well as governmental policy. As the industry has profited, the citizens they have preyed upon have paid the price in human lives and healthcare dollars.

Even now as cigarette profitability decreases in the US and other Western countries because of increased awareness regarding the toxicity of tobacco, multinational corporations increasingly target the citizens of developing nations as potential tobacco customers. The same unethical tactics of non-disclosure and deceptive advertising practiced in the mid-twentieth century and rebuked (at least in Western industrialized nations) in the late twentieth century have been resurrected in the Third World. Cigarette promotions glorifying the use of tobacco with no indication of harmful side effects can be found throughout developing nations in Africa, Asia and South America as well as post-communist Europe. Perhaps most appalling is the industry's promotional assault on the youth of these regions. Tobacco companies continue to lend visible sponsorship to youth oriented events including teen beauty pageants, sporting events, new music promotions, dance clubs and other popular entertainment venues (Sklair, 2002). These companies and the political and social leaders, which allow unfettered access to their child and adult citizens because of financial incentives, continue to abuse the authority they have assumed.

Case: Radiation Experiments

The nature of warfare changed forever with the 1945 atomic bombing of Hiroshima and Nagasaki. The United States Department of Defense (DOD) recognized the change and decided to make preparations for future battles that would require the use of nuclear devices. In 1948, the DOD began detonating atomic bombs on and above American soil. The Pentagon not only sought to determine the physical capabilities of bombs but also the ability to coordinate troops and nuclear weapons. The Army began positioning troops in the vicinity of atomic detonations in the Nevada desert. By 1955, troops were only one and a half miles from a 1-kiloton bomb and moved towards ground zero immediately after its detonation. A 74-kiloton bomb, the largest ever detonated in the continental United States, exploded just three and a half miles away from 2,000 Marines in 1957. Later that year, the Army conducted perhaps its most dangerous test within the states. Soldiers were supposed to be stationed 4,500 yards – just over 2.5 miles – from a 42 kiloton detonation (three times the size of the Hiroshima bomb) but a shift in winds made that position unsafe. The troops piled into trucks and ended up just short of three miles from ground zero on an exposed hillside with no bunkers. Shock waves from the blast tossed the troops around like rag dolls, and they were covered in radiation.

The DOD also tested atomic devices on islands in the South Pacific. Between 1948 and 1953, the Army detonated 43 bombs in the Eniwetok Islands. During these experiments, soldiers and sailors were forced to watch the detonations through safety goggles at a distance of five miles. Many vocally protested their participation but their concerns went unheeded. Unfortunately, troops were not the only victims of nuclear testing. Radioactive fallout blanketed nearby regions filled with unsuspecting civilians including inhabited islands of the Pacific and communities in Carson City, Nevada and Salt Lake City, Utah. During one incident, radiation levels were elevated enough for the Army to recommend the evacuation of St. George, Utah a town of 4,500; but because of logistical problems in evacuating 4,500 civilians, the Army withheld its recommendation.

The Pentagon surely did not know the complete consequences of the experiments it conducted, but it certainly used its personnel irresponsibly. While scientific observers and government monitors collected data from safe locales or shielded in protective gear, soldiers became test subjects. The army ensured their soldiers of such "facts" as radioactivity did not produce sterility; water exposed to nuclear blasts was safe to drink; and troops were never placed in unsafe training conditions. Soldiers were lied to and then forced to participate in exercises that would ultimately alter their lives. Not only did the government deceive its troops, it also misled and propagandized the public. A government pamphlet distributed to Southwesterners reported that research had "confirmed that Nevada test fallout has not caused illness or injured the health of anyone living near the test site" (Rosenberg, 1980, p.78). Tragically, the future would produce very different results.

Many scientists including Nobel Laureate Linus Pauling warned of the dangers associated with nuclear testing. The DOD sought to combat this negative publicity with studies conducted by their own scientists that proved the safety of nuclear defense. In 1962, the government employed Dr. John Gofman with a staff of 125-150 including 35 senior scientists and a $3–3.5 million annual budget. When Gofman and his staff started reporting that low levels of radiation had cumulative effects comparable to deadly doses of radiation, the Pentagon censored their work and quickly withdrew financial support. These scientists, as well as those who originally opposed DOD experiments, often found themselves the targets of smear campaigns against both their professional work and private lives. In retrospect, Gofman described the errors he and other government supporters made.

> My cardinal error was that I failed to realize a central principle of public health science – in ignorance refrain. My position should have been just the opposite of what I took. If there was not a way to disprove Pauling, then the correct approach was to refrain from going ahead with atomic energy until the issue was resolved. What I was, in effect, saying is that it was O.K. to go ahead experimenting on humans by allowing exposure so as not to interfere with AEC [Atomic Energy Commission] programs. (Rosenberg, 1980, p. 149)

The Pentagon reports that between 1946 and 1963, 184 nuclear bombs were tested. Ninety-eight bombs exploded on islands in the South Pacific while 86 were detonated in Nevada (National Research Council, 1999). Some records have been lost or are incomplete, but the Department of Defense estimates that between 250,000 and 500,000 soldiers, sailors, airmen, Marines, and civilians were exposed to radiation as a direct result of nuclear experimentation. Subsequent reports indicate that those exposed have suffered increased rates of genetic birth defects, myeloma, and leukemia, and have experienced chronic radiation sickness, loss of hair and teeth, sterility, and a range of cancers, including thyroid, lung, breast, esophagus, stomach, urinary organs, tongue, colon, pancreas, skin, and bone. There is no way to determine the full effects of the radiation experiments of the 1940s through the 60's. We do not know exactly how many people were exposed and how many people have suffered as a result. Casualties will continue to mount as diseases caused by the radiation emerge in soldiers, civilians and their offspring (Rosenberg, 1980).

Unwitting Errors: Errare Humanum Est

Case: Widespread Use of DDT

Society often looks toward science for magic bullets: we want a vaccine to halt the spread of AIDS, pills to counteract fast food fat grams, and oil-eating bacteria to clean our catastrophes. Scientists believed they had found a magic bullet to eliminate problems with insects and the diseases they carry in 1934 when Swiss chemist Paul Muller discovered the pesticidal properties of DDT (dichloro-diphenyl-trichloethane). DDT appeared to be an ideal insect control agent: it was cheap, soluble in oil, easily spread, highly toxic to insects, and relatively nontoxic to mammals. In agricultural settings, one application typically destroyed 90% of the damaging pests. DDT also became a powerful tool in World War II when disease-carrying insects posed as serious a threat as opposing armies. On the home front, DDT was utilized to control human irritants such as mosquitoes and flies as well as costly agricultural pests such as potato beetles and corn earworms. Between 1943 and 1950, the United States applied more than 50 million pounds of DDT to its cities, fields, forests and streams (Cunningham & Saigo, 1999).

In the mid to late 1960s reports emerged indicating that DDT might produce unintended harmful consequences. Biological assays proved that DDT caused cancerous tumor formation in laboratory animals such as mice and guinea pigs. The same material that was freely broadcast in neighborhoods, beaches, and even directly on people was linked to cancer. Researchers never produced direct evidence of DDT as a human carcinogen, but they did find elevated levels of the chemical concentrated in exposed individuals. The risk concerned the public and Congress enough to ban its use in June 1972 and most other industrialized nations quickly followed suit (Gots, 1993). However, these same industrialized nations continue to export the pesticide and its associated problems throughout the Third World (Cunningham & Saigo, 1999).

At the time of its discovery, scientists, political leaders and the public hailed the value of DDT. In fact, Paul Muller won the Nobel Prize in 1947 for its discovery (Cunningham & Saigo, 1999). How did such a seemingly beneficial product of science become so bad? A cursory examination suggests that the scientific community understood DDT's ecological effects (killing insects) but it failed to understand the chemical's long-term effect on humans. Ironically, current evidence does not support either contention. Agents that cause cancer in lab animals do not necessarily produce the same effects in humans. Science still does not know whether DDT is a human carcinogen and the question will probably remain a mystery.

Not only did the scientific community misunderstand the relationship between DDT and human health, it misjudged DDT's role in the environment. Pesticide applicators knew DDT would kill pests but they did not realize that spraying would have more global effects. No species exists in natural isolation; all living things require interaction with other life forms in competition for food, space, light, water, nutrients or other necessities. Impacting one aspect of the biosphere necessarily produces changes in other segments of interdependent environments.

Continual DDT applications immediately killed most of the target pests but also altered the evolutionary trajectory of the populations remaining. Within a few years, successfully controlled populations developed resistance rendering further applications useless. Applicators then chose other pesticides leading to an evolutionary arms race between science and insects. Science has yet to win any such race. A well-studied case in Peru involving boll weevils infesting cotton fields illustrates the problem. In 1949, DDT was applied to fields and cotton yields increased 50%. By 1953, the boll weevils developed resistance to DDT and another pesticide was applied. The weevils rebounded once again but the wasps that naturally preyed on both weevils and a species of worm were decimated. In 1955, weevils and worms growing unchecked by their natural predator reduced yields 34% below those harvested before any pesticides were used (Cunningham & Saigo, 1999).

DDT also produced indirect, yet more noticeable results. Organisms that ingested DDT could not metabolize it into waste products; therefore, DDT and its chemical derivatives accumulated in living tissue. Even if the chemicals did not produce immediate effects, they remained in an organism until it died. If the organism decayed, the DDT molecules reentered the environment to be ingested by another living thing; if the organism was eaten, the molecules accumulated in the predator. The process of chemical accumulation within animals, known as biomagnification, was most harmful to predators at the top of the food chain (Begon, Harper & Townsend, 1996). Top carnivores like birds of prey accumulated dangerous levels of pesticides. DDT inhibited enzymes, which deposit calcium in eggshells. Birds such as eagles, ospreys and hawks produced eggshells too weak to protect the offspring. Populations of many carnivorous birds dwindled to dangerous numbers throughout the 1960s. Peregrine falcons declined to only 120 individual birds in the continental United States. Other factors, such as habitat destruction, contributed to the decline of these populations but it is unlikely that many species would have survived without the ban on DDT. Birth rates among bald eagles increased 260% in the twenty-two year period following the ban (Cunningham & Saigo, 1999). These adverse impacts of "scientific progress" did not result from an intentional assault on the environment, but rather unwitting errors committed in ignorance. The question remains whether or not society learns from history or is doomed to repeat the same fate.

Case: CFC's and Ozone Degradation.
The Frigidaire Division of the General Motors Research Corporation charged a young chemist named Thomas Midgley to solve a cooling problem. Midgley had to find a chemical coolant that was nonflammable, nonpoisonous and nonvolatile. He met the challenge by combining chlorine, fluorine and methane to produce a molecule he dubbed chlorofluorocarbon (CFC). The new product gained widespread use when DuPont marketed it commercially in 1930. Over the next half century, CFC's became a primary component for all refrigerators, air conditioners for both buildings and automobiles, aerosol cans and circuit board cleaning devices (Christianson, 1999).

Because of their physical properties, CFC's drift out of the earth's first atmospheric layer and accumulate in the stratosphere. Their use across the globe, most abundantly in the United States, coupled with the fact that individual molecules persist for 60 to 100 years yields stratospheric accumulation estimates in the millions of tons (Christianson, 1999). In 1974, two researchers shocked the world by claiming that CFC's transformed ozone molecules. Ozone is a molecule that can absorb ultraviolet radiation, but when its structure is compromised, it no longer does so. Chlorine atoms dissociate from CFC's and bond to oxygen atoms from ozone molecules rendering the ozone incapable of absorbing UV radiation (Cunningham & Saigo, 1999). A single chlorine atom can destroy 1,000 to 10,000 ozone molecules. The research suspicions of the 1970s became the reality of the 1980s when atmospheric monitoring confirmed the degradation of ozone in the stratosphere. In addition to ozone degradation, CFC's contribute to the greenhouse effect because they prevent heat from reradiating out from earth. To address the problems created by CFC's, the United States banned aerosol spray cans in 1978 and overall CFC usage has been drastically reduced since 1989 (Christianson, 1999).

The general public might not have known CFC's by name but they certainly enjoyed air conditioning, refrigerators and aerosol deodorant. No one expected science to put its seal of approval on products that could harm the world. Unfortunately, science failed. Midgley, his successors and the community of scientists charged with peer review created a molecule that satisfied industry requirements but had unknown effects beyond the business of cooling. They failed to understand the global consequences of synthesizing and releasing new chemicals. Could Midgley or anyone else have expected the consequences of CFC's? Probably not, but society is still left to deal with the aftermath.

How bad has ozone depletion become? Ground-based spectrophotometry and satellite imaging revealed a 20% reduction in ozone over Antarctica in the early 1980's. By the middle of the decade, ozone was 40% below normal levels. The ozone hole, as it has been termed, stretched to Tierra del Fuego in South America. CFC usage has been drastically reduced but many cooling devices still require CFC's and the possibility for atmospheric leaking still exists. The ozone hole seems to have stabilized but future activity is uncertain (Litfin, 1994).

Experimental evidence suggests that CFC's have eliminated part of the ozone layer, and atmospheric data supports the conclusion that less ozone translates into more ultraviolet radiation reaching the earth. Persons exposed to UV rays possess a greater chance of suffering from skin cancer, immune system impairment and eye damage. Environmental scientists have estimated that ozone depletion will cause an additional 130 million cases of skin cancer over the next century. Ultraviolet radiation is also a genetic mutagen with the potential to cause heritable cancers or other genetic diseases. The potential for damage to other species exists as well. Some researchers suggest that genetic malformations may appear in crops and forests as a direct result of exposure to increased radiation. Phytoplankton and zooplankton, the basis of all aquatic food chains, are particularly susceptible to UV rays and populations may dwindle (Makhijani & Gurney, 1995). Around the world, frogs and toads, historically one of the most prolific and diverse vertebrate groups, are disappearing. Some herpetologists hypothesize that these amphibians cannot cope with increased ultraviolet radiation (Christianson, 1999).

Conclusive evidence about the ultimate consequences of the ozone hole does not yet exist. Despite the fact that science does not have definitive answers, society must prepare for potential consequences. The CFC saga was an unintentional scientific miscue resulting from the failure to consider environmental interdependence. When humans artificially add components to the environment especially with concentrations as high as CFC's, unpredicted impacts will probably arise.

Case: Exotic Species

Any plant, animal or microorganism living in a place that it does not naturally occur is an exotic species. Humans aid the dispersal of exotics across natural barriers and/or promote their establishment by creating favorable conditions for growth and reproduction. In many cases, humans have been unknowing accomplices; live specimens, seeds or eggs get transported across barriers in ship ballast water or food products and other imports. Some exotic infestations have been clearly inadvertent such as flushing a pet fish from Africa into a sewer system that eventually leads to one of the Great Lakes. However, several exotic species have been intentionally released into foreign environments for ecological purposes. Typically, the releasers are authority figures such as government agencies that, with or without the aid of scientists, embark on biological experiments.

While there are numerous examples of intentionally introduced exotics, the case of melaleuca serves to illustrate the potential environmental and social impacts. At the turn of the twentieth century melaleuca, also known as "paper-bark tree", so named for the sheets of white, spongy bark covering its trunk and stems, was imported to Florida for ornamental purposes. Melaleuca is a tree native to Australia and New Guinea that can grow up to 100 feet tall. Mature trees consume and transpire enormous amounts of water, so in the 1930s officials liberally scattered seeds to "drain swampland". Aerial spreading and rapid growth rates aided the species' establishment throughout the Everglades and other Florida wetlands (Langeland & Burks, 1998).

Two errors were made in the introduction and distribution of melaleuca. As the two previous cases (DDT and CFC) illustrate, whenever something is put into or removed from an environment in large enough concentrations, large-scale alterations usually follow. Exotics can often out compete native species because the invaders do not have natural predators, parasites or diseases with which to contend. When melaleuca was introduced, it possessed properties that enabled it to exploit the environment differently than native plants. Native plants lacked the time needed to evolve adaptations to successfully compete. As the exotic displaced the natives, all organisms dependent and ecologically related to the natives were also affected.

The other mistake was a misunderstanding of natural ecosystems' roles. When melaleuca seeds were broadcast across Florida, scientists and the general public equated wetlands with wastelands. Land covered in standing water could not be used for building, farming, or recreating so people sought ways to convert wetlands into dry lands. After "swamp drying" had begun, ecologists realized the environmental significance of wetlands. Wetlands ensure the health of the surrounding physical environments by filtering toxins, preventing erosion, cleaning fresh water and absorbing floodwater. Wetlands are also crucial to wildlife: migratory birds use marshes as stopover points; birds, reptiles, mammals, and fish (including economically important species) breed and rear offspring in wetlands; and nutrients stored in wetlands impact a multitude of food webs. The scientific community now knows that swamps once deemed useless are actually vital.

By 1994, melaleuca infested 500,000 acres in South Florida. In at least 26,000 acres, 95% or more of the trees present were melaleuca. Natural communities in the Everglades support several tree species creating a mosaic inhabited by hundreds, perhaps thousands, of other organisms. Monolithic stands prove deadly not only for the trees that were displaced but also for ground plants which do not receive enough light through the dense canopy and animals which are not suited to exploit the trees themselves (Cox, 1999). Those responsible for spreading the exotic correctly surmised that it would dry swamps. Melaleuca has altered Florida's hydrology and compromised wetland areas because it absorbs much more water than native trees and releases most of it into the atmosphere. We cannot assess the final consequences because the "experiment" continues. Since its establishment, no one has been able to stop or even slow the spread of melaleuca. The Everglades have been altered by other factors as well, including canal digging, agricultural runoff, and residential development. The combined effects of these factors and the spread of melaleuca have prompted the federal government and the state of Florida to spend hundreds of millions of dollars on wetland restoration. Between 1994 and 1999, the Everglades Trust Fund, which drew both federal and state money, spent over $330 million on ecosystem restoration (South Florida Water Management District, 2000). The economic and environmental costs of this shortsighted scientific mishap will inevitably increase as melaleuca continues to destroy natural habitats.

PROMOTING MORAL DEVELOPMENT WITH BAD SCIENCE CASE STUDIES: IMPLICATIONS FOR SCIENCE EDUCATION

Granting authority and accepting the use of the power that follows is a necessary aspect of civilization. Citizens encounter the application of authority in all facets of their lives; they depend on governments, schools, churches, and other social institutions to bring order to a naturally chaotic existence. The acceptance of these “natural authorities” is a fundamental tenet of democracy. The social institutions that enable democracy have to be upheld and respected by the populace; however, a healthy democracy requires a citizenship sensitive to the use of power and authority as opposed to blind acceptance of that power and authority. In other words, citizens need to both revere and challenge authority. Civilization requires authoritative institutions, but not all entities with authority deserve it, and it becomes the task of the citizen to make these distinctions. An education system charged with producing good citizens should foster the development of skills to critically evaluate the products of authority.

Science is an enterprise that assumes a degree of authority based on the purported expertise of those who carry out the enterprise; however, as the cases in this chapter indicate, not all science is socially desirable. It is true that science penetrates and improves nearly all aspects of society. The modern conveniences we enjoy, the medical breakthroughs that save our lives, the technology that solves our crimes are just a few of the many ways that science edifies our world, and learners should confront these successes. However, if the scientific community vocally maintains its role in improving society, then it must also garner the courage to illuminate its own shortcomings. Our collective history is dotted with episodes in which the pillars of science not only cracked but also transmogrified into monsters of oppression, greed or misjudgment. Despite our natural inclinations to shroud these moments in darkness, we must know that they inevitably rear their ugly heads throughout a society that is forced to deal with the aftermath.

We can draw a parallel between the initial stages of moral development and the coverage of controversial cases of bad science. Piaget (1965) terms the first phase of moral development the morality of constraint. During this phase, children blindly follow the requests of their parents or other adults whom they are instructed to respect. In the mind of the child, right and wrong are determined entirely by the authority of their adult caretakers. Kohlberg’s (1985) reformulation and extension of Piagetian theory further categorizes this class of moral behavior. Kohlberg’s preconventional level (stages 1 and 2) of moral development as well as aspects of Stage 3 (within the conventional level) subsumes Piaget’s morality of constraint. The absolute obedience to people in authority positions, as described in these taxonomies, is analogous to the blind faith that much of the public has in science. In our society, statements attributed to science carry more weight than those that do not. The immediate question arises, why does science have more authority than other ways of answering questions and solving problems? The answer lies in our collective ideas about science as an enterprise. Many think of science as the “objective” quest for understanding natural truths. However, it is dangerous to believe that the outcomes of scientific endeavors are always objective revelations of the truth. Piaget and Kohlberg suggest that children move from the relatively naïve stages described above to stages characterized by the ability to evaluate situations with a framework broader than the authority of their parents. Individuals who progress through the higher stages of moral development make decisions with perspectives more distant from the primitive reliance on an immediate authority figure. For instance, a person who reasons post conventionally would consider the broader context of a social contract and possibly consider further issues of universal justice and reciprocity. In science education, the correlate of advanced moral development is the ability of students to disavow themselves from the monolithic authority of science. We are not trying to recommend that the aim of science education should be to tear down science; we are however, suggesting that students be given the opportunity to free themselves from blind reliance on science. To fully understand the power and potential benefit of science, students must also be aware of its shortcomings and drawbacks. Most products of science do not have as devastating consequences as those reported in this chapter, but students should have the skills to judge the merit of scientific activity and discovery independent of the authority the name carries.

We argue that science educators have a responsibility to share not only the triumphs of their field but the failures as well. Unfortunately, scientists and teachers of science often fall short of their mark in displaying the true, sometimes schizophrenic, nature of science. One need look no farther than the vast majority of science textbooks in use. They are filled with hundreds of pages chronicling successful experiments, "proven" theories and philanthropic results. Seldom do textbooks reveal the mistakes, failures and cover-ups that have been just as much a part of the field as some of the more meritorious accomplishments. Textbooks could serve as an effective forum for the discussion of how scientific findings and methods can be perverted to promote ideologies as in the craniology and intelligence testing cases, financial gain as in the tobacco case, or atrocities against the public as in the syphilis and radiation cases. Science texts would also be an ideal place to reveal honest mistakes such as the cases on CFC's, DDT and exotic species. By not sharing the reality of bad science with our students, we deny the fact that science is a human enterprise. The self-correcting mechanisms inherent to science help temper misguided experiments and mistakes, but science remains prone to error because it is performed by people. All people, whether they wear lab coats or not, have prejudices and make mistakes; therefore, we must expect problems in the enterprises they create, including science. Incorporating examples of bad science and its social impact into science classrooms is one way of returning to the brute fact that the activity of science has a human face.

How does the presentation of bad science differ from other suggestions to teach about the nature of science such as historical approaches or traditional STSE techniques? We are not proposing that case studies of bad science should replace historical approaches or traditional STSE topics; rather, bad science could be another tool for teachers to address the nature of science and the relationship between science and morality. This approach goes beyond simple historic examples because it forces students to grapple with the social and moral aspects of science. They go beyond traditional STSE topics because they require student to not only identify societal impacts of science but also make decisions about the ethics of the interaction.

These cases could also be used in classrooms to address issues related to\ the nature of science; consider, for instance the tentative nature of science. We want students to understand that science is developmental and our understanding of phenomena can change, but actual examples of how the field changes are treated sparsely in the classroom. The traditional examples used to reveal the evolution/revolution of science (i.e. Lamarckism to Darwinism, geocentrism to heliocentrism) are insulated from the present by the distant past. Typically the examples we use suggest that science is tentative only in those instances in which a new theory is better able to solve empirical and theoretical problems than the older. Although this is an important aspect of the development of scientific knowledge, it is not the only one. In some instances such as polygenism, conclusions should be altered because of process errors. Students of science and citizens in general need to be cognizant of the fact that whereas some scientific knowledge is very well supported, other knowledge is subject to change. Students cannot develop an understanding of these realities without critical thinking (the evaluation of arguments, assumptions and conclusions) or moral reasoning (deciphering right and wrong, just and unjust). Therefore, introducing these types of cases not only addresses issues related to the nature of science, it also provides an excellent opportunity to incorporate both critical thinking and moral reasoning into the science classroom.

In terms of morality, the cases offered in this paper provide educators with a means to address the multi-faceted nature of this domain. The Kohlbergian paradigm suggests that the most efficient way to stimulate moral development is the presentation of dilemmas for learners to work through (Kohlberg, 1985). Typical moral dilemmas, such as Heinz's struggle over stealing medicine for his dying wife, are designed so their content will not impede the processes of moral reasoning. In contrast, the cases we present encourage the mingling of content and process as recommended by contemporary moral theory (Rest et al., 1999). Discussing instances of bad science allow students a chance to employ several aspects of their moral anatomy in addition to moral reasoning. The cases of phrenology and intelligence testing challenge students to invoke their moral sensitivity and character (among other things) (Rest et al., 1999; Berkowitz, 1997). The abuses of government and business as revealed in the syphilis, tobacco, and radiation tap into a student's emotion and values (among other things) (Berkowitz, 1997).

If the aims of education are in part the promotion of critical thinking skills, moral development and argumentation, then case studies in unethical science and scientific mishaps can be a useful tool in meeting seminal educational goals. How can we expect students to critically evaluate information if they are only presented with "facts" that we emphatically assert are true? Likewise, in order to foster moral development, teachers need to present their students with ethical challenges rather than sterilized curricula, which fail to highlight moral issues. Discussions surrounding case studies will probably not, in and of themselves, improve moral reasoning skills (or any skills for that matter), but they are a good starting point for transforming traditional science classrooms into environments that stimulate moral growth. Such environments encourage students to dissect the assumptions, decisions and mistakes associated with incidents of bad science as well as investigate the morality behind them. A populace armed with these skills can justly challenge the authority that it creates, and by doing so will edify and strengthen the communication between society and its authoritative institutions.

REFERENCES

American Cancer Society (2000). Information on smoking. Retrieved August 24, 2000, from http://www.cancer.org/.

Arendt, H. (1958). *The human condition*. Chicago: The University of Chicago Press.

Begon, M., Harper, J. L., & Townsend, C. R. (1996). *Ecology: Individuals, populations and communities* (3rd ed.). Oxford: Blackwell Science.

Berkowitz, M. (1997). The complete moral person: Anatomy and formation. In J. M. DuBois (Ed.), *Moral issues in psychology: Personalist contributions to selected problems* (p. 11-42). Lanham, MD: University Press.

Berger, P.L. (1969). *The sacred canopy: Elements of a sociological theory of religion*. Garden City, NY: Doubleday & Company, Inc.

Burt, C. (1909).Experimental tests of general intelligence. *British Journal of Psychology, 3*, 94-177.

Burt, C. (1940). *The factors of the mind*. London: University of London Press.

Burt, C. (1961). Factor analysis and its neurological basis. *British Journal of Statistical Psychology, 14*, 53-71.

Callon, M. (1995). Four models for the dynamics of science. In S. Jasanoff, G. Markle, J. Peterson, & T. Pinch (Eds.), *Handbook of science and technology studies*. Thousand Oaks, CA: Sage Publication, Inc.

Christianson, G. E. (1999). *Greenhouse: The 200-year story of global warming*. New York: Walker and Company.

Colbert, C. (1997). *A measure of perfection. Phrenology and the fine arts in America*. Chapel Hill: The University of North Carolina Press.

Cooper, H. & Cooper, P. (1983). *Heads, or the art of phrenology*. London: The London Phrenology Company Ltd.

Cooper, H. M. & Good, T. L. (1983). *Pygmalion grows up: Studies in the expectation communication process*. New York: Longman.

Cooper, P. & Childs, K., (1997). *Phrenology: A guide*. London: The London Phrenology Company Ltd.

Cox, G. W. (1999). *Alien species in north America and Hawaii: Impacts on natural ecosystems*. Washington, DC: Island Press.

Cozzens, S. E. (1990). Autonomy and power in science. In S. E. Cozzens & T. F. Gieryn (Eds.), *Theories of science in society*. Bloomington: Indiana University Press.

Cunningham, W. P., & Saigo, B. W. (1999). *Environmental science: A global concern (5th ed.).* Boston: WCB McGraw-Hill.

Dawkins, R. (1976). *The selfish gene*. Oxford: Oxford University Press.

Dawkins, R. (1981). *The extended phenotype: The gene as the unit of selection*. San Franscisco: Freeman.

De Coulanges, N. D. F. (1873). *The ancient city*. In Peter Smith, Garden City, NY: Doubleday and Company, Inc. (1956).

Fourtner, A. W., Fourtner, C. R., & Herreid, C. F. (1994). Bad blood: A case study of the Tuskegee syphilis project. *Journal of College Science Teaching 23*(5), 277-285.

Gardner, H. (1993a). *Frames of mind: The theory of multiple intelligences*. New York: Basic Books.

Gardner, H. (1993b). *Multiple intelligences: The theory in practice*. New York: Basic Books.

Giere, R. N. (1988). *Explaining science: A cognitive approach*. Chicago: The University of Chicago Press.

Gieryn, T. F. (1995). Boundaries of science. In S. Jasanoff, G. Markle, J. Peterson, & T. Pinch (Eds.), *Handbook of science and technology studies*. Thousand Oaks, CA: Sage Publication, Inc.

Glantz, S. A., Slade, J., Bero, L. A., Hanauer, P., & Barnes, D. E. (1996). *The cigarette papers*. Berkley, CA: University of California Press.

Gots, R. E. (1993). *Toxic risks: Science, regulation, and perception*. Boca Raton, FL: Lewis Publishers.

Gould, S. J. (1995). *Dinosaur in a haystack: Reflections in natural history*. New York: Crown Trade Paperbacks.

Gould, S.J. (1996). *The mismeasure of man*. New York: W.W. Norton & Company.

Graham, S. (1991). A review of attribution theory in achievement contexts. *Educational Psychology Review, 3*, 5-39.

Guilford, J. P. (1967). *The nature of human intelligence*. New York: McGraw-Hill.

Harding, S. (1993). Introduction. In S. Harding (Ed*.), The "racial" economy of science: Toward a democratic future*. Bloomington, IL: Indiana University Press.

Hedderly, F. (1970). *Phrenology: A study of mind*. London: L.N. Fowler and Co. Ltd.

Herrnstein, R. J., & Murray, C. (1994). *The bell curve: the reshaping of American life by difference in intelligence*. New York: Free Press.

Hilts, P. J. (1996). Smoke Screen: *The truth behind the tobacco industry Cover-up*. Reading, MA: Addison Wesley.

Hubbard, R. (1990). *The politics of women's biology*. New Brunswick, NY: Rutgers University Press.

Jensen, A. R. (1979). *Bias in mental testing*. New York: Free Press.

Jensen, A. R. (1992). Understanding g in terms of information processing. *Educational Psychology Review, 4*, 271-308.

Jones, J. H. (1993). *Bad blood: The Tuskegee syphilis experiment*. New York: The Free Press.

Kohlberg, L. (1985). A current statement on some theoretical issues. In S. Modgil & C. Modgil (Eds.), *Lawrence Kohlberg: Consensus and controversy*. Philadelphia: The Farmer Press.

Kohlberg, L., & Mayer, R. (1972). Development as the aim of education. *Harvard Educational Review, 42*, 449-496.

Kuhn, T. S. (1970). *The structure of scientific revolutions*. Chicago: The University of Chicago Press.

Lakatos, I. (1978). *The methodology of scientific research programmes*. Cambridge: Cambridge University Press.

Lakatos, I., & Musgrave, A. (1970). *Criticism and the growth of knowledge*. Cambridge: Cambridge University Press.

Langeland, K. A. & Burks, K. C. (1998). *Identification and biology of non-native plants in Florida's natural areas*. Gainesville, FL: University of Florida.

Laudan, L. (1977). *Progress and its problems: Towards a theory of scientific growth*. Berkeley: University of California Press.

Leek, S. (1970). *Phrenology*. London: Collier-Macmillan Ltd.

Lewontin, R. C., Rose, S. & Kamin, L. J. (1984). *Not in our genes: Biology, ideology, and human nature*. New York: Pantheon Books.

LIFE, (1946). *Advertisement*, August 19, p. 39. Chicago: TIME, Inc.

Litfin, K. T. (1994). *Ozone Discourses: Science and politics in global environmental cooperation*. New York: Columbia University Press.

Lombroso, C. (1895). Criminal anthropology applied to pedagogy. *Monist 6*, 50-59.

Lombroso, C. (1911). *Crime: Its causes and remedies*. Boston: Little, Brown.

Makhijani, A. & Gurney, K. R. (1995). *Mending the ozone hole: Science, technology, and policy*. Cambridge, MA: The MIT Press.

National Research Council. (1999). *Exposure of the American people to iodine-131 from Nevada nuclear bomb tests.* Washington, DC: National Academy Press.

Piaget, J. (1965). *The moral judgment of the child.* New York: The Free Press.

Nisbet, R. A. (1966). *The sociological tradition*. New York: Basic Books, Inc.

Rest, J., Narvaez, D., Bebeau, M. J., & Thoma, S. J. (1999). *Postconventional moral thinking: A neo-Kohlbergian approach.* Mahwah, NJ: Erlbaum.

Rosenberg, H. L. (1980). *Atomic soldiers: American victims of nuclear experiments*. Boston: Beacon Press.

Rushton, J. P. (1997). Racial research and the final solution: Review essay. *Society, 34*(3), 78-82.

Sklair, L. (2002). *Globalization: Capitalism and its alternatives* (3rd ed.). Oxford: Oxford University Press.

South Florida Water Management District. (2000). Everglades. Retrieved September 2, 2000, from http://sfwmd.gov/koe_section/2_everglades.html.

Spearman, C. (1904). General intelligence objectively determined and measured. *American Journal of Psychology, 15*, 201-293.

Spearman, C. (1939a). Determination of factors. *British Journal of Psychology, 30*, 78-83.

Spearman, C. (1939b). Thurstone's work re-worked. *Journal of Educational Psychology, 30*, 1-16.

Sternberg, R. (1984). Toward a triarchic theory of human intelligence. *Behavioral and Brain Sciences*, 7, 269-315.

Sternberg, R. (1985). *Beyond IQ: A triarchic theory of human intelligence*. New York: Cambridge University Press.

Terman, L.M. (1906). Genius and stupidity. A study of some of the intellectual processes of seven "bright" and seven "stupid" boys. *Pedagogical Seminary, 13*, 307-373.

Terman, L.M. (1919). *The intelligence of school children*. Boston: Houghton Mifflin.

Thomas, S. B. & Quinn, S. E. (1991). The Tuskegee syphilis study, 1932 to 1972: Implications for HIV education and AIDS risk education programs in the Black community. *American Journal of Public Health,* 81, 1498-1504.

Trilling, L. (1972). *Sincerity and authenticity*. Cambridge: Harvard University Press.

Van den Bossche, P. (2000a). Criticisms against phrenology. Retrieved August 27, 2000, from http://134.184.33.110/phreno/professions.html.

Van den Bossche, P. (2000b). Phrenology and human resources. Retrieved August 27, 2000, from http://134.184.33.110/phreno/kritiek.html.

Wegner, G. P. (1991). Schooling for a new mythos: Race, anti-semitism and the curriculum materials of a Nazi race educator. *Paedagogica Historica 27*(2), 189-213).

Weiner, B. (1986). *An attributional theory of motivation and emotion*. New York: Springer-Verlag.

Wilson, E.O. (1975). *Sociobiology: The new synthesis*. Cambridge: Harvard University Press.

Wilson, E.O. (1980). *Sociobiology: The abbridged edition*. Cambridge: Harvard University Press.

Wilson, E.O. (1996). *In search of nature*. Washington, DC: Island Press.

Wilson, E.O. (2000). *Naturalist*. NY: Warner Books, Inc.

Yerkes, R. M. (1921). Psychological examining in the United States army. *Memoirs of the National Academy of Sciences*, Vol. 15.

Yerkes, R. M. (1941). Man power and military effectiveness: the case for human engineering. *Journal of Consulting Psychology, 5*, 205-209.

SECTION VI: CONCLUDING REMARKS

CHAPTER 14

UNIFYING THEMES IN MORAL REASONING ON SOCIOSCIENTIFIC ISSUES AND DISCOURSE

DANA L. ZEIDLER & JENNIFER LEWIS

INTRODUCTION

It is clear from the research reviewed in this volume that current reforms in science education are calling for increased curricular emphasis on the nature of science (NOS) (Abd-El-Khalick, Bell & Lederman, 1998; Abd-El-Khalick & Lederman (2000) and scientific inquiry (NRC, 2000). In particular, students are expected to develop an understanding of the epistemology of scientific knowledge as well as the processes/methods used to develop such knowledge. Among other reform imperatives, ensuring that students gain an understanding of science as a "way of knowing" is believed to be absolutely necessary if students are to make informed decisions regarding the scientifically-based personal and societal issues with which they are increasingly confronted in a modern, technologically-advanced society. At the present time, ozone depletion, recycling, genetic engineering, alternative forms of energy and other environmental and health issues are part of the daily buzz. Successful advertising campaigns have urged consumers to choose "environmentally-friendly" products. Even something as fundamental as the food we eat has become a socioscientific issue, as an almost bewildering array of competing diet books claims support from the most up-to-date scientific findings. Society believes that scientific progress comes with consequences and requires hard decisions, as reflected in television dramas highlighting advances in medical technology by spotlighting ethical questions (Who deserves treatment? Should this little girl be saved?) The media melodrama merely amplifies a societal concern for pressing socioscientific questions: When does life begin? Should research for human benefit be conducted at any cost on other animals? How should we allocate scarce

D.L. Zeidler (ed.),
The Role of Moral Reasoning on Socioscientific Issues and Discourse in Science Education, 289-306.

and costly medical or environmental resources? Should stem cell research be conducted as a viable means of therapeutic cloning?).

In the public arena, there is little support for the process of sound decision-making. Sound decisions involve careful evaluation of scientific claims by discerning connections among evidence, inferences and conclusions. Content knowledge of science is simply not enough. Students who are able to negotiate competing scientific claims will necessarily debate not only the claims themselves but also competing scientific evidence, competing inferences drawn from evidence, and competing conclusions resting on those inferences. Neither quick recitation of memorized facts nor facile use of algorithms can substitute for crucial reasoning skills or for a fully developed understanding of science in practice. To use the current socioscientific debate about global warming as an example, it is not sound to enter the debate without a well-developed understanding of issues surrounding the development and codification of scientific evidence. Claims in this case require a key piece of evidence, usually presented in the form of global temperature data. Not only does the method of data collection matter, but as seemingly straightforward a choice as the period of time over which the data is collected can also affect the resulting temperature trends. These differing trends can then be used to support rival claims. Without an understanding of the nature of science and scientific inquiry, it is impossible to ask meaningful questions (how did data collection and analysis decisions affect the data?) about contrasting temperature data presented as evidence for competing claims. Further interrogating inferences drawn from the data requires the application of reasoning skills. Hence, such decisions will necessarily involve careful evaluation of scientific claims by discerning connections among evidence, inferences and conclusions.

Arming our students with improved understandings of nature of science and scientific inquiry does not provide a complete picture of the scientifically literate individual. Moral development and ethical reasoning play an important role as students consider what is best for the common good of society or whether the "common good" is relevant to the issue at hand. The decisions that individuals choose are intimately related to their moral judgment and ability to demonstrate ethical reasoning. Up to this point in time, moral development and ethical reasoning have not been given adequate attention relative to considerations of students' understandings of nature of science and scientific inquiry. The functional degree of scientific literacy described as necessary for understanding socioscientific issues is rendered unnecessary (and unattainable) if the development of an ethical framework for moral decision-making has not been part of the picture. For example, a student's sense of the relative importance of intergenerational justice is a critical factor in determining the value to be placed upon competing claims regarding global warming. Without the development of intergenerational justice as an ethical concept, there is no need for careful consideration of competing claims; no need, in fact, to think about global warming at all.

Students who are able to think carefully about socioscientific issues may be said to exhibit a degree of scientific literacy. If they are to become fully scientifically literate, these individuals will also cultivate a positive skepticism concerning the ontological status of scientific knowledge. Their decisions will be tempered by an awareness of the cultural factors that guide and generate knowledge. Perhaps most importantly, their decisions will not occur in a vacuum. If educators structure the learning environment properly, then students will come to recognize that the decisions we all face involve consequences for the quality of social discourse and interaction among human beings and our stewardship of the physical and biological world. Moreover, if we as science educators wish to cultivate future citizens and leaders who care, serve the community, and provide leadership for new generations, then we have a moral imperative to delve into the realm of virtue, character, and moral development. Through a discussion of many aspects of socioscientific issues in science education, this book has attempted to systematically delineate the interrelationship among socioscientific elements that contribute at least in part, to a functional view of scientific literacy. We have attempted to explore how nature of science issues, discourse issues, cultural issues, and case-based and STSE issues interact with scientific inquiry, moral development, and ethical reasoning as manifest in reform based science education.

A FUNCTIONAL VIEW OF SCIENTIFIC LITERACY

To better understand the inherent connections that bind the socioscientific elements of functional scientific literacy (see Figure 1 in Chapter 1), it is appropriate to conceptualize the aims, processes/methods and products of science as a human endeavor contributing to varying epistemological positions and ontological beliefs about the status of scientific knowledge itself. Gould (1995) illustrates this point well when he writes:

> our ways of learning about the world are strongly influenced by the social preconceptions and biased modes of thinking that each scientist must apply to any problem. The stereotype of a fully rational and objective 'scientific method,' with individual scientists as logical (and interchangeable) robots, is self-serving mythology…Scientists reach their conclusions for the damnedest of reasons: intuition, guesses, redirections after wild-goose chases, all combing with a dollop of rigorous observation and logical reasoning to be sure…This messy and personal side of science should not be disparaged, or covered up, by scientists for two major reasons. First, scientists should proudly show this human face to display their kinship with all other modes of creative human thought… Second, while biases and references often impede understanding, these mental idiosyncrasies may also serve as powerful, if quirky and personal, guides to solutions. (p. 93-94)

Gould's description suggests that the activity of science is sometimes a bit rumpled like a well-worn lab coat! This in and of itself is neither good nor bad. It simply conveys what is the case; that science is always conducted in a human and therefore social context. If we, as science educators are truly concerned about a functional vision of science literacy, then that vision ought to subsume the human and social context of science.

The view that science is a social enterprise is, of course, not new (see Kuhn, 1970; Laudan, 1978; Ziman, 1980). What we advocate is that science education move beyond a vision that contrasts science with technology and society, to one that conveys science as a microcosm of society. This view entails conveying science as a process of inquiry, discourse, decision-making, commitment, negotiation, and compromise, ethical reasoning – in short, a broad-based socioscientific view. Driver, Leach, Millar and Scott (1996) also share the judgment that understanding the nature of science entails attention to the aims of science, the status of scientific knowledge (epistemological and ontological beliefs) *and* science as a social endeavor.

Once the implications of science as a social endeavor have been thoroughly infused into science education, the definition of scientific literacy must also be re-examined in light of those implications. Driver et al. present several key arguments from the literature that encompasses "functional" scientific literacy. These include: 1) a democratic argument: participation in discussion, debates and decisions concerning socioscientific issues (participation in discourse is central to an open society); 2) a cultural argument: recognition that science represents a major achievement of a given culture and understanding how the aims, processes and products are cut from the same fabric of society is of paramount concern in decisions about how resources are to be used; 3) a utilitarian argument: science for all means that everyone should have access to information relating to the goals of science as they connect to society (i.e. functional scientific literacy for all); and 4) a moral argument: realizing that there are varied institutional, cultural, societal and scientific norms (discipline-specific) that may or may not be in harmony with one another and may or may not be consistent with an individual's beliefs or convictions. It is important to note that when these arguments are considered together, a holistic view of scientific literacy –one that necessarily entails a practical knowledge of how NOS considerations, inquiry, ethical reasoning and moral development are interdependent – emerges to the forefront of science education reform.

It has been argued (see chapter 1) that in order for a functional view of scientific literacy to become realized in the science education community, a holistic view of interrelated and interdependent attributes described in this volume is necessary. Appendix 1 illustrates what some of these key attributes might look like if orchestrated together into a holistic view. We do not claim that a complete picture has been presented; rather its presentation serves as a reference point and pedagogical basis from which more detailed analyses of these elements may ensue and further discussions and research may be considered. Most important at this time is for the science education community to refine conceptualizations regarding the role of moral reasoning on socioscientific issues and discourse in science education. The authors of this book have taken the first steps to do just that.

PLURALISTIC VIEWS OF MORALITY IN SCIENCE EDUCATION

The chapter authors have all contributed to the shaping of a functional view of scientific literacy. Yet, they do so in varied ways in that the treatment given to moral reasoning on socioscientific issues and discourse is conceptualized differently depending upon the pedagogical aims at-hand. While the common denominator has been the inclusion of controversial issues in an interdisciplinary science curriculum, each author presents views of moral reasoning that emphasize unique aspects of these issues. This does not imply that holding pluralistic views is equivalent to an "anything goes" approach that is relativistic in nature. On the contrary, it suggests that there are cogent arguments supported by research and accompanied by well-developed rationales to think about the role of moral reasoning as it relates to science teaching in different ways and contexts. It also suggests, importantly, that this transformative vision of science as social endeavor (and the subsequent use of socioscientific issues as classroom illustrations of this vision) requires specific attention to the development of moral reasoning as well as the more traditional instructional goals for science education.

Zeidler and Keefer (Section I) provide an overarching context for the consideration of morality in science education. They do so by combining neo-Kohlbergian cognitive-developmental research tempered with "classical theory" thereby providing a clear pedagogical rationale for a path to moral education – one that when traveled encounters discussion, rhetoric, and argument concerning the normative role of different values in the use of classroom discussions regarding socioscientific issues. This provides a broad overarching framework under which the remaining sections may be subsumed.

Section II (Nature of Science Issues) reveals the emphasis authors place on students' epistemological beliefs as they pertain to decisions regarding socioscientific issues. Epistemological orientations regarding the nature of science impact how students attend to evidence in support of, or in conflict with, their pre-instructional belief systems regarding social issues. In this context, moral reasoning proper is understood to be the result of the opportunity for learners to make meaning using empirical and social criteria in both formal and informal educational contexts through rational discourse. Critical thinking about available information, what constitutes reasonable data, selection of data, the role of anomalous data to induce cognitive dissonance, etc. becomes central to the development of moral reasoning. Equally important in this section is the realization that increased understanding of NOS does not ensure that students automatically transfer this ability to better resolving socioscientific decisions. The necessary attention to the development of moral reasoning, which can assist in enabling the desired transfer, comes via explicit connections between students' epistemological views of science and the methods in which they seek and evaluate evidence regarding socioscientific issues. Opportunities to explore these issues are seen as central to the development of thinking in general, and to moral reasoning in particular.

Section III (Classroom Discourse Issues) presents a synopsis of the importance discourse plays in peer interactions and its impact on reasoning. The authors of this section stress the importance of developing students' views about science through argumentation in the constructions of shared social knowledge via discourse about socioscientific issues. Evaluating the quality and types of arguments and knowledge of common fallacious argument helps to ensure the delivery of pedagogically important outcomes; however, to fully engage in argumentation about socio-scientific issues, students quickly move beyond considering only STS interrelationships and quite naturally pay attention to the moral dimensions of the issues. Accordingly, teaching science in this context includes attention and sensitivity to students' moral commitments, emotions, and moral behavior. The development of character in children (as seen via the development of moral reasoning) becomes an additional important pedagogical outcome arising from the intrinsic nature of argumentation as pedagogy. Transactive peer discussions and tasks, use of authentic, real world problems, and careful multi-faceted assessment (particularly portfolio products) are all tools available to the science educator to promote the development of epistemic and conceptual structures, metacognitive practices, the ability to evaluate scientific knowledge claims and inquiry processes, and perhaps most importantly, the social development of the child. Again, the use of socioscientific issues in the classroom has necessitated explicit attention to moral reasoning.

Section IV (Cultural Issues) stresses the inclusion of all students in scientific inquiry. This in itself is a moral commitment. Scientific inquiry that is sensitive to cultural perspectives gains even broader meaning when understood in terms of the moral growth of the child. Scientific inquiry, in this context, transcends mere description, interpretation, experimentation, and explanation; it includes teachers' awareness of their students as moral agents intimately involved with nature – making decisions that affect their own subjective experiences with nature as well as with those around them. Related to this is how teachers themselves model, apply and enforce ethical codes in their own profession as well as those related to scientific research that are defensible. This is an area generally under-examined in preservice science teacher education programs. Tolerance, mutual respect, and knowledge of adaptations for cultural differences (including those differences of students with disabilities) in science classes are necessary components of inclusive settings. The opportunity to examine such values for both preservice and inservice teachers is necessary to help facilitate a value-fair environment. In terms of our focus on moral reasoning, it is only in a value-fair environment that the moral development of the child can be fostered. Attention to teacher education practices that support the creation of value-fair classrooms is sorely needed.

Finally, Section V (Science-Technology-Society-Environment Social and Case-based Issues) reinforces the stance that in order to develop scientifically literate citizens, the science education community must move beyond past STS practices which usually do not pay explicit attention to the moral growth of the child. STSE moves a step in the right direction in that a concerted emphasis is placed on identifying the elements of socioscientific problems that entail decision-making, moral reasoning and responsible action (moral and ethical reasoning in action). Case-based approaches to science instruction that consider the underlying ethical and moral dimensions of science are presented as a means to stimulate and nurture the moral development of the child. The use of these types of cases, it has been argued, is appropriate for both science teacher education courses (professional ethics applied to science and science education) and students in the K-12 classroom. Morality, authority and power are viewed as core concepts in the scientific enterprise and having students "dissect" these concepts through case analysis and evaluate their relative impact on the progress of science as well as the public's confidence in science holds powerful lessons in the moral education of our students.

A FINAL WORD

We thought it fitting to close this volume by considering two interesting and perhaps (mildly) amusing quotations. They both have bearing on how the science education community ultimately wishes to view its role with respect to the development of the child. Let us examine them in concert:

> Theoretical morals are the sort you get on your mother's knee, in good books and from the pulpit. You gather them in your head and not in your heart; they are theory without practice. (Mark Twain, 1899 p. 186)

> The opinions that are held with passion are always those for which no good ground exists. Indeed, the passion is the measure of the holder's lack of rational conviction. (Bertrand Russell, 1928 p. 301)

There are, in all likelihood, a number of educators (science teachers or otherwise) who believe our role is to teach content, not morals! If the contributing authors of this book have not convinced such individuals of the primary role moral reasoning holds in science education, nor the pedagogical importance of infusing socioscientific issues and discourse in our classrooms, then we might add just one more thought: consider that we teach children first and foremost – we teach our subject matter second. Mark Twain, while not often cited for his contributions to education, was an astute observer of human nature. He seemed to realize that knowledge from books, culture or authority was empty unless one has the opportunity to *experience* those ideas. With the emphasis on real world problems in science education reform, we know of no better way to cultivate informed judgment unless educators provide the kinds of experiences that will allow children to do something with what is in their heads – put theory into practice as they discuss competing and sometimes conflicting ideas, negotiate varied points of view, and formulate consensual decisions while understanding the consequences for those decisions. Bertrand Russell seems to be warning us that stark passion lulls us to blindly hold beliefs that are immune to self-inspection in the face of discrepant evidence or discourse. Open-mindedness is a virtue held in high regard by many but probably practiced by view. Surely, the best we can offer our students is the opportunity and ability to develop openness of mind! This perhaps, is the moral imperative of all science educators.

Table 1: Interdependent Developmental Attributes Affecting Scientific Literacy

Developmental Attributes			**Recommended NOS Focus**	**Habits of Mind**
Cognitive Stages: Structures or Schemes	**Moral Reasoning:** Stages or Patterns	**Sociomoral Discourse:** Argumentation	**Nature of Science:** Exemplars or Indicators	**Scientific Inquiry:** Exemplars or Indicators
Preoperational Thinking	*Pre-conventional (Stages 1 and 2*	*Pre-argumentation (Stage 0)*		*PreK-Grade 2*
• Intuitive Thought • Animistic Thinking • Transductive Reasoning • Confusion between apparent quantitative / qualitative changes with actual changes in physical systems or phenomena.	• Dominated by egocentric reasoning • Focus on advancing own needs by self-serving actions. • Interprets cultural rules and labels as dichotomies (good/bad; right/wrong; punishment/ reward). • Instrumental exchange of favors. • Pragmatic but relativistic fairness	• Does not recognize a need for discourse. • Idiosyncratic/ irrelevant. *Single Reason Argumentation (Stage 1)* • Isolated justifications, unconnected or loosely related arguments. • Pragmatic argument to maintain chosen position	• Scientific knowledge is empirically-based. • Scientific knowledge is stable, but never absolute.	• Importance of observing the same things and comparing them. • Tests repeated under the same conditions usually produce similar results. • It is helpful to work in teams and share findings with others.

Developmental Attributes			**Recommended NOS Focus**	**Habits of Mind**
Cognitive Stages: Structures or Schemes	**Moral Reasoning:** Stages or Patterns	**Sociomoral Discourse:** Argumentation	**Nature of Science:** Exemplars or Indicators	**Scientific Inquiry:** Exemplars or Indicators
Concrete Operational and Transitional Thinking	*Conventional Reasoning (Stages 3 & 4)*	*Maintaining Connections (Stage 2)*		*Grades 3-5*
• Serial Reasoning • Concrete Reversibility • Establishing correspondence and inverse correspondence between sets of (concrete) variables.	• Focus on interpersonal relationships and expectations. • Concern towards those who are immediately important to oneself (family, friends teachers, etc.). • Behavior based on stereotypical images of “proper” conduct by those who are close or perceived to be important to oneself. • Reasoning marked by an increasing orientation toward fulfilling fixed social rules and duties and maintaining social order.	• Exchange multiple justifications with some logical coherence, identify a central thesis, search for shared solution. *Counterevidence (Stage 3)* • Use of counterevidence, attempts at falsification, defends against such strategies.	• Scientific knowledge is empirically-based. • Scientific knowledge is influenced by subjectivity. • Scientific knowledge involves creativity. • Scientific knowledge entails observation and inference.	• Importance of accurate records and descriptions to provide clues for possible causes of discrepancies in repeated experiments. • Observations and analyses need to be carefully communicated to others. • Collaboration allows for all team members to reach, explain and justify their own conclusions. • A model of something is different from the actual thing but can help us to understand more about the real thing.

Developmental Attributes			**Recommended NOS Focus**	**Habits of Mind**
Cognitive Stages: Structures or Schemes	**Moral Reasoning:** Stages or Patterns	**Sociomoral Discourse:** Argumentation	**Nature of Science:** Exemplars or Indicators	**Scientific Inquiry:** Exemplars or Indicators
Concrete Operational and Transitional Thinking	*Conventional Reasoning (Stages 3 & 4)*	*Maintaining Connections (Stage 2)*		*Grades 3-5*
				• People alone (but usually in groups) invent new tools to solve problems, do work, make decisions, and form new ideas that affect other people's lives outside of science. • Before a group of people build something or try something new,
				Grades 6-8
			• Testable / Evidence Empirical	• Importance of accurate record keeping and openness in maintaining an investigator's credibility with other scientists and society.

Developmental Attributes			**Recommended NOS Focus**	**Habits of Mind**
Cognitive Stages: Structures or Schemes	**Moral Reasoning:** Stages or Patterns	**Sociomoral Discourse:** Argumentation	**Nature of Science:** Exemplars or Indicators	**Scientific Inquiry:** Exemplars or Indicators
Concrete Operational and Transitional Thinking	*Conventional Reasoning (Stages 3 & 4)*	*Maintaining Connections (Stage 2)*		*Grades 6-8*
			• Tentative NOS	• Scientific knowledge is subject to modification as new information challenges prevailing theories or as new information leads to examining past observations in a new way.
			• Observation vs. Inference • Creative • Subjectivity	• The study of the events that led scientists to discoveries can provide information about the inquiry process itself and its effects.
			• Objective /Subjective	• Science disciplines differ from one another in focus, techniques, and outcomes but they share a common purpose.

Developmental Attributes			**Recommended NOS Focus**	**Habits of Mind**
Cognitive Stages: Structures or Schemes	**Moral Reasoning:** Stages or Patterns	**Sociomoral Discourse:** Argumentation	**Nature of Science:** Exemplars or Indicators	**Scientific Inquiry:** Exemplars or Indicators
Concrete Operational and Transitional Thinking	*Conventional Reasoning (Stages 3 & 4)*	*Maintaining Connections (Stage 2)*		*Grades 6-8*
			• Objective / Subjective • Creativity • Cultural Influences	• Scientific contributions are made by individuals of diverse backgrounds, interests, philosophies, and motivations.
			• Amoral vs. Ethical Considerations	• Scientists must not knowingly subject others to health or property risks.
			• Amoral vs. Ethical Considerations	• Special care must be taken in using animals in scientific research.
			• Amoral vs. Ethical Considerations	• Research involving human subjects requires informed consent about the risks and benefits as well as the right to refuse to participate.

Developmental Attributes			**Recommended NOS Focus**	**Habits of Mind**
Cognitive Stages: Structures or Schemes	**Moral Reasoning:** Stages or Patterns	**Sociomoral Discourse:** Argumentation	**Nature of Science:** Exemplars or Indicators	**Scientific Inquiry:** Exemplars or Indicators
Concrete Operational and Transitional Thinking	*Conventional Reasoning (Stages 3 & 4)*	*Maintaining Connections (Stage 2)*		*Grades 6-8*
			• Amoral vs. Ethical Considerations	• Technological designs should take into account constraints such as natural laws, the properties of the materials used, and economic, political, social, ethical, and aesthetic values

Developmental Attributes			Recommended NOS Focus	Habits of Mind
Cognitive Stages: Structures or Schemes	**Moral Reasoning:** Stages or Patterns	**Sociomoral Discourse:** Argumentation	**Nature of Science:** Exemplars or Indicators	**Scientific Inquiry:** Exemplars or Indicators
Formal Operational Thinking	*Postconventional Reasoning (Stages 5 & 6)*	*Shared Analysis (Stage 4)*		*Grades 9-12 and College*
• Hypothetico-Deductive Reasoning • Systematic Control of Multiple Variables • Probabalistic Reasoning • Proportional Reasoning • Correlational Reasoning • Combinatorial Reasoning • Propersitional Logic	• Reasoning encompasses a contractual, legalistic view of due process. • A utilitarian concern for social justice. • Evaluation of moral and legal points of view. • Rational and impersonal calculation of formal judicial and social processes. • Recognition of certain non- relative values (e.g. life, liberty). • Respect for universal ethical principles.	• Mutual discourse, each argument is critically examined and understood to be subject to counter argumentation. • Reasoning about the argument. *Ideal Discourse (Stage 5)* • Discussants recognize that everyone in a discussion must strive toward the most just or best solution. (See Criteria of internal coherence (my term).	• Tentativeness • Subjectivity • Creativity • Observation vs. Inference • Empirically-Based	• The importance of skepticism in science -- all possible sources of bias in the design of investigations and in data analysis should routinely be done for one's own work and the work of others. • Investigations are conducted to answer questions, explore new phenomena, check on previous results, test how well a theory predicts, and compare different theories.

Developmental Attributes			**Recommended NOS Focus**	**Habits of Mind**
Cognitive Stages: Structures or Schemes	**Moral Reasoning:** Stages or Patterns	**Sociomoral Discourse:** Argumentation	**Nature of Science:** Exemplars or Indicators	**Scientific Inquiry:** Exemplars or Indicators
Formal Operational Thinking	*Postconventional Reasoning (Stages 5 & 6)*	*Shared Analysis (Stage 4)*		*Grades 9-12 and College*
			• Subjectivity • Tentativeness • Cultural Influences • Zeitgeist Influences	• New ideas in science are limited by the context in which they are conceived.
			• Empirically-Based • Subjectivity • Tentativeness	• In the short run, new ideas that do not mesh well with mainstream ideas in science often encounter vigorous criticism; -- In the long run, theories are judge by how they fit with other theories, how well they explain all salient observations, and how effective they are in predicting new findings.

Developmental Attributes			Recommended NOS Focus	Habits of Mind
Cognitive Stages: Structures or Schemes	**Moral Reasoning:** Stages or Patterns	**Sociomoral Discourse:** Argumentation	**Nature of Science:** Exemplars or Indicators	**Scientific Inquiry:** Exemplars or Indicators
Formal Operational Thinking	*Postconventional Reasoning (Stages 5 & 6)*	*Shared Analysis (Stage 4)*		*Grades 9-12 and College*
			• Subjectivity • Tentativeness	• The importance of peer review, truthful reporting of the methods and outcomes of investigations, and public awareness of the findings.
			• Subjectivity • Creativity • Observation vs. Inference	• The degree of objectivity in science is relative – science is a very human activity.
			• Subjectivity • Cultural Influences	• In practice, scientific progress is subject to personal and societal values, agendas, and priorities as much as any other human activity.

Developmental Attributes			**Recommended NOS Focus**	**Habits of Mind**
Cognitive Stages: Structures or Schemes	**Moral Reasoning:** Stages or Patterns	**Sociomoral Discourse:** Argumentation	**Nature of Science:** Exemplars or Indicators	**Scientific Inquiry:** Exemplars or Indicators
Formal Operational Thinking	*Postconventional Reasoning (Stages 5 & 6)*	*Shared Analysis (Stage 4)*		*Grades 9-12 and College*
			• Cultural Influences • Zeitgeist Influences	• Ethical questions are interwoven with the activity of science and have bearing on the reciprocal relationships among Science, Technology, Society, and the Environment.

REFERENCES

Abd-El-Khalick, F., Bell, R.L., & Lederman, N.G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education, 82*, 417-437.

Abd-El-Khalick, F., & Lederman, N.G. (2000). Improving science teachers' conceptions of the nature of science: A critical review of the literature. *International Journal of Science Education, 22*, 665-701.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science*. Buckingham, Philadelphia: Open University Press.

Gould, S. J. (1995). *Dinosaur in a haystack: Reflections in natural history* (1st ed.). New York, New York: Harmony Books.

Kuhn, T. S. (1970). *The structure of scientific revolutions*. Chicago: The University of Chicago Press.

Laudan, L. (1977). *Progress and its problems: Towards a theory of scientific growth*. Berkeley, CA: University of California Press.

National Research Council, (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, DC: National Academy Press.

Russell, B. (1928). Skeptical Essays. In E. Knowles (Ed.), *Oxford dictionary of phrase, saying and quotation*s. (1997, p. 301). New York: Oxford University Press.

Twain, M. (1899). Speech in London, June 29, 1899. In R. Kent Rasmessen (Ed.), *Mark Twain: His words, wit and wisdom* (1997, p. 186). New York: Gramercy Books.

Ziman, J. M. (1980). *Teaching and learning about science and society*. New York: Cambridge University Press.

NOTES ON CONTRIBUTING AUTHORS

Fouad Abd-El-Khalick is an Assistant Professor of Science Education at the Department of Curriculum and Instruction, University of Illinois at Urbana-Champaign, USA. He received his PhD in Science Education from Oregon State University (1998), Corvallis, Oregon, USA, and MA in Science Education (1995) and BS in Biology (1991) from the American University of Beirut, Lebanon. His research primarily focuses on the teaching and learning of nature of science in K–12 and preservice and inservice teacher education settings, the development of learners' global and scientific epistemological views, and science teachers' content and pedagogical content knowledge.

Randy L. Bell is an Assistant Professor of Science Education in the Curry School of Education at the University of Virginia, where he teaches courses in secondary science methods, educational technology, and science education research methods. His educational background includes a B.S. in Botany and an M.S. in Forest Ecology. Prior to obtaining the Ph.D. in Science Education, Dr. Bell taught high school and middle school science for six years in Oregon, where he was recognized as the "New Science Teacher of the Year" in 1991. Dr. Bell's primary research interests center on teaching and learning about the nature of science and scientific inquiry. He has published research and commentary in a variety of journals, including *Science Education*, the *Journal of Research in Science Teaching*, the *Canadian Journal of Science, Mathematics, and Technology Education, Science & Education, Learning and Leading with Technology, Ecology,* and the *Canadian Journal of Forest Research*.

Marvin W. Berkowitz is the Sanford N. McDonnell Professor of Character Education at the University of Missouri-St. Louis. Formerly he served as the Ambassador Holland H. Coors Professor of Character Development at the US Air Force Academy and Professor of Psychology at Marquette University. A developmental psychologist (Ph.D., Wayne State University, 1977), his research interests are in character education, moral development, adolescence, and risk-taking.

Richard Duschl is Chair of Science Education at King's College London and past editor of *Science Education.* His research interests focus on the design of learning environments with emphases on assessment, inquiry, and argumentation discourse processes.

Sibel Erduran is a Research Associate at King's College, University of London. She received her Ph.D. degree in Science Education from Vanderbilt University, MS degree in Food Chemistry from Cornell University and BA degree in Chemistry and Biochemistry from Northwestern University, USA. She was an educational researcher at University of Pittsburgh and a high school chemistry teacher in northern Cyprus. Her research interests include the application of history and philosophy of science in science education, with a particular interest in promoting epistemological reasoning in chemistry education.

Matthew Keefer received his Ph.D. in 1994 from the University of Toronto's Ontario Institute for Studies in Education. He was a visiting scholar at Georgetown University and pursued post-doctoral studies at the University of Pittsburgh's Learning Research and Development Center. Dr. Keefer's research and scholarship focuses on the areas of cognitive studies in teaching and moral education. He has published articles in the fields of moral philosophy, moral psychology, discourse and argumentation studies, inquiry-teaching, and professional ethics. Dr Keefer has been a Principal Investigator for three research projects two funded by NSF and one by The James S. McDonnell Foundation. Dr Keefer is presently Associate Professor and Chair of the Division of Educational Psychology at the University of Missouri, St Louis.

Norman G. Lederman is currently Chair and Professor of Mathematics and Science Education at the Illinois Institute of Technology. He has taught a full range of graduate (Masters and Doctoral) courses in secondary science education. Dr. Lederman received his Ph.D. in Science Education from Syracuse University (1983). He has received the Illinois Outstanding Biology Teacher Award (1979), a Presidential Citation for Distinguished Service from AETS (1986), the Burlington Resources Foundation Faculty Achievement Award for Excellence in Teaching and Research (1992), the AETS Outstanding Mentor Award (2000), and the NARST Award for Outstanding *JRST* Paper (2001). Dr. Lederman is internationally known for his research and scholarship on the development of students' and teachers' conceptions of the nature of science and scientific inquiry. Dr. Lederman is Past-President of the NARST and AETS. Dr. Lederman is presently the Editor of the journal *School Science and Mathematics* and serves, or has served, on the Editorial Boards of numerous international educational research journals.

Jennifer Lewis is an Assistant Professor of Chemistry at the University of South Florida. She received her Ph.D. in Chemistry from The Pennsylvania State University in 1998. Following that, she spent two years at Beloit College as part of the ChemConnections project, teaching general chemistry via topical modules driven by real-world questions. She is active in the evaluation of national college chemistry curriculum reform projects. Currently, she teaches graduate courses in chemical education and undergraduate chemistry courses. Her research is on student conceptual understandings of chemistry and faculty perceptions of teaching.

Cathleen C. Loving is an associate professor in the Department of Teaching, Learning & Culture at Texas A&M University. She received bachelor's and master's degrees in biology from Pennsylvania State University and Duke University, respectively, and taught high school biology for a number of years before returning for a Ph.D. in science education at The University of Texas at Austin. She has a particular research interest in the relationship between conceptions of the nature of science and science teaching, especially modern versus postmodern notions. She is also involved in research on the role information technologies have in improved science conceptual understanding and improved notions of the nature of science. She has published in *The American Educational Research Journal*, *Journal of*

Research in Science Teaching, Science Education, Science and Education and The Journal of Science Teacher Education among others.

Susan Lowy is a Senior Lecturer in the Department of Health and Kinesiology at Texas A&M University. She received her Bachelor of Science degree from State University of New York College at Cortland in 1972, and a Master of Science degree from the University of Colorado in 1975. After several years as a public school physical education teacher she came to Texas A&M University. Susan works in the area of teacher education, contributing to physical education pedagogy and the foundations program in secondary education. She became involved with developing the ethics teaching protocol used at TAMU when the secondary education program was being redesigned. Susan currently serves as a School Board Trustee and brings that perspective to undergraduate teacher education.

Nancy MacGregor received her Ph.D. from the University of Illinois where she is currently an instructor in the Department of Curriculum and Instruction and teaches language/literacy methods, general methods, and children's literature. She is a former elementary school teacher with more than 30 years of classroom experience, including science instruction. Her work is primarily in the area of reading and how children engage with literature.

J. Randy McGinnis is an Associate Professor of Science Education in the Science Teaching Center (Department of Curriculum & Instruction) at the University of Maryland, College Park. In addition to teaching undergraduate and graduate courses in science education and directing graduate studies he has been a Co-Principal Investigator for the Maryland Collaborative for Teacher Preparation (MCTP), an NSF funded mathematics and science teacher education program. Dr. McGinnis's research interests are clustered in three areas and reported in journal, book, and conference formats: science teachers' beliefs and attitudes; equity education; and the role of history and philosophy in science teaching/learning. In 1998, NARST recognized his research with "The Early Career Research Award." He serves on the Executive Board of NARST and AETS. He also is an Associate Editor for the *Journal of Research in Science Teaching.*

Martin Monk was appointed a temporary lecturer at Chelsea College in 1981. As Chelsea was absorbed by King's College London in 1985 he continued to work with trainee science teachers, masters students and supervise PhD students. Currently he spends a lot of time with science teachers from Egypt and in Southern Africa. Martin's interests focus on designing science learning activities that fit the constraints of large classes, few resources and under trained science teachers. His Translation Activities are in use from Cape Town to Cairo.

Jonathan Osborne is a Professor of Science Education at King's College London where he has been since 1985. His work involves teaching beginning teachers on the Post-Graduate Certificate of Education, teaching on Masters and professional development courses and supervising research students. Prior to this he worked as a teacher of physics in Inner London comprehensive schools for 12 years. He has conducted research in the area of primary children's understanding of science, attitudes to science, informal learning, teaching the nature of science and argumentation. He was a co-editor of the influential report *Beyond 2000: Science Education for the Future*.

Erminia Pedretti, Ph.D., is an Associate Professor of Science Education at the Ontario Institute for Studies in Education of the University of Toronto (OISE/UT). She also serves as the Associate Director for the Imperial Oil Centre for Studies in Science, Mathematics and Technology Education at OISE/UT and teaches in both the pre-service and graduate programs. Her current research interests include: science, technology, society and environment (STSE) education; action research; teacher professional development; and learning science in non-school settings.

Troy D. Sadler is a Doctoral Candidate at the University of South Florida (USF). After conducting research in ecological and evolutionary genetics at both the University of Miami and Harvard University, Troy turned his attention to science teaching. He spent four years teaching science in middle and high schools and now works with pre- and in-service science teachers at the college level. His research endeavors in science education have focused on socioscientific issues, moral reasoning, argumentation, and informal reasoning. He has also presented that research at international and regional conferences and has related articles in international and national journals. He is currently completing his dissertation research, which focuses on the effects of moral decision-making and content knowledge on informal reasoning regarding genetic engineering issues and has accepted an Assistant Professor position at Indiana University.

Michael L. Simmons is currently a Doctoral Candidate in Curriculum and Instruction of Science Education at the University of South Florida. After graduating from the University of Southwestern Indiana with a B.S. in Biology, he moved to Florida and began teaching high school science in St. Petersburg, accumulating 17 years of classroom experience. From 1992 to 1995, Michael gained science research experience as a full-time marine biology master's student in the College of Marine Science at the University of South Florida, and then changed his course of study to Science Education. Michael has taught science content and science education methods and trends courses as an adjunct and graduate assistant at St. Petersburg College and the University of South Florida since 1994. His research interests include moral and cognitive development, conceptual change, critical thinking, and the nature of science. Michael lives in St. Petersburg, Florida with his wife Joan and their two children, Jasmine and Trent.

Patricia E. Simmons currently holds the William R. Orthwein, Jr. Professorship of Life-long Learning in the Sciences at the University of Missouri-St. Louis, a special endowed collaborative professorship between the University of Missouri and the St. Louis Science Center. She received a Bachelors degree in Secondary Education, a Masters in Biology, and a Ph.D. in Science Education. She is a former high school science teacher. Much of Dr. Simmons's scholarship focuses on the role of technology in science education (i.e., computer-based instruments for analysis of teacher beliefs and knowledge). Her recognitions for excellence include Outstanding Teaching and Faculty awards, Outstanding Science Teacher Educator from the Association for the Education of Teachers of Science, and two Ohaus Awards for Excellence in College Science Teaching from the National Science Teachers Association

Shirley Simon is a Lecturer in Science Education at the Institute of Education, University of London. She is a course tutor for the Initial Teacher Education program in science, specialising in chemistry, and leads the Professional Development Portfolio module for the Institute's Master of Teaching program. She contributes to the MA in Science Education in the areas of conceptual change, language in science, thinking skills and research methodologies. Her current research interests include classroom discourse and argumentation in science, curriculum innovation and teachers' professional development. She has published in the areas of science investigations, progression in learning and cognitive acceleration. She holds a Ph.D. degree, has taught in secondary schools and has been a consultant for the British Broadcasting Corporation's work in science education.

Klaus Witz is an Associate Professor of Education in the Department of Curriculum and Instruction at the University of Illinois at Champaign-Urbana. His interests include methodology in the social sciences, philosophy of education, philosophy of science, and spirituality. Currently he is working on a book of case studies of undergraduate students becoming involved in mathematics and making mathematics their academic career.

Dana L. Zeidler is a Professor of Science Education and the Program Coordinator for Science Education in the College of Education at the University of South Florida. He received his Ph.D. from Syracuse University in 1982 and has worked closely with both science and non-science majors for over 25 years. Currently, he teaches undergraduate science methods (K-12) courses, masters and doctoral courses. Dr. Zeidler has presented numerous papers, symposiums and workshops at international, national and regional conferences on invoking moral reasoning about socioscientific issues, discourse about moral and ethical issues in science and society, nature of science and critical thinking-related issues. He is also the past president of SAETS and has received Outstanding Position Paper Awards from that association. Dr. Zeidler presently serves on numerous editorial review boards of international science education journals. He also holds a 5th Dan and is a certified Sensei of Isshinryu Karatedo.