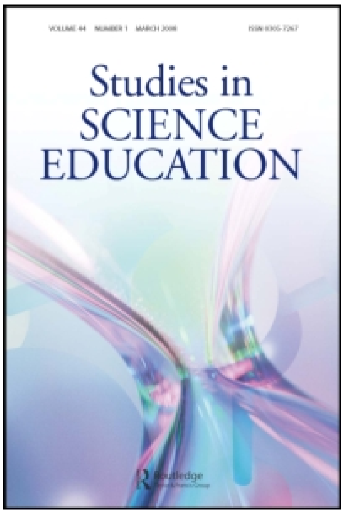

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What Role for the Humanities in Science Education Research?[1]

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Many researchers in the field of education aspire to influence what actually happens in schools and classrooms. They entered their profession aware of the need to improve educational practice; many of them want to make a difference. Yet few observers would claim that the results of education research are eagerly awaited by teachers, school administrators, those who work at shaping education policy, or the general public. While research findings occasionally capture the attention of a broad audience of practitioners and the public, and indeed exert influence on policy and practice, such instances are all the more notable for their rarity.

This essay focuses on one way of possibly increasing the relevance of education research, and improving it. It argues that science education researchers might enhance their impact on practice if they expand the theoretical foundations from which they usually operate and the methods they commonly employ.

Like much of education research, the science education branch tends to draw most heavily from scholarly traditions associated with the social and behavioural sciences. These fields, in turn, strive to emulate physical science—especially physics. Hypothesis testing, experimentation, replication, and generalization are the hallmarks. In recent years, comparisons of educational programmes based on randomized samples have been advanced as the scientific ideal in the field of education (National Research Council, 2002). The result is that certain kinds of research, and their results, are favoured over others. But it is by no means clear that the phenomena that tend to be examined in scientifically inspired and conducted educational research today get to the heart of some of the most salient issues associated with understanding educational practice and improving it.[2]

Scientifically grounded replication-oriented perspectives tend to be oriented toward objectives that are most readily measured by commonly accepted methods in the social and behavioural sciences. That's one limitation. More fundamentally, however, research yoked too tightly to a scientific model almost always treats matters of worth as secondary or implicit. That is, significant moral and value questions are subsumed in scientific research on methods of teaching, or on techniques for grouping students, or on means of assessing certain levels of achievement; but these values are rarely addressed directly by scholarly examination. This stance, which is seldom overt, can sidestep matters that educators and the general public care about deeply, and regarding which the research community might have something to say if it were to broaden its canvas of objectives and its palette of techniques.

APPLIED SCIENCE?

It may be instructive to turn first to the limits of the physical and biological sciences themselves when scientists in these fields attempt to address a policy issue that is permeated with scientific content. Scientists often assume that decisions about the policy in question should flow primarily from the current understanding of the relevant research. If there is growing pollution of a river and steps are being proposed to mitigate the problem, scientists might try to find out about the sources of contamination and recommend action that might reduce damage to the environment. Looking only at the science, the necessary steps sometimes seem straightforward and unproblematic—but misleadingly so.

Many interests are centered on the river. Perhaps the pollution is associated with contaminants from an upstream factory. Large costs may be necessary for mitigation of the problem. Who pays? Assigning financial responsibility may stimulate opposition from the factory owners concerned about profit and workers who worry about their jobs. The resistance may have little to do with the relevant science alone. How is such a matter to be addressed? The decisions that need to be made (or not made) become entwined in a complex mix that includes much more than the applicable science.

The situation often becomes even more confusing because those who are apprehensive about the scientifically derived steps to reduce pollution may choose to strengthen their arguments by raising doubts about the underlying science itself. And it isn't unusual to find at least some scientists who advocate a contrary view to the actions proposed by most scientists who have addressed the issue.

During the past ten years, it has not been unusual to see scientists emerge on opposite sides of almost every major controversial science-related social issue, including the existence of global climate change, the uses of stem cells for medical research, the use of extraordinary efforts to prolong life in long-comatose patients, and the teaching of biological evolution. Often, in such instances, there is a solid consensus on one side: Earth's climate is changing. Evolution is a cornerstone of biology and should be a prominent feature of the science curriculum. Stem cells offer considerable promise for alleviating an array of human afflictions.

Regardless of scientific consensus, however, much of the public takes very seriously the opinions of the small number of scientists who do not take the dominant scientific view. In the interest of fairness, it is claimed, isn't it important to listen to the dissenters? In a culture of increasingly polarized political conflict about complex issues, it is often assumed at the outset that there might be equal merit on all sides. This phenomenon is sustained and exacerbated by the fact that journalists, who seldom have strong science backgrounds, are themselves taught to value fairness in their reporting by presenting at least two sides of any controversial issue. In hewing to what they see as an evenhanded journalistic standard, they often magnify and lend legitimacy to the claims of scientists who do not reflect a consensual view. The potential distortions of an issue are particularly acute in the case of television reporting for at least two reasons: coverage gravitates toward the visual, which militates against verbal analysis; and it is more limited than print journalism by constraints of time and space.

To complicate matters, it isn't unusual for those who hold opinions counter to the prevailing view to possess formal credentials as strong as those who reflect the current scientific consensus. The United States has dozens of think tanks. These institutions are established to provide scholarly and research-based advice to government and industry. Many of them, however, have come to be associated with particular political preferences. Studies undertaken at the Brookings Institution, for one example, are more likely than those conducted at the American Enterprise Institute or the Hoover Institution to favour policies on the political left. Yet the researchers at both institutions often earned their credentials at the same universities, sometimes with the same professors.

The analysis advanced here may seem unnecessarily bleak about the use of science in societal affairs. After all, the public still wants to know how science relates to issues that may be controversial. Scientific research is still a component of political debate, even when different research studies point in different directions. Nevertheless it may be useful to look a bit more carefully in gauging the extent to which policy is, can be, or even should be, primarily a matter of applied science. For purposes of this essay, it is particularly important to examine more closely the attempts made to extend scientific methods to matters that are much less rooted in physical or biological science than global warming, the spread of disease, or protection of the environment—specifically when social and behavioural science is turned toward educational improvement.

A personal story about the uses of social science in the formulation of educational policy may embody a consequential lesson regarding the influence of social and behavioural scientists in a value-laden and predominantly social enterprise. During the years immediately following World War II, some European countries began to move away from a highly selective and differentiated system of secondary education toward comprehensive high schools. Sweden was one of them. But, of all the countries in Europe, Sweden was the one that most prided itself at the time for being 'scientific' in the formulation of social policy. What is the evidence about the effects of comprehensive schools? Before making the firm and essentially political decision to restructure its schools along more inclusive lines, the Swedes wanted to be sure they had the research foundation that would support so massive and fundamental an alteration of its education system. What did the research seem to show about how comprehensive schools make a difference in the achievement of low-performing students?

Torsten Husén, a young social scientist, was asked to direct a large-scale study to examine the achievement of low-performing students in the ability-tracked schools they were attending at the time to the achievement of a comparable group of students who attended comprehensive high schools. It was, and remains, one of the largest scale comparative studies of educational outcomes ever conducted. The results? The students judged to be low performing did significantly better in the comprehensive schools than they did in those that were more highly tracked and specialized. Furthermore, the students in the highly selective schools did no worse in a comprehensive school than in the grammar schools. Sweden went comprehensive, as did almost all the other countries in Europe.

About 30 years later in a private conversation between this author and Husén, I commented that his study provided an impressive example of how scientific research shapes social policy. With a patient warm smile, he responded along the following lines: 'Oh, no, the political decision to go comprehensive already had been made. The public and the politicians wanted the research to provide justification for a conclusion they already had decided was best for the country.'

This story provides a somewhat different perspective on the use of scientific research in the establishment of educational policy. Making a decision about using the results of science in the policy sphere may be less a matter of applying the relevant science than it is of providing support for a resolution of an essentially political matter that already had been determined. Economic interests, peer pressures, religious convictions, taste, and complex social priorities all come into play. The science may be a factor, even an important one, but it can serve to justify and legitimate as much as to formulate the policy decision that ultimately results. In the Swedish case, the new education policy grew primarily from a growing ethical commitment to social justice that was arising across Europe. One way to strengthen social justice was to de-track the public schools. The science lent support to the emerging political consensus about essentially a moral issue.

What if the research had turned out otherwise? What if it had indicated that performance of the students considered most able declined with the elimination of tracking by academic ability (as indeed it might have, if that question has been asked)? Few observers believe that such results would have delayed the establishment of comprehensive secondary education for very long because the social and moral momentum to move in that direction was too powerful to withstand.

Decisions about many other value-laden educational questions are no more matters of applied science alone than establishment of a policy to move toward comprehensive secondary schools in Sweden. Scholarly styles rooted in science are inadequate intellectual tools alone for reaching decisions that center on identifying just what schools and teachers *should* strive to accomplish, despite the fact that what is of worth is at least as important as what works. The question addressed in this essay is how perspectives developed in the humanities—fields like classical studies, literature, history, and philosophy—might be better utilized both theoretically and practically in the science education community, including the scholars and researchers who hope to understand and improve the schools.

CURRICULUM: THE QUINTESSENTIAL CHALLENGE TO SCIENCE-BASED PRACTICE AND RESEARCH

The central element in devising a suitable science programme for students is deciding on what to teach: the curriculum. All the other complex challenges to improving science education—effective teaching, better teacher education, educationally sound assessment practices, equitable access for all students—hinge on questions of what is significant enough to warrant inclusion in the curriculum. What studies are sufficiently important to occupy the time of students and teachers for thousands of hours? While it is not difficult to find controversy in matters of education, some of the most contentious debates do indeed center on what students are expected to learn in school. Yet, despite deep public interest, curriculum as a central focus receives relatively little attention in the science education *research* community.

For one prominent example, the National Research Council prepared a report 20 years ago titled *Mathematics, Science, and Technology Education: a research agenda* (National Research Council, 1985). It was organized around the following research themes: 'reasoning,' 'instruction,' 'settings,' and 'new learning systems.' The report was mute on the matter of research on *what* should be taught. In short, it was less an agenda for research in mathematics, science, and technology education than an agenda for social and behavioural science research in science education.

Not much seems to have changed in 20 years. The 2005 issues of two leading, refereed science education research journals contain a total 90 papers.[3] Four of that number place their major focus on curriculum, even using a broad definition of the category. The remaining articles examine a range of other topics, predominantly teaching, learning, the use of instructional materials, and assessment.[4]

If one examines the provenance of the most influential curriculum documents in the United States, like the *National Science Education Standards* (National Research Council, 1996) and *Science for All Americans* (American Association for the Advancement of Science, 1989), there is little indication that the selection of science concepts for inclusion in either one is based on scientific research.[5] For one crucial example, both documents accent the importance of teaching scientific inquiry. It is, in fact, the conceptual spine of the national standards. But the process that led to this emphasis was much less one of drawing from science education research and much more one of consensus development in painstaking discussions over several years among experts in many fields.[6] Some would say that consensus is 'only' informed opinion. Nevertheless the methods that are employed in the creation of such documents have been recognized for centuries as necessary dimensions of decision making in human affairs (even in science[7]).

If deciding on the centrality of inquiry in the science curriculum is not primarily a matter for scientific determination, what role can the science education researcher play in helping to address such a vital issue? The challenge that this essay attempts to examine can be framed as one of trying to open a window on how some well-established conceptual and methodological scholarly traditions from the humanities and the arts might be utilized more systematically and centrally in addressing educational issues that large numbers of people care about deeply, but that cannot be addressed adequately by scientific scholarship alone—at least as such scholarship currently is conceived in the community of researchers in science education.

A GLANCE AT THEORY

This challenge, and its difficulties, would not be unfamiliar to the ancient Greeks. They made the distinction between thought directed toward *understanding* how the world works and thought directed toward *taking action* in the world. Plato spoke of the former as *episteme*, by which he meant formulating the abstract idea that is universal in its meaning and manifestations. It is the primary goal of modern science. Rorty (1982) calls these overarching conceptions Theories (with a capital 'T'). For Plato, identifying such Theories was the central quest in trying to understand how the world works and why humans behave as they do.

Aristotle was more skeptical about the uses of *episteme,* though he valued it highly; for him, the contemplative life is worthy in and of itself. But to act well, he argued, grappling with the vicissitudes of context and particularity is central.[8] *Phronesis*, usually translated into English as *practical wisdom*, was for him the highest form of thought directed toward *human* purposes (Dunne, 1993: 241-242). It is developed partly as a person acts in a particular situation. Not only is action sometimes derived from thought, but practical thought is generated *through* action. That is, a person often must act in a given set of circumstances without much opportunity for extensive forethought. In that action (and in reflecting upon it while it takes place, and afterward), a person comes to know more clearly what he or she thinks. Those thoughts are then subject to deeper examination through further thought and subsequent action.

Scientific Theory (*episteme*) focuses on the abstract, the universal, and the timeless. Practical wisdom (*phronesis*) is about theory (small t, in the Rorty sense) of the concrete, the particular, and the timely. This distinction in western culture between the abstract and the concrete and between the universal and the particular, which dates back at least 2400 years, has a central bearing on most matters that involve making choices in classrooms or in educational policy. Differences of opinion, often undergirded by conflicts about values, are endemic in such situations.

In the classification of the academic disciplines, *practical* reasoning is located in moral philosophy. As such it is a part of one of the humanities. Practical reasoning is about what is prudent, what is obligatory, what is moral, and what is appropriate for the particular situation (Gauthier, 1963). Near the heart of the humanities are moral issues and the matter of worthiness. What do we value? What principles do we live by? On what are they based? Unlike science, the humanities invite examination of appropriate behaviour with respect to the situation at hand. Most important, they embrace the ambiguities of human existence. They don't usually strive for 'conclusions' in the way that natural science does. In fact there are usually many plausible ways of taking action to meet a particular challenge in a given situation. The action to be taken can be loaded with moral questions, and usually includes a personal dimension. Generalization and replication are rarely significant goals in trying to act well.

Typically, the humanities deal with tangible situations. A novel tells a story about named people and what they do. In examining the specific, the novel stimulates the reader to relate the people in the story to those in the reader's own life, even if the events took place in another time and place. The connection is through some set of underlying human attributes that is illuminated in the work of fiction—like trust, dependability, anger, love, revenge, and honesty—the meaning of which is enriched by both the printed page and what the reader brings to it.

Just before the steep rise of western science in the 17th Century, the major sources of collective human wisdom were in the stories that people told one another. Such stories permeate all cultures. Many of the learned figures of the time were essentially essayists, like Montaigne and Erasmus. These scholars and writers spoke to human wants, needs, and actions in essentially personalized terms. There were also those who used fiction to examine how men and women cope with their worlds: playwrights, like Shakespeare, and early modern novelists, like Cervantes, for example. We learn about the thinking of the people in these stories and plays through what they said, how they said it, what they did, and—always—a recognition of the consequences, both intended and unintended. Cervantes in his stories of Don Quixote and Sancho Panza could reveal more about psychological development in a relationship between two people over time than those who might have striven directly to make general statements about enduring friendship and interdependency. In focusing on concrete descriptions, the essayists, playwrights, and novelists used language that is amenable to examination of historical and moral questions in ways that are inaccessible to the methods considered today to be scientific.

It is this aspect of the difference between science and the humanities that may relate most closely to the issues examined in this essay. Both scientific and humanistic perspectives have a bearing on many of the issues that face those responsible for the education of children. The task of a scholarly community intent on increasing its own relevance may be to learn how to utilize both of these ways of knowing in a manner that capitalizes on the strengths of each perspective in the service of improving what goes on in schools.

MORE ABOUT THEORIES: BIG T AND LITTLE t

Historians and philosophers of science date the development of modern science to the 17th Century. People like Galileo and Newton were developing broad and far-reaching principles that seemed to have universal applicability. The conceptual achievements were indeed remarkable. The movement of an apple falling from a tree is governed by exactly the same force as the movement of the moon as it falls toward Earth. When there is a change of speed or direction in an object, whether an apple or the moon, there is always an associated force; without the force, speed and direction are constant. Furthermore the magnitude of the force is related directly to the mass of the objects. Until these powerful principles had been articulated, in fact, there had been no physical explanation for the heliocentric solar system that Copernicus had proposed more than 100 years before Newton formulated his Laws.

Scientists like Galileo and Newton in the 17th Century were beginning a 400-year project that continues today, in which the physical and biological world was coming to be seen in many ways as a much more ordered and orderly place than it had seemed. A relatively small number of scientific principles might be able to explain the known universe. The major job of science was to identify those principles.

And so we learned over the centuries about the atomic structure of matter, the generation of electrical charges, germ theory, the transmission of genetic characteristics, and about the evolution of life on Earth. The laws and theories associated with these fields were ubiquitous and universally applicable. If one knows Newton's Laws, then one has a conceptual tool to understand motion anywhere. If one understands germ theory, then one has a major tool in understanding and controlling many diseases. If one knows about Darwin and biological evolution, then one begins to understand the remarkable and unanticipated explanations about how species are simultaneously similar to and different from one another.

As it happened, the 17th was also a particularly horrendous century across many parts of Europe. While some of the most powerful principles of physical science were bringing clarity and elegance to comprehension of the physical world, the human world was chaotic and frightening. Henry of Navarre in France, a revered figure who tried to dampen deep-seated and bitter religious conflict, was assassinated in 1610. The Thirty Years War seemed particularly endless and destructive, consuming much of Europe. Noting the powerful laws and theories that helped to make the natural world more comprehensible and tractable, it seemed attractive for those interested in improving the human condition to turn to the methods of science. Why can't we bring scientific goals and techniques to bear on making the social fabric on earth more predictable and peaceful?[9] And, to this day, we still are trying to figure out how to use the methods of science to understand and improve the human condition, and even blunt the tendencies that lead us to wars, cruelty, and fundamental inequalities.

But, however laudable the aim, the complexities and challenges of bringing science to bear on essentially human social problems demand theories that are relevant to how people act when confronted by an actual science-laden situation in highly particularized circumstances. Science surely relates to many decisions people must make, but using science to address human affairs is seldom straightforward. When social and behavioural scientists work in the field of education, they naturally bring social and behavioural science Theories with them. Therein lies their strength and their potential to be helpful. A certain kind of psychologist might bring the concept of reinforcement to the classroom and therefore tries systematically to encourage students when they take sensible steps toward understanding something. One kind of social-psychologist sees students trying to model peers, so might try to organize groups that enable such modelling to be positive. A particular kind of psycholinguist might see the heart of the matter as helping students learn to 'talk science.' An anthropologist sees schools as perpetuators of a dominant culture. One kind of economist sees a classroom as a market for exchange of goods and services that advance the involvement and learning of the individual student. And so it goes for cognitive scientists, sociologists, and organizational theorists. Each social or behavioural scientist brings a particular set of Theories and tries to apply them to the improvement of education.

These Theories are often powerful and ubiquitous. But it is difficult for a teacher faced with a particular predicament to act well on the basis of Theories. Each one is also constrained by its own particular perspective on the many facets of classroom life; dozens of them probably apply in almost any situation. Like the environmental scientist trying to work on a plan to improve water quality, the teacher is faced with the need for a useable theory that will guide action and that is appropriate for the situation at hand.[10]

Using Rorty's (1982) convention, Theories must be supplemented with theories that are limited in scope, serve as guides to immediate action, and often are transitory. They aren't as robust as Theories, but they need not be because they can be modified readily based on what is learned by the teacher when action is taken.[11] A teacher might be aware of Theories suggesting that the level of a student's engagement in learning is a crucial factor in how much that student actually learns. But what is there about this particular student that holds promise of increasing engagement? What theories about the student and the setting might be useful in deciding on a course of pedagogical action? The student has seemed more engaged when studying science in the past. What was there about those instances that seemed to promote involvement those cases? What does the teacher know about the student's favourite activities outside school, or about the interests of friends and family? The teacher uses theory to decide on action, learns from the consequences, relatively quickly revises the theory accordingly, and repeats the cycle.[12] Contextualized theories are essential. They give operational meaning to the more universalized Theories in ways that are necessary for the teacher to take action. It is these plentiful and shifting theories that people develop and test almost daily in meeting the inevitably novel situations they face in both their professional and personal lives.

EMOTIONS AND LEARNING

Nussbaum (2001a, Part II) suggests that Plato believed that a greater threat than Aristotle to understanding the world through Theory may have been the playwrights. Dramatists, Plato observed, were able to speak directly to the people. Citizens were excited about new plays. They flocked to the theatre. They talked about what they saw and heard. Euripedes in his *Medea* could say more to the people of Athens about the ravages of anger and revenge than anyone who tried to speak in abstract and general terms about these human feelings and the resulting action. Shakespeare took up some of the same themes in *Othello*, but with different nuances and in different contexts, thus adding to an understanding of these emotions—and the tragedies sometimes associated with them—that had deeper resonance for audiences two millennia later. Of course theatergoers today see both *Medea* and *Othello* through still different lenses that shape their understanding and interpretation of the plays.

We have long known that emotions are powerful motivators, for good or bad. When we care, we work harder. We focus more sharply. We become more involved. We also develop more of a stake in the outcome of a given situation. We also realize that emotion can cloud our vision. We are taught that emotional involvement is to be avoided when making important decisions. This detachment is espoused as an important goal and value in scientific research, thus fortifying the separation between the methods and goals of science and the methods and goals of coping with everyday predicaments in the classroom, or anywhere else.

A relatively new area for scholarship and research focuses on the role of emotions in thought and learning. It is incontrovertible that we learn more deeply when we are emotionally involved. And it is incontrovertible that emotions bias our thinking. But it is coming to be realized that certain things that we know *because* of personal attachment and concern can also be relevant to the decisions that are made and what is learned from them.

The parents of an autistic son know more than anyone else about their child, not solely because of intense experience but also because of poignant attachment. That is not to say that such knowledge is all that may needed about the child in a given situation. Others—a physician, a neighbour, a friend, the teacher—may know things about the child that a parent does not know and that may be very important in reaching a decision that affects him. The parents' knowledge of their son in the situation may even be imprecise or unreliable. But that knowledge is nonetheless relevant with regard to accurate diagnosis and, just as important, development of a course of treatment. The parents have an emotionally under-girded intelligence about their son that is accessible only to someone intimately involved with the child and who bears ultimate responsibility for his welfare. (See, especially, Nussbaum, 2001b.)

DELIBERATION

Assuming that the analysis to this point has some merit, what are some implications for theory and practice of educational research? One key to bridging the general with the specific in understanding practical decision-making is to identify the links between science and matters that have a direct influence on people and society—like personal health, a clean environment, conservation of limited resources, prudent uses of different energy sources, public sanitation, ensuring biological diversity, and policies for national defense. What might a science curriculum look like that also makes explicit use of modes of inquiry and decision-making that have their roots in both science and the humanities?

Like science, the humanities strive for deep understanding. But because its methods tend to focus on particular events that unfold in a distinctive fashion, it tends more than science to highlight some of the *differences* among people and circumstances. Variation is as much a part of the human condition as similarity. Human action is guided by and rooted in experience. But since everyone has somewhat different experiences, how are personal histories and different judgments of value brought to bear on practical predicaments?

Once again Aristotle is helpful. The search for the ubiquitous principle with broad applicability that characterizes science relies centrally on the interplay of induction, deduction and generalization. Much else is involved to support a scientifically justifiable conclusion, of course: careful observation, experimentation, evidence, predictability, and replicability, for example. The procedures and methodological artifacts drawn from the sciences are emphasized in school. But when the matter at hand requires deciding on a course of action, Aristotle taught that procedures like induction, deduction, and generalization are not enough. Deliberation is needed.

Deliberation about practical matters invites an examination of values and moral issues. Through deliberation, experiences can be shared. One begins to sense whether accommodations and compromises are possible, not necessarily about the science but about the action that is to be taken. Through deliberation, history can enter a practically oriented conversation. What has happened in the past with respect to matters like the one at hand? Priorities become important. Deliberations enable people to understand what drives different individuals who are trying to resolve a particular quandary to advocate different courses of action. They afford a way to bring the explicitly human feelings and intuitions to the foreground, while anchoring the conversation in both science and the need for action.

Discussions of personal values and experiences can also help to illuminate the possible side effects of different courses of action, which sometimes are as important as the main effects. It may be realized in a particular community that a significant component of its acid rain is produced almost entirely by factories more than 300 miles away in a different political jurisdiction. While the long-term benefits of reducing the pollution seem plausible, it is costly to mitigate the problem. Who pays? What basis is there for accommodation?

Many people want to drive faster, and automobile manufacturers are eager to provide the cars. But what are some side effects? Speed is directly related to fuel consumption, pollution, and highway safety—which are all concerns not only of the driver of the automobile but of the public at large. Take an example in the field of education: Everyone wants higher standards in science for all students, and everyone wants to gauge achievement in ways that can be understood by the public. In many places, however, standardized tests are virtually the only means of trying to meet demands for higher standards and expectations for accountability. Yet almost all teachers recognize that standardized tests—particularly those that must be concluded in minutes or hours, not days or weeks—can measure only some of the outcomes of a high-quality science programme, and not necessarily the most important ones. Relatively short, standardized tests are expensive, but it is even more expensive to assess student work over the extended periods of time that are necessary in a curriculum that includes opportunities for genuine scientific inquiry.

Deliberation is at the heart of much human decision-making. In almost any occupation, meetings to decide about the action to be taken in the face of continually changing challenges and circumstances consume much of one's work time. While science can tell us a great deal about how to eliminate certain diseases associated with a poor diet, humans must make the decisions about just how to modify their diets to eat the necessary nutrients—especially in view of cultural preferences, tradition, and religious convictions. It is known that genetically modified rice would improve the health of millions of people who suffer malnutrition and for whom rice is a dietary staple. But there are certain moral objections to genetically modified foods, many of them related to unknown and possible side effects. Deliberation is necessary to consider the full range of relevant factors when deciding what actually to do about a puzzling situation that has no single and obvious solution.

SEARCHING FOR WHAT'S REASONABLE—IN SCIENCE

During the last decade or two, questions have been raised about whether or not the formal procedures that have served the science enterprise itself so well for the 17th through the 20th centuries will prove as applicable in the 21st. While the issue is receiving examination within the physical and biological sciences, it becomes particularly stark in the social sciences that most insistently have tried to replicate traditional scientific methods: experimental psychology, quantitative sociology, and economics, for example. Emblematic of this attempt by some social scientists to be 'scientific,' their facilities are often labelled laboratories. There are Memory Labs, Assessment Labs, Teaching Labs, and Curriculum Labs. The sign on the door is meant to signal that these places aspire to the highest standards of scientific excellence and rationality. The message intended is that findings generated in these places have the imprimatur of some of the most esteemed researchers who practice the most rigorous kinds of scholarship.

Nevertheless Stephen Toulmin, an historian and philosopher of science, has raised pointed questions about attempts to achieve scientific rigor in the social sciences.[13] Economics is often considered the most 'scientific' of the social sciences. Toulmin titled a recent book *Return to reason* (Toulmin, 2001). One chapter is called 'Economics, or the physics that never was.' Toulmin points out that physicists are very good at predicting the motion of two objects in idealized space. But the Three Object Problem still poses conceptual obstacles. And economics deals with matters much less straightforward than the gravitational interactions of two objects under hypothetical and simplified conditions.

Writing recently in a similar vein about economics, Foley (2006) asserts: 'At its most abstract and interesting level, economics is a speculative philosophical discourse, not a deductive or inductive science.' He claims that its central fallacy is the idea that economics deals with a separate sphere 'in which the pursuit of self-interest is guided by objective laws to a socially beneficent outcome.' It is unlike the rest of social life 'in which the pursuit of self-interest is morally problematic and has to be weighed against other ends.'[14]

Toulmin (2001) suggests that we are trying to carry scientific rationality to realms that do not easily yield to scientific analysis. Today's 'evidence-based' decision making with respect to education and other realms of social policy is being stretched to its limits, and probably beyond. He proposes a different and more appropriate mode of trying to figure out how humans can reach informed decisions. Instead of seeking solely solutions that are irrefutable through scientific scrutiny, we may do well to figure out what is most *reasonable* as a mode of understanding and acting when faced with a given situation. What makes sense under these circumstances? What might reasonable people do, given the alternatives? Such methods of justifying a course of action must comport with what is known about the underlying science, but the underlying science isn't the only factor that leads to valid decisions.

Take an example involving genetic theory and human behaviour. At this writing, there is a chance that Avian Flu will mutate to a form that will enable its spread from human to human. What is that chance, and what do we do about it? What if it's 10 percent? Do we act differently if it's 40 percent? What about 80 percent? Even if we knew the probabilities precisely, the steps we should take are far from clear. They will be based on confidence levels in the research, feasibility, costs, and some knowledge of the likely side-effects (including long-term effects).

One more example: the possible harmful effects of cigarette smoke to the nearby non-smoker are reasonably clear, but secondhand smoke won't affect everyone who is exposed to it. Even for those affected, the consequences are unlikely to be apparent until many years in the future. What might be done to decrease risks? Some additional questions: What are the rights of the smoker in the situation? If reducing risk costs money, who pays? Who pays for increased medical expenses if people become ill because of other people's smoke?

Gradually the public is beginning to learn to think in terms of probability. But probability estimates are nevertheless estimates. And even the probability estimates with the greatest confidence levels don't tell us what actually to do about a given situation, partly because judgments are inevitably highly contextualized and subjective. Toulmin argues that reasonableness frequently is all that can be hoped for.

It is crucial in advancing many of the arguments for more extensive use of humanistic perspectives in addressing educational problems to acknowledge that often science cannot lead to the *right* or *correct* answer with respect to a practical decision. Perhaps those responsible for taking action should strive instead to find the best answer, under the existing circumstances.

SOME CURRICULUM IMPLICATIONS: TEACHING ABOUT THE HUMAN SIDE OF SCIENCE

One curriculum approach that highlights the role of human beings in the development of scientific ideas is for teachers to delve into examples of how key ideas have developed historically. What happened when new ideas challenged the existing ones? What was at stake? Who was involved? What drove those who favoured the new concept and those who opposed it?

Science is full of episodes in which there were heated disputes among fascinating people within the scientific community about new ideas. Take the Copernican Revolution. When Copernicus posited a heliocentric solar system, his conception was firmly rejected by the outstanding observational astronomer of the 16th Century, Tycho Brahe. As it happened, Tycho also happened to have the best data. Take biological evolution. Darwin's views were rejected by many of his contemporaries (and by some of our own!), who had their own theories about evolutionary mechanisms. The story of Crick, Watson, and Franklin and our understanding of DNA and RNA is partly one of intense competition among competing scientists (and of possible attitudes we would today consider sexist). These stories and many like them reveal a great deal both about how science works and about scientists themselves as people. Like the rest of us, scientists display most of the human strengths and frailties. Far from least, the stories have the potential of teaching science itself at a deeper level than one learns when science is presented only as a series of conclusions to be accepted on the basis of authoritative assertion.

Unquestionably it would be a huge advance in the quality of science education if more teachers felt qualified and were encouraged to teach more about the history of the ideas that are emphasized in the science texts. What are the connections between Greek impetus theories to explain motion and Newton's Laws? The impetus theories were powerful predictors; they did not, however, recognize the forces associated with friction, nor did they grasp principles of gravitation. What was there in their respective views of matter that led Priestly to 'discover' oxygen and Lavoisier, working with the same substance, to develop the origins of an entirely new and modern chemistry? There are similarly human and intriguing stories about germ theory, atomic theory, plate tectonics, and much more.

An historical approach to science teaching would probably make the subject more interesting for some students who are not now easily attracted to the subject. And quite likely such an historical approach to the subject would help all students learn the subject more deeply. Nevertheless adolescents frequently want to know how their studies in school relate to their own lives. 'So what?' they sometimes ask when the topic turns to the atomic structure of matter or the laws of planetary motion. In a period when so many elements of public policy seem to be based on knowledge of science, it may be hard to defend a science curriculum that does not also address contemporary social issues, including those currently faced by the students themselves.

There is a suggestive and provocative precedent. In the late 1960s, England made the political decision to raise the age of compulsory education from 14 to 16 over a two-year period. Curriculum developers faced the question of how courses might be changed to engage all students, including those who probably would not have been in school if the law had not changed. In one effort outside the science curriculum, the Humanities Curriculum Project, the decision was made to identify controversial issues that students could be presumed to care about: relations between the sexes, war and peace, race relations, for example. Instructional packets were prepared containing samples of fiction, drama, art, poetry, essays, pamphlets, propaganda, and history related to each of these broad topics (Stenhouse, 1982). The pedagogic approach promoted in the project required the teacher to introduce the topic and encourage discussion. If opinions began to crystallize about a particular topic, some artifact from the packet was chosen to counter the emerging view. The teacher was expected to chose a poem, or part of a play, or a poster, or a relevant portion of political rhetoric, or anything else from the packet that might break consensus. As a result, students who might not have been in school if they had become 15 years-old a year or two earlier were reading Shakespeare, examining famous paintings, reading judicial opinions, and citing poetry.

There might be potential for an analogous approach to science issues, like global warming, or stem-cell research, or development of nuclear power. Along with the science, students might examine advocacy statements regarding different lines of action regarding 'conservation,' 'preservation,' and 'management' of forests, for example. In this instance, they might study the selection of the words used to characterize the problems, and the meanings they evoke to frame and influence the decisions that are to me made. They might study visual images that are portrayed in posters or on film and how they might affect their own sense of urgency and influence the actions they believe might be taken.

The aim of such an approach is to highlight a way of understanding the world, and human activity within it, that augments scientific perspectives. It opens the analytic door somewhat wider for introduction of the more ambiguous and contextualized modes of thought associated with philosophy, fiction, the arts, drama, and history. These perspectives match more closely the way people actually make decisions about matters they care about; and they may be necessary, it is suggested here, if students are to understand many aspects of the connection between knowledge of science and the taking of action to improve the human situation. In the process, there is the possibility, perhaps the likelihood, that they will be stimulated to try to understand the underlying science more deeply.

THE SEARCH FOR GREATER RELEVANCE IN SCIENCE EDUCATION RESEARCH

This essay has outlined an argument for including humanistic modes of thought in the science curriculum, especially when students consider the role of science in human affairs, and particularly when they examine action that may contemplated regarding the use of scientific knowledge. It further suggests that, in such instances, reasonableness become an accepted standard for quality of thought, rather than stronger claims of certainty. And it also raises the possibility of using such scholarly styles, including similar standards of reasonableness, in research into issues designed to enhance understanding of science education in the classroom, and improve it.

What does such research look like, and what might it look like? One setting conducive to examining such student and teacher efforts is by studying what happens in classrooms oriented toward a science, technology, and society (STS) emphasis, especially those that are characterized by controversy. Many programmes associated with efforts to link science, technology, and society have been called 'humanistic,' in fact, because they focus on people in their relationship to science.[15] In such instances, values and emotions are very near the surface, and research might be helpful in better understanding their role in how students come to understand how science connects with human affairs.

Researchers have begun to focus systematically on such matters. Some of them characterize their point of view as 'socioscientific' (Zeidler, *et al.*, 2005; Sadler & Zeidler, 2005). The studies guided by this particular orientation, however, seem primarily to employ social and behavioural science lenses. That is, the questions asked by the researchers tend to centre on how cognitive or sociological theories might be brought to bear in developing deeper understanding of student thinking in settings in which they are emotionally involved and in which moral questions are embedded.

The approach suggested in this essay raises an additional possibility by highlighting questions about how approaches that draw from conceptions developed in the humanities themselves might be used to supplement the social scientific analyses. How might they be utilized in examination of value-laden issues that also contain high levels of science content?[16] To move further in this direction, it may be necessary for science education research to refocus itself to become somewhat narrower.

GOING LOCAL WITH RESEARCH IN SCIENCE EDUCATION

Humanistic perspectives tend to place specificity and context in the foreground. They gravitate toward settings that are seldom reproducible in any precise sense. When playwrights, novelists, and poets try to illuminate the human condition, they usually focus on individual people and their unique situations. Many visual artists exhibit the same humanistic predilection. Rodin's *Burghers of Calais* commemorates a very particular and difficult time and place in French history. In 1347, Calais had been under siege by the English for almost a year. Its citizens were starving. It is said that Edward III offered to spare the people of the city if any six of its major citizens would surrender. He demanded that they walk out carrying the keys to the city and castle, wearing nooses around their necks. Six volunteered. Rodin's work portrays a downtrodden, defeated, and emaciated group of people. His composition and subject matter were in sharp contrast to the triumphalist statues of the time.

But the sculpture was commissioned in 1885. France was still trying to come to grips with its devastating losses during the Franco-Prussian War. The country yearned to find a way of honouring valour, even in defeat. Rodin chose to present the six men as sullen, resigned, shoddily clothed, and bedraggled—thus revealing a different face of heroism, literally. Recognizing that the French of the 1880s had to reconcile their conventional meaning of defeat with their conception of nobleness and patriotism, he chose to give a different shape to events that had occurred more than 500 years earlier. He tried to help them recast their historical memories to enable them to come to grips with the present.

Like art, music, fiction, and the writing of history, education research is guided by contemporary values. It may look back, but it cannot escape the present. In universities, where much education research is conducted and where almost all education researchers learn their craft, one of those espoused values is a commitment to be at least nominally pluralistic in outlook and method. Though far from dominant in today's academic world, case studies of particular people and events have their recognized place—even in realms that are dominated by scientific and technical perspectives. Medicine, organizational management, and environmental studies are examples. Writing about two more, ethnography and law, Geertz (1983) has suggested that these two fields of scholarly inquiry may be 'like sailing, gardening, politics, and poetry,...crafts of place: they work by the light of local knowledge' (167).

And, in the terminology of this essay, local knowledge usually pivots around theory (small t).

What might be the consequence if more researchers were to focus on relatively parochial knowledge and circumstance using one of several approaches to case study? What if the science education research community were to shift a much greater fraction of its effort toward understanding the distinctive features of the particular situations in which teachers and students actually are engaged? How is a certain classroom activity being examined like similar situations elsewhere? How might it be different? If the classes are studying energy production and distribution, for example, are the students also considering action that might be taken to use energy prudently in their own communities? Science education researchers might try to learn more about how both theories and Theories are used by teachers and students when they try to decide on what might be done in such instances, and sometimes in different classrooms.

There is no shortage of research questions that might be asked about how conflicting viewpoints about practical issues figure in classroom deliberations. What is the nature of the local knowledge that is brought to bear? Crucially, how are homes in this particular community different from others? What resources are available if reduction of energy use is an aim? What local customs and preferences are relevant? How do personal experiences of the teacher and the students enter the picture? How is this information factored into the decisions that are made? What does the teacher do to advance the quality of the deliberations as questions of values and priorities become part of the conversations? Most importantly, how are theories—and perhaps Theories—about these matters best articulated, examined, and tested? How might Theories support the examination and comprehension of theories, and vice-versa?

A central element of this line of thought is encapsulated in a couplet from the opening stanza of T.S. Eliot's *The Rock* (1934):

> Where is the wisdom we have lost in knowledge?
> Where is the knowledge we have lost in information?

Practical theorizing in science education research, done well, might help reveal the special kind of wisdom that is often associated with an emphasis on specificity and particularity. It can have the effect of moving the goal of a significant segment of research away from the almost universal scientific emphasis on generalizability and predictability toward a deeper understanding of *variation* and the insights that become more apparent as a consequence of such a shift.

Four teachers seem effective with their students, but they appear to be quite unlike one another in how they conduct a science discussion in the classroom. To what extent are the differences a matter of personal style? To what extent are they a function of their specific goals, or of the students they teach? How is an understanding of the differences among teachers suggestive for designing more effective modes of teacher professional development? If humanistic approaches, with their attention to exceptionality, can add a significant dimension to our understanding of what happens in classrooms, one way might be to devote greater attention than at present to trying to fathom the nature of defensible and desirable *dissimilarity,* and the factors that seem to be operating.

Analogies are sometimes helpful, though they also can be intellectually risky when one strains for parallels. Nevertheless, research on biological evolution may have some implications for research in science education. Crucial to an understanding of evolution is the emphasis on natural variation. Like a biological niche, each science classroom is special. So are teachers, schools, communities, and levels of financial support. They, too, vary naturally. But what is the nature of the variation? How are the settings similar and how are they different, simultaneously? Finally, and importantly, how might the variations be uniquely adaptive to the particular settings in which they are found, and what are the educational implications, both locally and broadly?

The challenge to this mode of inquiry is formidable. It is difficult to imagine a more humanistic approach to science education research (or to science education in the schools, for that matter) expanding notably during the present decade. Nevertheless, justifiable improvement of educational policy and practice must always be a priority for educational researchers who hope to make a difference.

Furthermore, moral and value questions will always be at the core of educational decision making. The heart of the matter centers on what students *should* be learning and doing. Education research is about past, present, and future. The advancement of the public interest cannot be based solely on traditional conceptions of science alone or on a particular set of contemporary expectations for the advancement of knowledge, especially if these conceptions are not adequate to the task of addressing some of the key questions in education.

It is argued here that it would be salutary if the science education community were to examine more seriously and systematically just what can be taken from that vast storehouse of human understanding and wisdom that we call the humanities. More precisely, how can the approaches and perspectives that have come to be associated with literature, the classics, and philosophy be used in research to help teachers and students act reasonably well in trying to cope with the myriad predicaments they face on an almost daily basis? This essay has tried to draw attention to some possibilities and suggest some of the challenges.

NOTES

[1] This essay is based on a paper presented at a seminar on 'Scientific Culture and the Culture of the Schools,' University of Valladolid, Spain, February 2006.

[2] Research in education is not alone. 'Evidence-based' practice is being sought in attempts to modify practice in many professions, including medicine, nursing, and other social services. The impetus is also clear. How does the public know 'what works,' and therefore can be better positioned to make informed decisions about support of vital services?

[3] *Science Education* and *Journal of Research in Science Teaching*

[4] Additional specific examples include integration of assessment and learning, professional development of teachers, informal reasoning, linguistic perspectives in science teaching, materials development for science instruction, and development of students' cognitive structures.

[5] Science education research, as contrasted with opinion, is cited in sections on teaching, professional development, and assessment, but not in the section on science content.

[6] The author was a member of the oversight committee for the development of the *National Science Education Standards*.

[7] For an extreme case, members of International Astronomical Union took a formal vote in 2006 on whether or not Pluto should be considered a planet.

[8] *Nichomachean Ethi*cs, Book 6

[9] See Toulmin (1990) on the origins of social science and its goal of modelling inquiry on the physical sciences.

[10] Action theory is a lively interdisciplinary field of contemporary scholarship. It tends to take a task-oriented perspective on human activity and is relevant to themes in this essay. See, for an early example, Bourdieu (1977) and Searle (2001) for a more recent one.

[11] Consequently they need not be subjected to the same standards of predictability and generalizability as Theories; theories sacrifice reliability for validity.

[12] This is a thumbnail description of *action research*, which is used in many programmes of teacher professional development, as well as in fields like social work, management, and community development.

[13] Toulmin also notes that there are scholars in several of the humanities who also strive for scientific rationality, including some philosophers, linguists, and literary critics.

[14] At the time this essay was completed, Foley's book had not yet been released and was unavailable to the author. The quotations are from an article in the New York Times of November 25, 2006 titled, 'Economics: the invisible hand of the market' and are taken from Foley's book.

[15] There is an extensive literature about 'humanistic science education' programmes, including those in science, technology, and society (STS). See, for one recent and comprehensive example, Aikenhead (2006). For an additional examination of STS programmes, see David D. Kumar and Daryl E. Chubin (eds.) (2000).

[16] Donnelly's (2004) examination of humanistic perspectives in science education is more clearly in this realm, and complements perspectives featured in this essay.

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