Humanistic Perspectives in the Science Curriculum

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Probably the most pervasive alternative to the traditional science curriculum has been a humanistic approach to school science that aims to prepare future citizens to critically and rationally assess science and technology. This goal views science as a human endeavor embedded within a social milieu of society and carried out by various social communities of scientists. The purpose of this chapter is to synthesize the research that has investigated humanistic perspectives in the school science curriculum, perspectives that would significantly alter the tenor of school science.

Any perspective on the science curriculum, be it humanistic or solely scientific, expresses an ideological point of view explicitly or implicitly (Cross, 1997; Fensham, 2000b; Fourez, 1989). This chapter's ideology gives priority to a student-centered point of view and to citizens as consumers of science and technology in their everyday lives; as opposed to a scientist-centered view aimed at scientific or science-related careers. In the political arena defined by Spencer's (1859, p. 5) question, "What knowledge is [should be] of most worth?" the research literature expresses essentially two contrary positions, often in combination: educationally driven propositions about what is best for students and society, and politically driven realities supported by de facto arguments supporting the status quo. For instance, although empirical evidence overwhelmingly speaks to the *educational* failure of traditional school science (described below), the continuous survival and high status enjoyed by traditional school science attest to its *political* success. The research reviewed in this chapter reflects the tension between educational soundness and political reality.

We must not forget that curriculum decisions are first and foremost political decisions (Brickhouse & Bodner, 1992; Fensham, 1992; Roberts, 1988; Rudolph, 2003; Young, 1971). Research can *inform* curriculum decision making, but the rational, evidence-based, findings of research tend to wilt in the presence of ideologies, as curriculum choices are made within specific school jurisdictions, most often favoring the status quo (Blades, 1997; Carlone, 2003; Cross & Price, 2002; Fensham, 1993, 1998, Gaskell, 1992, 2003; Hart, 2002; Hurd, 1991; Roberts, 1995).

Humanistic perspectives in the science curriculum have been described in various ways, including: values, the nature of science, the social aspects of science, and the human character of science revealed through its sociology, history, and philosophy. Since the 1970s, a humanistic perspective has often been identified with science-technology-society (STS) curricula.

Humanistic perspectives have a long history, dating back to the early 19th century when natural philosophy was sporadically taught in some schools. This history, particularly events following World War II, provides a context for appreciating both the educationally and politically driven agendas that motivate the research found in the science education literature, and for understanding the literature's conceptualization of humanistic perspectives in the curriculum.

This chapter synthesizes pertinent research studies concerning the formulation of curriculum policy; clarifies different research methods employed; and draws conclusions concerning the strengths, weaknesses, and gaps in the research literature. The chapter unfolds in the following sequence: history of humanistic perspectives in science education, curriculum policy, and a discussion of the research with implications for future research studies.

A humanistic perspective is not the only innovation to challenge the status quo of school science. Other chapters in the *Handbook* are related to humanistic content in the science curriculum (e.g. Ch. 9, culture studies; Ch. 11, gender studies; Ch. 13, urban studies; Ch. 25, environmental education; and Ch. 30, nature of science) and consequently their topics are not given much attention here, but are cross-referenced.

This chapter restricts itself to the intended school science curriculum that serves 11 year-old students and older. (For a review of research into the taught and the learned curricula of humanistic school science, see Aikenhead [2003].) This chapter excludes literature that simply offers a rationale for a humanistic science curriculum.

A Short History of Humanistic Perspectives in the Science Curriculum

School subjects are grounded implicitly on the historical process through which they arose (Sáez & Carretero, 2002). The ideology of the traditional science curriculum is easily understood when placed in the historical context of its 19th century origin, an origin that emerged within the on-going evolution of science itself.

Research into the history of the school curriculum provides a framework for the conceptualizations of humanistic perspectives in the science curriculum. Based on Chapter 27 (this volume), DeBoer (1991), Donnelly (2002), Fuller (1997), Hurd (1991), Kliebard (1979), Layton (1986, 1991), MacLeod (1981), Mendelsohn (1976), and Orange (1981), the following outline is offered: (1) the name "science" was chosen to replace "natural philosophy" during the birth of a new organization in 1831, the British Association for the Advancement of Science (BAAS); (2) in a speech to the 3rd annual meeting in 1834, Whewell, the president of the BAAS and natural philosopher, coined the term "scientist" to refer to the cultivators of the new science; (3) the professionalisation of natural philosophy into science was completed in England by 1850, by distancing itself from technology and ensconcing itself within the cloisters of university academia where it could control access to its various disciplines; (4) English education reformers in 1867, directed by a BAAS committee, produced a science curriculum that marginalized practical utility and eschewed utilitarian issues and values related to everyday life. At the same time their "mental training" argument helped squeeze the new science disciplines into an already crowded school curriculum; (5) meanwhile in the US, the BAAS served as a model for establishing the American Association for the Advancement of Science (AAAS) in 1848; (6) in 1894 critics of the US national education Committee of Ten erroneously accused it of imposing college entrance expectations on the high school curriculum, a criticism that college science faculty then embraced as an actual Committee recommendation; (7) by 1910, the American school science mirrored England's; and (8) many events, but particularly World War II, caused science and technology to form a new social institution called research and development (R&D), which is still called "science" today.

By contemplating the historical origins of today's traditional science curriculum, we recognize it as essentially a 19th century curriculum in its educational intent. As well, we can better appreciate the powerful ideologies that guide and sustain school science today (i.e. moving students through "the pipeline;" Frederick, 1991). These same ideologies cause most science teachers to teach in very similar ways toward very similar goals (Cross, 1997; Gallagher, 1998). The traditional ideologies of pre-professional scientific training, mental training, and screening for college entrance challenge any attempt to reform school science into a subject that embraces a humanistic perspective (Fensham, 1992).

There have always been educators who promoted school science as a subject that connects with everyday society. Different eras have brought different social, economic, political, and educational forces to bear on reforming the science curriculum into a humanistic type of curriculum (Hurd, 1991). Recent historical and case study research shows how innovative humanistic proposals in the UK and Australia contravened the social privilege and power that benefited an elite student enrolled in a traditional science curriculum (Fensham, 1998; Hodson, 1994; Layton, 1991; Solomon, 1994a). Accordingly, attempts at reforming the traditional school curriculum into a humanistic one have largely been unsuccessful. This indicates that political and social power is involved in reaching curriculum decisions, an issue revisited throughout this chapter.

A Recent Humanistic Science Curriculum Movement

The empirical research reviewed in this chapter is framed by several post-World War II humanistic conceptions of school science often associated with the STS movement (Ziman, 1980). Details of its particular history are found elsewhere (Aikenhead, 2003b; Bybee, 1993; Cheek, 1992; Fensham, 1992; Solomon, 2003b; Solomon & Aikenhead, 1994; Yager, 1996a) but can be summarized as follows.

Many proposals for a humanistic alternative to school science were inspired by university programs formally initiated in the late 1960s, in the US, UK, Australia, and The Netherlands. Some were highly academic history and philosophy of science programs that eschewed sociological perspectives on science. Others embraced sociology, economics and politics, and gave themselves the label STS. The university STS programs responded to perceived crises in responsibility related to, for instance, the environment and nuclear energy. Thus, social responsibility for both scientist and citizen formed one of the major conceptions on a humanistic perspective in school science (Aikenhead, 1980; Bybee, 1993; Cross & Price, 1992, 2002; Kortland, 2001). At the University of Iowa, for instance, a societal issue-oriented science curriculum project evolved from the integration of social studies and science (e.g. Cossman, 1969) and a decade later in Colorado (McConnell, 1982).

A second major conception to emerge from post World War II academia was the poststructuralist analysis of science itself, often associated with Kuhn's *The Structure of Scientific Revolutions* in 1962. This analysis tended to challenge the positivism and realism inherent in traditional science courses (Abd-El-Khalick & Lederman, 2000; Kelly, Carlsen & Cunningham, 1993).

Interest in humanistic content in the science curriculum enjoyed a renaissance at several university centers after World War II. At Harvard, for instance, President J.B. Conant (1947) encouraged his faculty to give serious attention to the history, philosophy, and sociology of science. He influenced Ph.D. student Leo Klopfer who produced the *History of Science Cases* (Klopfer & Watson, 1957) and who critically researched their impact in schools (Klopfer & Cooley, 1963). Similarly influenced was Jim Gallagher (1971) who presciently articulated a blueprint for an STS science curriculum (echoed in Hurd's 1975 seminal publication). It rationalized teaching scientific concepts and processes embedded in the sociology, history, and philosophy of science, relevant technology, and social issues. Probably the most influential science education project to emerge from Harvard was Harvard Project Physics, a historical and philosophical perspective on physics aimed at increasing student enrolment in high school physics (Cheek, 2000; Walberg, 1991; Welch, 1973). It stimulated many other humanistic curriculum innovations worldwide (Aikenhead, 2003b; Irwin, 2000).

The integration of two broad academic fields, (1) the interaction of science and scientists with social issues and institutions *external* to the scientific community, and (2) the social interactions of scientists and their communal, epistemic, and ontological values *internal* to the scientific community; produced a major conceptual framework for STS (Aikenhead, 1994c; Ziman, 1984). In practice, however, some STS projects narrowly focused on just one of these domains. Other important conceptual frameworks for humanistic school science have been articulated in the research literature:

1. The degree to which a humanistic perspective supports or challenges a traditional positivist and realist view of science (Bingle & Gaskell, 1994).
2. Whether a humanistic perspective advocates: being aware of an issue, or making a decision on the issue, or taking social action on the issue (Roth & Désautels, 2004; Rubba, 1987; Solomon, 1994b), a framework particularly salient to environmental education (Ch. 25, this volume) and to social responsibility (Cross & Price, 1992, 2002).
3. The degree to which humanistic content is combined with canonical science content (Aikenhead, 1994b; Bartholomew, Osborne & Ratcliffe, 2002).
4. The degree to which the content and processes of technology are integrated into the humanistic perspective (Cheek, 2000; Fensham, 1988).
5. The degree to which school science is *integrated* – the integration of scientific disciplines, and the integration of school science with other school subjects (Ch. 20, this volume).
6. The degree to which schooling is expected to reproduce the status quo or be an agent of social change and social justice (Ch. 13, this volume; Apple, 1996; Cross & Price, 1999).

Slogans for a humanistic science curriculum, such as STS, can change from country to country and over time. In every era, slogans have rallied support for fundamental changes to school science (Ch. 26, this volume). Today, there are a number of slogans for humanistic science curricula worldwide, for instance: science-technology-citizenship, science for public understanding, citizen science, functional scientific literacy, public awareness of science, Bildung, cross-cultural school science, and variations on science-technology-society-environment. These humanistic science programs are often seen as vehicles for achieving science for all (Ch. 8), girls' participation in science (Ch. 11), scientific literacy (Ch. 26), and nature of science (Ch. 30).

Just as science had to compete in the 1860s with the classics and religion to get a foothold in the school curriculum, today a humanistic perspective must compete with the pre-professional training of elite students (moving through the pipeline) to earn a place in the school science curriculum. This reflects a competition between two ideologies: on the one hand, promoting practical utility, human values, and a connectedness with societal issues to achieve inclusiveness and a student-centered orientation; while on the other hand, promoting professional science associations, the rigors of mental training, and academic screening to achieve exclusiveness and a scientist-centered orientation.

Humanistic perspectives are represented by a variety of conceptual frameworks defined in the literature on research into the intended science curriculum, that is, curriculum policy.

Curriculum Policy

Four areas of research address an educationally sound curriculum policy for humanistic perspectives in the science curriculum: major failures of the traditional curriculum, successes of learning science in non-school contexts, the relevance of curriculum content, and the processes for formulating curriculum policy itself. Each area is discussed in turn.

Major Failures of the Traditional Science Curriculum

Deficiencies in the traditional science curriculum have been the cornerstone of arguments supporting a humanistic perspective. At least three major failures are documented in research studies.

The first failure concerns the chronic declines in student enrollment (Dekkers & Delaeter, 2001; Hurd, 1991; Osborne & Collins, 2000; Welch & Walberg, 1967) due to students' disenchantment with school science (Hurd, 1989; SCC, 1984). This failure of school science threatens its primary goal: to produce knowledgeable people to go into careers in science, engineering, and related jobs; or at least to support those who do. It is instructive to examine the pipeline data from a 15-year longitudinal study (beginning in 1977 with grade 10 students) conducted by the US Office of Technology Assessment (Frederick, 1991). Of the initial sample of four million grade 10 students, 18% expressed an interest to continue toward university science and engineering courses. Of these interested students, 19% lost interest during high school (i.e. they moved out of the pipeline), and then during university undergraduate programs, 39% of first year science and engineering students lost interest; *twice* the proportion than in high school. These quantitative data support in-depth qualitative research that concluded: the problem of qualified students moving out of the pipeline resides much more with universities than with high schools, especially for young women (Astin & Astin, 1992; Seymour, 1995; Tobias, 1990).

Another substantial reduction in the pipeline population occurred between high school graduation and first-year university, a transition that showed a 42% loss in the number of students interested in pursuing science and engineering courses (Frederick, 1991; Sadler & Tai, 2001). These data are partly explained by studies that discovered highly capable A-level science students, particularly young women and minority students, switched out of science as soon as they received their school science credentials, because the curriculum *discouraged* them from studying science further (Gardner, 1998; Oxford University Department of Educational Studies, 1989).

Most research into the science curriculum concluded that school science transmits content which is socially sterile, impersonal, frustrating, intellectually boring, and/or dismissive of students' life-worlds (Hurd, 1989; Lee & Roth, 2002; Osborne & Collins, 2001; Osborne, Driver & Simon, 1998; Reiss, 2000; SCC, 1984). This perception prevails even for science proficient students who enroll in senior science courses in high school (Lyons, 2003). One major reason for advocating humanistic content in school science has been to reverse this chronic loss of talented students (Eijkelhof & Lijnse, 1988; Ziman, 1980). Evidence suggests that humanistic perspectives in the science curriculum can improve the recruitment of students (Solomon, 1994a; Welch, 1973; Welch & Rothman, 1968).

A second, and related, major educational failure of the traditional science curriculum concerns the dishonest and mythical images about science and scientists that it conveys (Ch. 30, this volume; Aikenhead, 1973; Gallagher, 1991; Gaskell, 1992; Larochelle & Désautels, 1991; Milne & Taylor, 1998). As a consequence: some strong science students lose interest in taking further science classes, some students become interested in science for the wrong reasons, and many students become citizens illiterate with respect to the nature and social aspects of the scientific enterprise. One major reason for offering humanistic content has been to correct these false ideas (Ziman, 1980).

A third documented major failure dates back to the 1970s research into student learning: *most students tend not to learn science content meaningfully* (Anderson & Helms, 2001; Gallagher, 1991; Hart, 2002; Osborne, Duschl & Fairbrother, 2003; White & Tisher, 1986). Research suggests that the goal of learning canonical science meaningfully is simply not achievable for the majority of students in the context of traditional school science (Aikenhead, 1996; Cobern & Aikenhead, 1998; Costa, 1995; Hennessy, 1993; Layton, Jenkins, Macgill & Davey, 1993; Osborne et al., 2003; Shapiro, 2004). As a result, alternative science curriculum policies have been proposed to radically change the meaning of school science, a controversial idea to be sure (e.g. Ch. 9 & 13, this volume; Aikenhead, 2000a; Fensham, 2000b, 2002; Jenkins, 2000; Millar, 2000; Roth & Désautels, 2002, 2004).

An important consequence to this third *educational* failure of the traditional science curriculum is the reaction of most students and many teachers to the *political* reality that science credentials must be obtained in high school or a student is screened out of post-secondary opportunities. Empirical evidence demonstrates how students and many teachers react to being placed in the political position of having to play school games to make it appear as if significant science learning has occurred (Bartholomew et al., 2002; Costa, 1997; Loughran & Derry, 1997; Larson, 1995; Meyer, 1998; Roth, Boutonné, McRobbie & Lucas, 1999). The many rules to these school games are captured by the phrase "Fatima's rules" (Larson, 1995). Playing Fatima's rules, rather than achieving meaningful learning, constitutes a highly significant *learned curriculum* of students and a ubiquitous *hidden curriculum* of school science (Aikenhead, 2000a).

A curriculum policy that inadvertently but predictably leads students and teachers to play Fatima's rules is a policy difficult to defend educationally from a humanistic perspective, even though the policy flourishes for political reasons.

Learning and Using Science in Other Contexts

Although the goal of meaningful learning of canonical science is largely unattainable for many students in the context of traditional school science, it seems to be attained in other contexts in which people are personally involved in a science-related everyday task (Davidson & Schibeci, 2000; Dori & Tal, 2000; Goshorn, 1996; Michael, 1992; Roth & Désautels, 2004; Tytler, Duggan & Gott, 2001; Wynne, 1991). Thirty-one different case studies of this type of research were reviewed by Ryder (2001) who firmly concluded: *When people need to communicate with experts and/or take action, they usually learn the science content required*.

Even though people seem to learn science content in their everyday world as required, this learning is not often the "pure science" (canonical content) transmitted by a traditional science curriculum. Research has produced one clear and consistent finding: *most often, canonical science content is not directly useable in science-related everyday situations*, for various reasons (Furnham, 1992; Gee, 2001; Jenkins, 1992; Layton, 1991; Layton et. al., 1993; Ryder, 2001; Solomon, 1984; Wynne, 1991). In other words, the empirical evidence contradicts scientists' and science teachers' hypothetical claims that science content is directly applicable to a citizen's everyday life. What scientists and science teachers probably mean is that scientific concepts can be used to abstract meaning from an everyday event. The fact that this type of intellectual abstraction is only relevant to those who enjoy explaining everyday experiences this way, attests to the reason most students perceive science as having no personal or social relevance.

How well do science teachers apply science content outside the classroom? When investigating an everyday event for which canonical science content was directly relevant, Lawrenz and Gray (1995) found that science teachers with science degrees did not use science content to make meaning out of the event, but instead used other content knowledge such as values (i.e. humanistic content).

This research result, along with the 31 cases reviewed by Ryder (2001), can be explained by the discovery that canonical science content must be *transformed* (i.e. deconstructed and then reconstructed according to the idiosyncratic demands of the context) into knowledge very different in character from the "pure science" knowledge of the science curriculum; as one moves from pure science content for explaining or describing, to "practical science" content for action (Jenkins, 1992, 2002; Layton, 1991). "This reworking of scientific knowledge is demanding, but necessary as socio-scientific issues are complex. It typically involves science from different sub-disciplines, knowledge from other social domains, and of course value judgements and social elements" (Kolst_, 2000, p. 659). When the science curriculum does not include this reworking or transformation process, pure science remains unusable outside of school for most students (Layton et al., 1993). When students attempt to master unusable knowledge, most end up playing Fatima's rules instead. This empirical evidence supports the educational policy of incorporating everyday action-oriented science content (citizen science; Irwin, 1995); for instance, researchers Lawrence and Eisenhart (2002, p. 187) concluded, "science educators and science education researchers are misguided not to be interested in the kinds of science that ordinary people use to make meaning and take action in their lives."

Given these research conclusions that question the efficacy of teaching for meaningful learning in the context of the traditional science curriculum, there would seem to be little educational advantage for a teacher "to cover" the entire science curriculum but instead, greater advantage to teaching fewer canonical science concepts chosen because of their relevance to a humanistic perspective (Eijkelhof, 1990; Kortland, 2001; Häussler & Hoffmann, 2000; Walberg & Ahlgren, 1973). The latter approach is supported by a plethora of comparison studies, based on standardized achievement tests of canonical science, that showed no significant effect on students' scores when instruction time for the canonical content was reduced to make room for the history of science, the nature of science, or the social aspects of science (Aikenhead, 1994b, 2003b; Bybee, 1993; Eijkelhof & Lijnse, 1988; Irwin, 2000; Klopfer & Cooley, 1963; Pedersen, 1992; Welch, 1973); and on occasion, students in a humanistic science course appeared to fair significantly better on achievement tests of canonical science (Häussler & Hoffmann, 2000; Mbajiorgu & Ali, 2003; Rubba & Wiesenmayer, 1991; Solomon, Duveen, Scot & McCarthy, 1992; Sutman & Bruce, 1992; Wang & Schmidt, 2001; Wiesenmayer & Rubba, 1999; Winther & Volk, 1994; Yager & Tamir, 1993).

In summary, a recurring evidence-based criticism of the traditional science curriculum has been its lack of relevance for the everyday world (Millar & Osborne, 1998; Osborne & Collins, 2000; Reiss, 2000), a problem dating back at least 150 years. The issue of relevance is at the heart of most humanistic science curricula.

Research on Relevance

Humanistic approaches to school science represent many different views on relevance (Chs. 8, 9, & 30, this volume; Bybee, 1993; Cheek, 1992; Irwin, 1995; Kortland, 2001; Kumar & Chubin, 2000; Millar, 2000; Solomon & Aikenhead, 1994; Yager, 1996b). "Relevance" is certainly an ambiguous term.

Mayoh and Knutton (1997) characterized relevance as having two dimensions: Relevant to whom? and Relevant to what? In this chapter, however, the multidimensional character of relevance is defined by a more political question (Häussler & Hoffmann, 2000; Roberts, 1988): *Who* decides? Research into humanistic curriculum policies is reviewed here according to seven types of relevance, a scheme developed in part from Fensham's (2000b) views about *who* decides what is relevant. These seven heuristic categories overlap to varying degrees.

Wish-they-knew science. This type of relevance is typically embraced by academic scientists, education officials, and many science educators when asked: What would make school science relevant? (AAAS, 1989; Fensham, 1992; Walberg, 1991). The usual answer, canonical science content, moves students through the pipeline for success in university programs.

But how relevant is this wish-they-knew content for success by science-oriented students in first year university courses? Research evidence suggests it is not as relevant as one might assume, and on occasion, not relevant at all (Champagne & Klopfer, 1982; McCammon, Golden & Wuensch, 1988; Stuart, 1977; Tanaka & Taigen, 1986; Yager & Krajcik, 1989; Yager, Snider & Krajcik, 1988). First year university students who had not studied the prerequisite physical science course in high school achieved as well as their counterparts who did enroll in the prerequisite. Sadler and Tai's (2001, p. 111) more recent survey research claims, "Taking a high school physics course has a modestly positive relationship with the grade earned in introductory college physics." An endorsement of "modestly positive" would seem to be faint praise indeed. These research studies might rationally assuage science teachers' fear that time spent on humanistic content and citizen-science content will diminish students' chances of success at university. Although the *educational* arguments favoring wish-they-knew science are particularly weak, political realities favoring it are overwhelming (Fensham, 1993, 1998; Gaskell, 2003).

Need-to-know science. This type of relevance is defined by people who have faced a real-life decision related to science and technology, for example, parents dealing with the birth of a Down's syndrome child, or town councilors dealing with the problem of methane generation at a landfill site (Layton, 1991; Layton et al., 1993). Curriculum policy researchers ask: What science content was helpful to the people when making their decisions? Ryder (2001) in his analysis of 31 case studies of need-to-know science concluded, "Much of the science knowledge relevant to individuals in the case studies was *knowledge about science*, i.e. knowledge about the development and use of scientific knowledge rather than scientific knowledge itself" (p. 35, emphasis in the original). In other words, the curriculum must expand to include knowledge *about* science and scientists (humanistic content). One reason that people tend not to use canonical science content in their everyday world (in addition to it not being directly useable, as described above) is quite simple: canonical science content is the wrong type of content to use in most everyday action-oriented settings; instead need-to-know science (humanistic content) turns out to have greater practical value.

Functional science. This is science content that is deemed relevant primarily by people with careers in science-based industries and professions. The category includes "workplace science" (Chin, Munby, Hutchinson, Taylor & Clark, 2004).

Coles (1998) surveyed UK employers and higher education specialists in science who were asked to identify scientific content thought to be essential to school science. Unexpectedly, these respondents thought that students' understanding of science ideas was least important, compared to a myriad of other more favored capabilities. Similar research findings emerged from broad studies into economic development within industrialized countries (e.g. Bishop, 1995; David, 1995; Drori, 1998). Consistently the research indicated that economic development depends on factors other than a population literate in canonical science, and on factors beyond the influence of school science, for example: emerging technologies, industrial restructuring, poor management decisions, and government policies that affect military development, monetary exchange rates, wages, and licensing agreements.

By conducting research *on the job* with science graduates, Duggan and Gott (2002) in the UK, Law (2002) in China, and Lottero-Perdue and Brickhouse (2002) in the US discovered that the canonical science content used by science graduates was so context specific it had to be learned on the job, and that high school and university science content was rarely drawn upon. On the other hand, Duggan and Gott's findings suggested that procedural understanding (ideas about how to do science) was essential across most science-related careers. More specifically they discovered one domain of concepts, "concepts of evidence," that was generally and directly applied by workers in science-rich occupations to critically evaluate scientific evidence, for instance, concepts related to the validity and reliability of data, and concepts of causation versus correlation. Similar findings arose in their research with an attentive public involved in a science-related societal issue. Duggan and Gott spoke for many researchers (e.g. Fensham, 2000a; Ryder, 2001) when they concluded, "Science curricula cannot expect to keep up to date with all aspects of science but can only aspire to teach students how to access and critically evaluate such knowledge" (p. 675).

The humanistic perspective germane here concerns a correct understanding of concepts of evidence when dealing with social implications, for instance: Is the scientific evidence credible enough to risk investing in a particular industrial process? or Is the scientific evidence good enough to warrant the social action proposed? In these contexts, it is useful for a person to understand the ways in which scientific evidence is technically and socially constructed (Bingle & Gaskell, 1994; Kelly et al., 1993; Cunningham, 1998; McGinn & Roth 1999), that is, humanistic content for the science curriculum. However, when "vocational science" courses are only concerned with vocational technology, they loose their humanistic perspective.

In a project that placed high school students into science-rich workplaces (e.g. veterinary and dental clinics), Chin and colleagues (2004) ethnographically investigated two issues: the relationship between school science and workplace science (a type of functional science), and the participants' perceptions of that relationship. The fact that students saw little or not connection between school science and workplace science was explained by the researchers this way: school science (canonical content) in the workplace was not central to the *purposes* of the workplace, and therefore, school science was not overtly apparent in the workplace. In short, knowing canonical science content was not relevant to one's accountability in a science-rich workplace (a conclusion very similar to the results of research into need-to-know science, reviewed above).

Surveys and ethnographic research methods are not the only ways to substantiate functional science content. The Delphi research technique used by Häussler and Hoffmann (2000) in Germany was an educationally rational, in-depth method for establishing a physics curriculum policy by consensus among diverse stakeholders over "What should physics education look like so it is suitable for someone living in our society as it is today and as it will be tomorrow" (p. 691). Their 73 stakeholders represented people associated with wish-they-knew science (e.g. physicists and physics teachers) and with functional science (e.g. personnel officers in physics-related industries and general educationalists). Häussler and Hoffmann did not initially group their stakeholders into these two categories, but instead used a hierarchical cluster analysis statistic to tease out like-minded stakeholders. This analysis produced two coherent groups: Group 1 generally favored "scientific knowledge and methods as mental tools" and "passing on scientific knowledge to the next generation" significantly more than Group 2 who favored "physics as a vehicle to promote practical competence" (p. 693). These statistical results lend credence to the two categories of relevance that distinguish between wish-they-knew and functional science. Interestingly, however, Häussler and Hoffmann found that both groups gave *highest* priority to topics related to "physics as a socio-economic enterprise" that show "physics more as a human enterprise and less as a body of knowledge and procedures" (p. 704).

Enticed-to-know science. By its very nature, enticed-to-know science excels at its motivational value. This is science content encountered in the mass media and on the internet, both positive and negative in its images of science and both sensational and sometimes dishonest in its quest to entice a reader or viewer to pay closer attention. Fensham (2000a, p. 75) reports that the OECD's Performance Indicators of Student Achievement project is using enticed-to-know science "to see how well their science curricula are equipping [15-year old] students to discern, understand and critique the reporting of science in newspapers and the Internet." Millar (2000) in the UK and Dimopoulos and Koulaidis (2003) in Greece described how a longitudinal analysis of the content of science-related articles in their respective national newspapers led to identifying the science and technology knowledge that would be most useful in making sense of these articles and the stories they presented. Millar's analysis stimulated a revision of the AS-level syllabus in the UK and eventually culminated in Hunt and Millar's (2000) high school textbook *AS Science for Public Understanding* that provides a humanistic perspective.

Moral issues and public risk are often associated with enticed-to-know science because the media normally attends to those aspects of events (Cross & Price, 1992, 2002; Eijkelhof, 1990; Nelkin, 1995; Osborne et al., 2003). Moreover, the more important everyday events in which citizens encounter science involve risk and environmental threats (Ch. 25, this volume; Irwin, 1995).

Have-cause-to-know science. This is science content suggested by experts who interact with the general public on real-life matters pertaining to science and technology, and who know the problems the public encounters when dealing with these experts (Law, Fensham, Li & Wei, 2000). This empirical approach to developing curriculum policy is being tested in China where the societal experts were drawn from the following domains: home and workplace safety; medical, health, and hygiene problems; nutrition and dietary habits; consumer wise-ness; and leisure and entertainment (Fensham, 2002; Law, 2002; Law et al., 2000). The approach assumes that societal experts are better situated than academic scientists to decide what knowledge is worth knowing in today's changing scientific and technological world.

Have-cause-to-know science is a feature of the Science for the Public Understanding of Science Project, SEPUP, in the US (Thier & Nagle, 1994, 1996). Societal experts in industry, the sciences, and education provided the curriculum developers with elements of a relevant issues-based curriculum that led to STS chemistry modules and three STS textbooks (SEPUP, 2003): *Science and Life Issues; Issues, Evidence and You*; and *Science and Sustainability*.

In the Netherlands, Eijkelhof (1990, 1994) used the Delphi research technique to gain a consensus among *societal experts* to establish the humanistic and canonical science content for an STS physics module, "Ionizing Radiation." The 35 Delphi participants in Eijkelhof's study were carefully selected to represent a variety of fields and opinions on the risks of ionizing radiation (a group purposefully more homogeneous than the stakeholders in Häussler and Hoffmann's [2000] study discussed above). After the normal three rounds in the Delphi procedure, Eijkelhof's radiation experts pointed to suitable societal contexts of application and concomitant scientific content that the public had cause to know. Eijkelhof (1990) warned, however, that policy research by itself should not *prescribe* the final curriculum. A curriculum development team must also consider educational issues, for example, learning difficulties of students, available instruction time, and pedagogical factors. He attended to those issues by drawing upon a decade or more of research by the PLON humanistic physics project (Eijkelhof & Lijnse, 1988; Ratcliffe et al., 2003).

In contrast, an Australian chemistry curriculum committee could not reach a consensus on a balance between societal contexts of application and scientific content, and as a result the committee's writers tended to promote the status quo wish-they-knew science rather than the intended have-cause-to-know science (Fensham & Corrigan, 1994).

The National Curriculum in the UK calls for humanistic content to be taught but does not specify the content. In a study focused entirely on humanistic content, Osborne and colleagues (2001) employed the Delphi technique to establish a consensus on what "ideas about science" should be taught in school science. During three rounds of the Delphi procedure, 23 experts (professional and academic people notable for their contributions to the clarification of science for the public) produced 18 ideas of which nine showed sufficient stability and support (the top three were: "scientific methods and critical testing," "creativity," and "historical development of scientific knowledge"). These nine ideas about science informed the development of classroom teaching materials (Bartholomew et al., 2002). These materials were then embedded in a large-scale research project, "Evidence-Based Practice in Science Education" (IPSE). The have-cause-to-know science, elucidated by the IPSE project, addressed humanistic content; the canonical science content had been established by the National Curriculum's wish-they-knew science.

A disadvantage of the Delphi procedure is evident in the ambiguous or "motherhood" statements that sometimes emerge (e.g. creativity). This disadvantage likely results from participants not meeting face to face to clarify and articulate the meaning of each statement.

Curriculum policy research has also included surveys of experts to determine which social issues (and therefore, which have-cause-to-know science) they valued most in a humanistic science curriculum. The experts included (Bybee, 1993): scientists and engineers, citizens, science teachers, and science educators in the US and internationally. The relevant contexts for have-cause-to-know science were identified, but their actual influence on curriculum policy has not been noticeable (Cheek, 2000). This survey research was perhaps more politically successful at raising awareness of STS than developing specific curriculum policies.

Personal-curiosity science. When students themselves decide on the topics of interest for school science, relevance takes on a personal, though perhaps idiosyncratic meaning, as students' hearts and minds are captured (Gardner, 1988; Osborne & Collins, 2000; Reiss, 2000). Based on a humanistic curriculum policy principle that one builds on the interests and experiences of the student, Sjøberg (2000) surveyed over nine thousand 13-year-old students in 21 countries to discover (among other things): their past experiences related to science, their curiosity toward certain science topics, their attitude to science, their perception of scientists at work, and their self-identity as a future scientist. Based on the same curriculum policy principle, Häussler and Hoffmann (2000) surveyed over six thousand German students, aged 11 to 16 years, to determine their interest in various physics topics. Sjøberg (2000) and Häussler and Hoffmann (2000) offer insights into students' differential interests, for instance, "music" was much more interesting than "acoustics and sounds," and "the rainbow and sunsets" much more than "light and optics." In other words, concrete themes embedded in student experiences were much more relevant than science discipline topics, a finding supported by three decades of research by the Dutch PLON project team (Kortland, 2001). In Sjøberg's study, students in non-Western countries had a significantly more positive image of scientists (heroic figures helping the poor and underprivileged) than their counterparts in Western countries, a finding that points to the importance of culture in a student's everyday world (a topic discussed below). In the Häussler and Hoffmann (2000) study, two outcomes are pertinent here: students' views were congruent with stakeholders who advocated a humanistic perspective in the physics curriculum, but discordant with the status quo. Häussler and Hoffmann pointed out that a curriculum policy founded on their Delphi research with stakeholders (reviewed above) would look very similar to a curriculum policy founded on student interests alone (i.e. personal-curiosity science).

Science-as-culture. A more holistic yet abstract concept of relevance in school science was advanced by Weinstein's (1998) research concerning the enculturation of students *into everyday society*, an approach to science education that stands in stark contrast to the enculturation of students *into scientific disciplines*. Culture decides, de facto, what is relevant for science-as-culture. For instance, in school culture, "Students constantly are being measured, sorted, and turned into objects of scrutiny. They learn science up close and personal but not as scientists; rather, they learn it as objects of science" (p. 493).

Weinstein identified a network of communities in students' everyday lives: health systems, political systems, the media, environmental groups, and industry, to name a few. Each community interacts with communities of science professionals, resulting in a *cultural commonsense notion of science*.

Science-as-culture is more than just pop culture (Solomon, 1998). As a category of relevance, science-as-culture serves in part as a super ordinate category to the need-to-know, functional, enticed-to-know, have-cause-to-know, and personal-curiosity science categories. Its relevance resides in the student's community's culture (a commonsense notion of science) and in the student's home and peer cultures (Ch. 9, this volume; Costa, 1995; Solomon, 1994b; 1999, 2003a). Science's role in society is also embedded in science-as-culture, as evidenced by roles such as: setting environmental standards, regulating commerce, providing legal evidence, announcing medical breakthroughs, creating novel ethical dilemmas, and requiring financial support for research and development (Dhingra, 2003; Jenkins, 2000; Stocklmayer, Gore & Bryant, 2001).

Future research into students' science-as-culture may reveal useful ideas for a humanistic science policy, particularly for the enculturation of students into their local, national, and global communities. Prelle and Solomon (1996), for instance, provide a rich account of the differences between students' orientation to an environmental issue and their scientific knowledge on the subject. The researchers explored students' science-as-culture by investigating those differences in three settings: the science classroom, students' homes, and on holidays. Nelkin's (1995) and Stocklmayer et al.'s (2001) seminal research into science and the media raises an important researchable policy question: What understandings of science and journalism are of critical value to consumers of the mass media?

Science-as-culture can also be captured by project-based learning in which local science-related real-life problems are addressed by students in an interdisciplinary way (e.g. Ch. 13 & 25, this volume; Dori & Tal, 2000; Jenkins, 2002; Lee & Roth, 2002; Roth & Désautels, 2004). This approach draws upon community resources and local culture to stimulate need-to-know, functional, and have-cause-to-know science, as well as science-as-culture; in short, citizen science. The presence of a humanistic perspective in a project-based curriculum depends, however, on the degree to which its humanistic content is made explicit in the instruction and assessment of students (Ch. 30, this volume; Aikenhead, 1973; Kortland, 2001; Ratcliffe, 1997).

Conclusion. These seven heuristic categories of relevance, based on who decides what is relevant, can help describe the content and contexts found in a humanistic perspective of a particular science curriculum. More often than not, a curriculum will embrace several categories simultaneously (e.g. Aikenhead, 1994a; Eijkelhof & Kortland, 1988).

Ideologies inherent in any science curriculum can be explained in terms of two mutually exclusive presuppositions of school science (Aikenhead, 2000a; Rudolph, 2003; Weinstein, 1998): (1) the enculturation of students into their *local, national, and global communities*, communities increasingly influenced by advances in science and technology, and (2) the enculturation of students into the *disciplines of science*. These presuppositions represent two fundamentally different axiomatic views of relevance. Therefore, relevance precipitates a policy dilemma. Depending on the humanistic science curriculum, relevance will be fundamentally framed by an allegiance to scientific disciplines or to students' cultural communities. In an attempt to resolve the dilemma by integrating the two positions into the same curriculum, educators risk confusing and alienating students (Egan, 1996). The research reviewed in this chapter suggests that any science curriculum, humanistic or purely scientific, dedicated to the enculturation of all students into scientific ways of thinking will constantly be undermined by Fatima's rules.

Processes of Formulating Curriculum Policy

Throughout this chapter's review of research, educationally driven research findings conflicted with political realities. These political realities intensify when we examine research into the processes by which people have formulated curriculum policy. For example, researchers have explored such questions as: Who has the socio-political power to set policy? and How do they assert and maintain that power? However, the paucity of research in this domain (Kortland, 2001; Roberts, 1988) may speak to the unease felt by research participants when political events come under public scrutiny, exposing the natural tension between maintaining the status quo of pre-professional training in the pipeline, and innovating a humanistic perspective for equity and social justice (Ch. 13, this volume; Apple, 1996; Fensham, 1998; Lee, 1997; Roth & McGinn, 1998).

Historical events, summarized earlier in the chapter, revealed the political context in which the first formal science curriculum policy emerged in 1867; a context characterized by the cultural values, conventions, expectations, and ideologies at that time, all of which determined what school science would be. Because context is paramount for policy inquiry, researchers have often employed qualitative methods such as case studies or vignettes to interpret and understand processes that led to a humanistic science curriculum policy. This was certainly the case for research into power conflicts over curriculum policy reported by Aikenhead (2002), Blades (1997), Fensham (1993, 1998), Gaskell (1989, 2003), Hart (2002), Roberts (1988, 1995), and Solomon (2002, 2003b). Each study revealed the various power dynamics adopted by different groups of stakeholders. When deciding what knowledge is of most worth, people usually negotiate by using both rational criteria and political power in an attempt to limit or enhance the influences of various stakeholders. Each educational jurisdiction has its own story to tell about how curriculum policy is formulated.

Two research studies are mentioned here to illustrate this type of research. In his book *Procedures of Power & Curriculum Change* (a research study into the temporary defeat of a humanistic science curriculum policy in Alberta, Canada), Blades (1997) allegorically described the intense clashes between newly aligned interest groups who organized a network of relationships (actor-networks; Carlone, 2003; Foucault, 1980; Gaskell & Hepburn, 1998) to serve their own self interests, and who enacted "rigor" as a power ploy in their discourse. Blades discovered that one very powerful stakeholder-group altered its alliances, thereby reversing its original policy position. A second study by Gaskell (1989) in British Columbia, Canada, showed how science teachers' allegiances to different professional organizations and to their own professional self-identities undermined an emerging humanistic science curriculum policy (Rowell & Gaskell, 1987).

Although each case study and vignette found in the literature was unique, all reached the same conclusion (with some unique exceptions): local university science professors have a self-interest in maintaining their discipline and will boldly crush humanistic initiatives in school science policy (Aikenhead, 2002; Blades, 1997; Fensham, 1992, 1993, 1998; Fensham & Corrigan, 1994; Gaskell, 1989; Hart, 2002; Pandwar & Hoddinott, 1995; Roberts, 1988; Shymansky & Kyle, 1988); resulting in what Gaskell (2003, p. 140) called "the tyranny of the few." If local science professors become marginalized and lose their power to control policy decisions, they tend to realign their actor-networks into international alliances to defeat a local humanistic curriculum policy (Rafea, 1999).

Science curriculum policy is normally formulated more smoothly through consultation with different stakeholders (Orpwood, 1985), for instance: government officials, the scientific community, science teachers, university science educators, students, parents, business, labor groups, industry, plus other groups and institutions. Government ministries of education generally rely on the advice of curriculum committees variously comprised of some of these stakeholders. Because government committee meetings are almost always held out of the view of an inquisitive researcher, their confidentiality has prevented research into the early stages of formulating government policy (De Vos & Reiding, 1999; Roberts, 1988).

Consultative research has also taken the form of research and development (R&D) studies that produced STS classroom materials (e.g. textbooks) as a means to influence or articulate a humanistic curriculum policy. Researchers have collaborated with ministries of education, selected teachers, students, and experts who furnished "functional" and "have-cause-to-know" science (among other types of relevance) for the science curriculum (Aikenhead, 1994a; Eijkelhof & Lijnse, 1988; Eijkelhof & Kapteijn, 2000; Kortland, 2001).

More rigorously systematic policy studies have used the Delphi research method to inform humanistic curriculum policy, for instance (as described above), the research by Eijkelhof (1990), Häussler and Hoffmann (2000), and Osborne and colleagues (2001). Their experts were able to reach a consensus, more or less, on the relevant contexts and associated knowledge for an educationally sound, humanistic science curriculum policy.

The most elaborate, theory-based, consultative methodology to produce curriculum policy is deliberative inquiry. Inspired by Schwab's (1974) "deliberative enquiry," it offers a combination of "top-down" central control by government bureaucrats and "grass-roots" populist control by other stakeholders. Deliberative inquiry is a structured and informed dialogic conversation among stakeholders who, face to face, help government officials reach a decision on curriculum policy by discussing and re-examining their own priorities (i.e. values) along with their reading of relevant research (Orpwood, 1985). Because science teachers will be central to implementing a humanistic science curriculum (Ch. 29; this volume; Roberts, 1988) and because curriculum evaluation research consistently shows that the teacher has more influence on student outcomes than the choice of curriculum taught (Aikenhead, 2003a; Welch, 1995), the science teacher is a key stakeholder and usually holds a central role during deliberative inquiry meetings. The process of deliberation encompasses both educational and political dimensions to formulating curriculum policy.

The Science Council of Canada (SCC) used deliberative inquiry to produce a national science curriculum policy that embraced a humanistic perspective (Orpwood, 1985; SCC, 1984). The SCC study ensured that significant problems in science education were identified, that appropriate evidence was collected, and that the problems and evidence were considered by diverse stakeholders attending one of the 11, two-day deliberative conferences held across Canada. Stakeholders included high school students (science-proficient and science-shy students); teachers (elementary and secondary); parents; elected school officials; the scientific community; university science educators; and representatives for the business, industry, and labor communities. The students' contributions were pivotal to recommendations related to student assessment. As Schwab (1978), predicted, "Deliberation is complex and arduous. …[it] must choose, not the *right* alternative, for there is no such thing, but the *best* one" (pp. 318-319, emphasis in the original). The "best" science curriculum policy for Canada was published as *Science for Every Citizen* (SCC, 1984). Inspired by the success of this deliberative inquiry, two other Canadian provinces conducted similar research but on a smaller scale. Drawing upon the SCC's national study, Alberta resolved the problems identified by Blades (1997) (described above) by holding a series of deliberative conferences that gave science teachers a political voice (Roberts, 1995). Saskatchewan almost replicated the SCC study during the renewal of its science curriculum and yielded a strong teacher consensus on a humanistic perspective (Hart, 1989).

A different method of policy formulation, illustrated by the AAAS's (1989) *Project 2061* and the National Research Council's (NRC, 1996) *Standards* in the US, utilizes consultation with stakeholders on a grand yet narrow scale. After conducting a complex series of inclusive national surveys and committee meetings, a "consensus panel of leading scientists" (Walberg, 1991, p. 57) determined the content of *Project 2061*; content critiqued as conveying a positivist non-contemporary view of science by Bingle & Gaskell (1994) and Fourez (1989), and as ignoring student relevancy by Settlage and Meadows (2002). Thus the final say in the curriculum was greatly influenced by people who generally espouse the conventional wish-they-knew science. This exclusivity, plus the lack of published research on the consultation process itself, suggests that the national agencies may have prioritized political realism over educational soundness, and have repeated their predecessors' 1867 policy decision. A humanistic perspective loses significance in the predominant wish-they-knew science of *Project 2061* and *Standards*.

Discussion of the Research

Contexts of Research

Four themes can be identified in the research literature on curriculum policy: scale, the effect of research on classroom practice, and research paradigms. Each theme represents a different context related to the research reviewed in this chapter.

Scale. As plenary speaker at the 2003 NARST annual meeting, Richard Elmore drew upon a great deal of research and experience with school innovation undertaken at Harvard University when he cryptically characterized a typical science education innovation study as follows: a gathering of "the faithful" (e.g. a few humanist science educators) to show that the innovation can work on a small scale, and then leave "the virus" (i.e. the innovative idea) to populate the system on its own because the innovation is such a good idea (i.e. it is educationally sound). This approach to changing school science through new curricula has continually failed, due mostly to a scaling-up problem: moving from a small-scale preliminary study to large-scale full implementation study. As an alternative, Elmore (2003) counseled researchers to treat a school jurisdiction as the unit of analysis through enacting larger scale projects.

However, the research synthesized in this chapter clearly indicates that a change to humanistic school science requires a broader context for research than a school system. Significant change demands a multi-dimensional context of scale that also includes teacher education programs, state curricula, and a host of diverse stakeholders of social privilege and power who provide support over a long period of time (Anderson & Helms, 2001; Fensham, 1992; Sjøberg, 2002). The most effective curriculum research would encompass a scale as broad as the interaction of research, political power, policy, and practice (Alsop, 2003).

The effect of research on classroom practice. As suggested by Elmore (2003) and Hurd (1991), noticeably absent from the research literature is evidence of a pervasive influence of science education research on practice. This was recently investigated by Ratcliffe and colleagues (2003, p. 21) who concluded: “Unless research evidence, including that from highly regarded studies, is seen to accord with experience and professional judgement [and ideology] it is unlikely to be acted on.” However, research is more influential on the “development of national policy on science education.” Again, the educationally sound defers to the political reality of teachers’ knowledge, beliefs, self-identities, and ideologies (Section V, this volume; Aikenhead, 2003a).

School culture. Elmore (2003) pointed out that school culture must be changed in order to nurture and sustain any significant innovation, a view broadly shared among researchers of humanistic school science (Aikenhead, 2000a; Brickhouse & Bodner, 1992; Carlone, 2003; Medvitz, 1996; Munby, Cunningham & Lock, 2000; Solomon, 1994c, 2002; Tobin & McRobbie, 1996; Vesilind & Jones, 1998). If research into a humanistic curriculum is to be more than an academic exercise acted out on a small scale, it must reformulate itself into a framework of cultural change, because a humanistic perspective would significantly alter the culture of school science.

Research paradigms. It is convenient to discuss research in terms of three paradigms: quantitative, interpretive (qualitative), and critical-theoretic (Ryan, 1988). A science educator trained in the natural sciences may feel comfortable in the role of disinterested observer (quantitative paradigm), but most of the research reviewed in this chapter emphasized the role of a curious empathetic collaborator (interpretive paradigm). Yet, if curriculum researchers expect to effect significant changes in school culture and classroom practice, they will also need to be seen as passionate liberators (critical-theoretic paradigm) generating emancipatory knowledge/practice in the face of seemingly unchangeable organizational structures, relationships, and social conditions.

Most of the research literature reviewed in this chapter reported on preliminary small-scale studies comprised of a few volunteer science teachers to initiate or participate in a novel humanistic project;

studies without sufficient resources to expand in scale or over time. One exception was the research on Harvard Project Physics (Welch, 1973), but it occurred in the 1960s at a time when a good science curriculum was deemed to be a teacher-proof curriculum (Solomon, 1999), when in-service programs simply transmitted the new curriculum's philosophy to passive teachers (White & Tisher, 1986), and when research strictly conformed to the quantitative research paradigm. This paradigm emphasized measurement of outcomes evaluated against expert judgments or against criteria from academic theoretical frameworks.

In contrast, research into humanistic science curricula has evolved dramatically since the 1960s. It is encouraging to see teachers and now students collaborate in the development of curriculum policy (e.g. Aikenhead, 1994a; Orpwood, 1985; Roberts, 1995), along with stakeholders other than university science professors and professional science organizations (e.g. Eijkelhof, 1990; Häussler & Hoffmann, 2000; Law, 2002). In-service programs now tend to be transactional (e.g. the Iowa Chautauqua Project; Yager & Tamir, 1993) and transformational (typically action research). Today research into humanistic science curricula most often follows the interpretive research paradigm, in which researchers attempt to clarify and understand the participants' views and convey them to others or incorporate them into a curriculum (e.g. Eijkelhof & Lijnse, 1988; Gallagher, 1991; Häussler & Hoffmann, 2000; Orpwood, 1985).

The four themes – scale, effect of research on classroom practice, school culture, and research paradigms – help clarify the contexts for past and future research agendas.

Past Research Agendas

Since WW II, the renaissance of humanistic school science has led researchers to produce new knowledge in the attempt to establish the *credibility* of a humanistic perspective among science teachers and policy makers. Their educationally sound prepositional knowledge, however, was almost insignificant in the arena of political reality. For the intended curriculum (this chapter) and for the taught and learned curricula (Aikenhead, 2003a), strong evidence supports the educational soundness of a humanistic perspective. Hence, the issue of credibility need not monopolize research agendas in the future. We do not need more research to show that humanistic school science is educationally sound.

Other agendas have emerged to create classroom change, for instance, agendas associated with action research that combines educationally sound knowledge with politicization (Hodson, 1994; Keiny, 1993). Examples of action research include: Ch. 13, this volume; Bencze, Hodson, Nyhof-Young and Pedretti (2002); Ogborn (2002); Pedretti and Hodson, 1995; Solomon et al. (1992), and Tal, Dori, Keiny and Zoller (2001). However, Solomon (1999) recognized its limitation as only involving a tiny proportion of excellent teachers.

Research agendas associated with classroom change have explored the interaction between political power and practice at the school level (e.g. Carlone, 2003) and have extended this interaction into policy formulation (e.g. Gaskell, 2003; Gaskell & Hepburn, 1998) and into community practice (Calabrese Barton & Yang, 2000; Roth & Désautels, 2004). These studies penetrated the political core of curriculum policy and hold promise for future R&D and developmental research.

Future Research Agendas

To investigate the interaction of research, political power, policy, and practice, with the expressed purpose of changing school culture, researchers must address the politics of school science currently encased in 19th century ideologies. In doing so, one fundamental dilemma must be resolved explicitly and continuously within each research project: does the curriculum aim to enculturate students into their local, national, and global communities (as other school subjects such as English do), or does it aim to enculturate students into a scientific discipline? The prospects of achieving the latter are extremely limited, according to the research synthesized in this chapter.

Politically motivated research in science education by itself may be necessary from time to time to re-invent the discovery that the traditional science curriculum fails most students, for various reasons (e.g. Reiss, 2000), or that humanistic school science can be credible. Of particular interest would be research into Fatima's rules played by various types of students and science teachers, and related to high-stakes testing, educational politics, and ideologies. Future research into humanistic science curricula will best be served by amalgamating the educational with the political, because educationally sound research by itself has had little impact in schools, although its influence is apparent in some official curriculum policies.

To achieve an amalgamation of the educational and political, research into consensus making on curriculum policy promises to be fruitful. Of all the studies into policy formulation reviewed in this chapter, the process of deliberative inquiry holds greatest potential for devising an educationally sound, politically feasible, humanistic perspective in the science curriculum. Deliberative inquiry provides a political forum to hold negotiations among various stakeholders. During a deliberative inquiry meeting, research concerning major failures of the traditional curriculum can be scrutinized, research concerning successes at learning science in non-school settings can be debated, and research on relevance can help clarify the participants' values. For instance, new research on relevance might include: (1) studies into potential content for science-as-culture (e.g. Who is engaged with science and technology in the community? and How?); (2) studies into science-related knowledge/practice that local workers learn in science-related occupations (e.g. What knowledge do nurses actually use day to day on their job?); (3) studies into how science-proficient students use canonical science in their everyday lives (if at all), compared with how science-shy students cope with similar situations; and (4) studies into how professional scientists actually use canonical science in their everyday lives. An example of this last point is Bell and Lederman's (2003) work that showed how university scientists made decisions on everyday socio-scientific issues primarily on values rather than primarily on scientific ideas and evidence; thus creating a rational evidenced-based expectation for students' socio-scientific decision making in humanistic science courses (i.e. students should not be expected to use science content in situations where scientists do not). Future research projects will be politically more effective if they involve clusters of science teachers and other stakeholders. This research will gain politically potency according to the diversity of the research team and the social privilege of it members.

Deliberative inquiry (i.e. consensus-making R&D) will have greater impact on classroom practice: the larger the project's scale (e.g. SCC, 1984), the more culturally transformational it is (e.g. Ch. 13, this volume; Leblanc, 1989), and the more it embraces all three research paradigms appropriately (a feature of scale). Future research could investigate the influence of stakeholders involved in the consensus making process: who they represent, their selection, their assigned versus their enacted roles (i.e. the dynamics of deliberative inquiry), and the actor-networks they bring into the deliberation and that develop as a result of the deliberation (e.g. Gaskell & Hepburn, 1998). R&D on actor-networks themselves could be a primary focus of a deliberative inquiry, forging networks to enhance a clearer and more politically endorsed humanistic perspective.

In the future, preliminary small-scale research studies can still be worthwhile: "Rather than viewing the powerful sociohistorical legacy of science as an oppressive structure that limits the potential of reform, we can view the meanings of science in local settings as partially fluid entities, sometimes reproducing and sometimes contesting sociohistorical legacies" (Carlone, 2003, p. 326); but small-scale studies will lose significance unless they explicitly embed themselves in a larger, articulated, politico-educational agenda for humanistic school science (Fensham, 2002).

Future research programs will be strengthened by forging alliances with researchers in others fields, such as educational cultural anthropology (Ch. 9, this volume), gender studies (Ch. 11), and transformative education studies (Ch. 13 & 25).

Caution is advised, however, from becoming side tracked by some new research methods such as "design-based research" (The Design-Based Research Collective, 2003) or "developmental research" (Lijnse, 1995), because their ultimate aim is to refine theories of learning and didactical structures, respectively. Rather than focus on the question, "*How* do students learn best?" the fundamental issues to be sorted out first are: "*Why* would students want to learn it?" and "*Who* will allow them to learn it?"

These two questions matter critically. The first (Why learn it?) speaks to educationally sound propositions, while the second (Who will allow it to happen?) speaks to the political reality in which all science education research resides.

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