Renegotiating the Culture of School Science:

Scientific Literacy for an Informed Public

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Science educators who have successfully changed aspects of school science know that their success depended on negotiating with many other people (colleagues, bureaucrats, teachers, administrators, etc.). Secondly, school science is an incredibly complex entity, tied as it is to the culture of: science, the nation, the community, the school, the teaching profession, and many more subcultures. Innovators know that school science is best viewed as a cultural entity itself. Therefore, any group wishing to improve science education in their country needs to renegotiate the culture of their school science.

Social and educational realities of our times have caused many science educators worldwide to rethink science education and to propose a renewed culture for school science (for example, Aikenhead, 1980, 2000a; Hurd, 1975, 2000; Millar and Osborne, 1998). These educators usually treat students as future citizens whose scientific literacy should be sufficiently informed to deal with personal or social issues related to science. For these innovative science educators, the future of science education lies in scientific literacy for an informed public.

The purpose of this paper is to clarify some key ideas and issues that Portuguese science educators should consider as they reach a consensus on their own meaning of scientific literacy, as they plan to translate that meaning into classroom practice, and as they renegotiate the culture of school science in Portugal. These key ideas and issues address the needs of the vast majority of high school students who do not require preprofessional scientific training for their post secondary studies or vocations.

For these students, the conventional science curriculum has little relevance to their current or future lives
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(Aikenhead, 1980; Layton, et al., 1993; Millar and Osborne, 1998). School science devoted to preprofessional training for university science courses largely fails to captivate enough student interest to develop scientific literacy. Internationally, research has shown that even bright creative science students are discouraged by a boring and irrelevant curriculum and drop out of science (Bondi, 1985; Eijkelhof, 1990; Oxford University, 1989; Science Council of Canada, 1984; Sjøberg and Imsen, 1988; Solomon, 1993).

This paper is organized around four major points. First, some meanings of scientific literacy are reviewed, followed by a description of some projects that claim to have achieved scientific literacy for their students. Next the future of those projects is discussed. The last point draws upon the collective experiences of science educators to outline how to renegotiate the culture of school science by establishing new policies, by developing new teaching materials, by enhancing teachers' practical knowledge, and by broadening classroom instruction and assessment methods.

Scientific Literacy

Scientific literacy is a slogan used by educators worldwide to guide curriculum development and classroom practice. Slogans also serve to rally support for fundamental changes to school science (Roberts, 1983). For instance the slogan "science-technology-society-environment," a Canadian approach to achieving scientific literacy, galvanised a diverse cluster of provincial ministries of education into collaborating on Canada's first national framework for a science curriculum (CMEC, 1997). This Canadian framework has already motivated curriculum revisions in some provinces and guided the production of new science textbooks (Aikenhead, 2000b). Each country must develop its own meaning of scientific literacy to meet the social, political, and economic needs of that country. Portugal is no exception.

How well will Portuguese students function in their own society with scientific and technological advancements such as genetically modified organisms, global energy mining, the human genome project, organ harvesting, Ritalin for the young, Viagra for the old, and Prozac for everyone? In other words, how can students be empowered to gain responsible control over their own destinies in dealing with the scientific and technological aspects of their society?

An informed public needs a critical consciousness, tempered with reasoned or justified beliefs and actions (Aikenhead, 1990). Such empowerment allows all citizens to handle scientific and technological challenges which people are certain to face in a society characterized by change. Ignorance or fear of science and technology (that is, scientific illiteracy) can enslave a citizen into a 21st century serfdom. "Techno-peasants" are such people; bewildered or intimidated by the new techniques and languages of science and technology (Prewitt, 1983). Techno-peasants are outsiders in their own society. Educating students to feel at home in their own culture is the prime goal of all schools.

In contrast to techno-peasants, a scientifically literate public acts upon a shrewd understanding of how
the system works (Prewitt, 1983):

The scientifically savvy citizen . . . is a person who understands how science and technology impinge upon public life. Although this understanding would be enriched by substantive knowledge of science, it is not coterminous with it. (p. 56)

Science educators need to renegotiate conventional school science with its goal of preprofessional training, and replace it with a school science that develops savvy citizens who understand the social context of science and technology (Aikenhead, 1980). A savvy public will recognize that scientific research is immersed in moral reasoning and political dynamics. In Portugal for instance, as elsewhere, scientific research competes for funding with other social activities, and its social goals can be linked to corporate profits, political prestige, and military prowess (Dickson, 1984). A savvy citizen knows this.

An informed public has the capacity to make reasoned decisions and take responsible action (Aikenhead, 1980, 1985; Kolstø, 2001; Kortland and Lijnse, 1996). Decisions and action arise from both knowledge and values. An informed public will make their decisions thoughtfully by bringing their pertinent knowledge into focus with the values that guide their decisions and action. Accordingly, citizens will need to clarify the values inherent in a scientific decision, including the values of public and private science that guided that decision (Bingle and Gaskell, 1994; Holton, 1978). In addition, an informed public (1) will be sensitive to the narrowing between basic research and its commercial implementation; (2) will have a sufficient grasp of science and technology to appreciate the communication conventions of science, its assumptions, its key beliefs, its conventions, and its human character; and (3) will appreciate the ways in which science and technology inform government policy nationally, as it relates to economic growth, and internationally, as it relates to a nation's bargaining access to scientific and technological knowledge held by international corporations and national super powers. A scientifically literate citizen will detect political motivation obscured by scientific jargon, calculations, forecasting, and policy development; and will have the capacity to influence the content of decision-making agendas and to influence the conditions of participation in societal decisions related to science and technology (Aikenhead, 1990).

Hurd's (1988, p. 4) conception of literacy underscores the idea advanced here: "As a teaching goal science and technology literacy translates into the ability of a student to interpret science and technological achievements and deficiencies in terms of the human and social forces that generate and sustain them." Hurd warrants his claim with the techno-peasant argument: "Students who are illiterate concerning the interaction of science, technology, and society are doomed to live isolated from the culture that surrounds them but which they cannot fully experience" (p. 4).

Achieving Scientific Literacy

A pressing educational agenda for science educators is to renegotiate the culture of school science to
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meet the 21st century needs of future citizens -- an informed public (Aikenhead, 1980; Eijkelhof and Kortland, 1988; Fensham, 1992; Millar, 1996; Millar and Osborne, 1998; Solomon, 1981). In order to challenge the status quo of school science, one needs a slogan to create networks of science educators dedicated to a renewed vision of how to achieve scientific literacy (Roberts, 1983). Over the past two decades in several countries, that slogan has been "science-technology-society" (STS). Its historical development is reviewed elsewhere by Aikenhead (2002a) and Solomon (2002). An international perspective on STS curriculum and pedagogy can be found in Solomon and Aikenhead (1994). STS instruction aims to help students make sense out of their everyday experiences, and does so in ways that support students' natural tendency to integrate their personal understandings of their social, technological and natural environments. In an STS science curriculum, canonical science content is connected and integrated with the students' everyday worlds, and in a manner that mirrors students' natural efforts at making sense out of those worlds. Thus, STS is student-centred, not science-centred; in other words, science is brought into the student's world on a need to know basis, rather than follow the conventional expectation that a student enter the world of science to adopt the view of a scientist.

STS science is also expected to fill a critical void in the conventional curriculum -- the social responsibility in collective decision making on issues related to science and technology (Aikenhead, 1985; Gaskell, 1982; Kortland and Lijnse, 1996; Sjøberg, 1997).

This pervasive goal leads to numerous related goals: individual empowerment (Layton, 1986; Solomon, 1993); intellectual capabilities such as critical thinking, logical reasoning, creative problem solving, and decision making (Aikenhead, 1992; Bybee, 1987); national and global citizenship, usually "democracy" or "stewardship" (Knain, 1999; Kolstø, 2000; Ødegård, 2001); socially responsible action by individuals (Cross and Price, 1992; 1999); and an adroit work force for business and industry (Bondi, 1985; Hurd, 1989; Moore, 1991; Wirth, 1991). These goals emphasize a student's enculturation into a society increasingly shaped by science and technology.

From country to country, STS science courses differ widely because of their different goals. Upon closer examination, however, this variation reflects only differences in the balance among similar goals. In other words, most STS science courses harbour similar goals but give different priorities to different goals.

Each country has its own story to tell. For instance in Canada and Israel, the environment was emphasised by adding an "E" to STS, producing STSE and STES respectively, with numerous school implementations achieved (Hart, 1989; Zoller, 1991). In the Netherlands, the PLON project grew by embracing environmental education, while at the same time, moving into the secondary schools and continuing the project's tradition of in-depth research studies with participating students (Eijkelhof, Kortland, and Lijnse, 1996). In the UK, a variety of state-of-the-art projects and syllabi were developed (Solomon, 1996). After taking an STS leadership role during the 1980's, the USA has slid back to a more conventional approach to school science (Aikenhead, 2002; Kumar and Berlin, 1996, 1998), with the exception of Berkeley's Science Education for Public Understanding Program (SEPUP, 2002). In Australia, a link to industrial technology became evident in some projects, in addition to the more conventional STS courses (Fensham and Corrigan, 1994; Giddings, 1996). In Belgium under the
guidance of Gérard Fourez, ethics was added to STS, which named the journal *Sciences Technologies Éthique Société*, published out of the University of Namur. In Italy, STS developed towards a more scientific discipline oriented approach to societal issues (Prat, 1990). In Spain, Maria Manassero-Mas, Ángel Vázquez-Alonso and José Acevedo-Díaz's (2001) have approached STS from an evaluative perspective, described in their book *Avaluació dels Temes de Ciència, Tecnologia i Societat*. The story from Japan involves science educators being influenced by projects in the UK and USA, but developing their own version of STS, along with considerable research (Nagasu and Kumano, 1996). However, as Gaskell (2001, p. 385) concluded, "Although STS has been widely accepted as part of science curriculum policy, there is little evidence that it has made much impact on classroom practice, particularly in the academic stream of secondary schools."

The Future of Science-Technology-Society

Slogans come and go as social realities change over time. Nevertheless, in every era or in every political setting, it is essential to use a slogan to rally support for fundamental changes to school science (Roberts, 1983). Today "Science-Technology-Citizenship" is a slogan in Norway where the culture tends to accentuate students' relationships with nature and with national citizenship (Royal Ministry of Church, Education and Research, 1995). Innovative Norwegian projects dedicated to teaching school science for an informed citizenry have been completed (Knain, 1999; Kolstø, 2000; Ødegaard, 2001; Sjøberg, 1997). Considerable research and development is also occurring around the slogan "Science for Public Understanding" (Eijkelhof and Kapteijn, 2000; Fensham and Harlen, 1999; Jenkins, 1999; Millar, 1996, 2000; Thier and Nagle, 1994). Also of interest is "Citizen Science" (Cross, Zatsepin and Gavrilenko, 2000; Irwin, 1995) and "Functional Scientific Literacy" (Ryder, 2001). All these initiatives are based on the rationale for scientific literacy described in this paper.

Negotiating an STS Type of School Science

For Portuguese science educators wishing to accept the challenge of changing the conventional science curriculum to an STS type of science curriculum (or citizen science, or science for public understanding, or whatever slogan coalesces consensus in Portugal), two decades of experience in Canada from developing STS programs and materials may provide sound advice about which pathways to follow and which to avoid (Aikenhead, 2000b, 2002b). In this section of the paper, I sketch out four products that need to be developed. Each product is associated with a particular process to produce best results. The first product required to change school science is a curriculum policy, best formulated through the process of deliberation (Aikenhead, 2000b; Hart, 1989; Orpwood, 1985; Roberts, 1988). The second product consists of classroom materials that support and guide instruction, best produced through the process of research and development (R&D). The third product to be achieved is teacher understanding of the policy and teaching materials. Although the involvement of key teachers in the processes of
deliberation and R&D is an excellent idea to secure teacher understanding, the best process to achieve overall teacher understanding turns out to be implementation. Teacher understanding evolves mainly during their attempts at implementing an STS course, for instance. The fourth product is student understanding. This is achieved, of course, through the process of instruction/assessment.

This sequence of products (from policy to student learning) reflects three levels of any curriculum: the intended curriculum (government curriculum documents), the translated curriculum (textbooks and teachers' ideas about what will be taught), and the learned curriculum (the concepts, capabilities, and attitudes that students actually take away with them). Science educators must consider all three levels of the curriculum before successful STS school science can be produced.

Changing conventional science instruction into an STS type of approach is an incredibly complex undertaking. When we partition this complexity into these four pairs of products and associated processes, we can focus more clearly on one aspect at a time. The four pairs of products and processes are outlined here. A more detailed description of them may be found in Aikenhead's (2000b) "STS Science in Canada: From Policy to Student Evaluation."

Curriculum Policy and the Process of Deliberation

When we consider curriculum policy itself, several aspects must be explored: (1) its function -- what are the goals and objectives for teaching the content? (that is, the ideas related to scientific literacy, such as those discussed in this paper); (2) its content -- what is worth learning? (3) its structure -- how should the canonical science and STS content be integrated and contextualized in students' everyday world? (4) its sequence -- how should the curriculum and instruction be organized? and (5) the process of establishing the function, content, structure, and sequence -- who should be involved? and how should curriculum policy decisions be decided? Each country must answer these questions for itself, because STS education responds to the idiosyncratic needs of each country, as described in Solomon and Aikenhead (1994).

Consensus is particularly difficult to achieve around the aspect of content. For this reason, let me mention a few ideas that address the question of content: What knowledge is worth knowing?

Scientific literacy calls for a relevant science curriculum, relevant from the point of view of future citizens. Fensham (2000) delineates four types of relevance, each related to who decides what is relevant. He claims that when scientists or science educators determine relevancy, it often is a wish list -- "I wish they knew . . ." -- a relevancy to the next level of science study. This type of relevancy, of course, leads to the conventional, status quo science curriculum which is generally rejected by STS educators in favour of a student-centred curriculum.

A second type of relevancy comes from an analysis of real-life events to determine what knowledge does a future public need to know. Excellent empirical analysis of this type was completed by Layton
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and his colleagues (1993) who drew upon a study of parents dealing with the birth of a child with Down's syndrome, a study of old people's dealings with energy use, a study of workers at a nuclear power plant dealing with scientific information on radiation effects, and a study of town councillors dealing with the problem of methane generation at a garbage dump (landfill site). But Fensham claims this second type of relevance is based on a retrospective look at what certain citizens needed to know to solve a specific social issue. Chances are great that most students will not face the same issue. Also, "the time gap between school and the 'need', make it unattractive to curriculum designers of school science" (p. 74).

Fensham recognized a third type of relevance, one based on the power of those aspects of the mass media that people focus on, even the sensational or dishonest aspects. He calls this relevance enticed to know science. Teachers can garner high student motivation by using the internet and other mass media, and then focus on the scientific knowledge found, or misrepresented, there. Fensham finds little lasting value in this type of relevance.

He does, however, support a fourth type of relevance based on the real life experiences of experts who continually deal with the general public on issues related to science and technology. This content of school science, have cause to know science, is empirically valid, Fensham argues, and it has a much greater chance to connect with a larger number of students. Fensham (2002) and Fensham et al. (2000) illustrate how curriculum designers can decide what "have cause to know" science to include in a curriculum, by proposing three phases:

Phase 1: Societal experts systematically determine features of society endemic to an informed public. These judgements are based on the problems these experts have had communicating with the public. In a Hong Kong project, for example, experts were a medical doctor working in a large general hospital emergency ward, a medical doctor involved in preventive care and community health education, an official in the Consumer Council of Hong Kong, a nutritionist, and a youth worker.

Phase 2: Academic scientists specify science content associated with the features of society identified in phase 1.

Phase 3: Based on the phases 1 and 2, science educators develop a school science curriculum.

These phases address the content to be included in a curriculum, not the implementation of the curriculum.

Fensham's (2002) three-phase plan differs from past and present STS projects that have essentially ignored phase 2 by eliminating from their team academic scientists who might foster Fensham's first type of relevance -- the "I wish they knew" science, an allegiance to university science departments. Instead these innovative projects have drawn upon a combination of "need to know" science, "enticed to know" science, and "have cause to know" science. Some examples include: Science: A Way of Knowing (Aikenhead and Fleming, 1975); the Science in a Social Context (SISCON)-in-Schools STS project
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Some more recent innovative curriculum projects that embrace scientific literacy for an informed public do not use the STS slogan. The Science Education for Public Understanding Program, SEPUP (SEPUP, 2002; Thier and Nagle, 1994), has produced STS chemistry modules and two STS textbooks, *Issues, Evidence and You* (SEPUP, 2000a) for 14 to 16 year old students, and *Science and Sustainability* (SEPUP, 2000b) for 15 to 17 year-olds. The content of the last publication, for instance, was chosen so students could explore four general themes: living on earth, feeding the world, using earth's resources, and moving the world. The SEPUP publications come with extensive teacher guides and classroom laboratory materials, as expected of projects in the USA.

A new Dutch course of studies, Public Understanding of Science for Senior General Secondary Education (Eijkelhof and Kapteijn, 2000), provides a syllabus for teachers to introduce their students to the following topics: life, human health, unity and diversity, the biosphere, sustainable development, substances, production of materials, origin of knowledge about matter, the solar system and the universe. Teachers have the freedom to choose specific issues to study within the topics listed. This gives teachers the opportunity to decide what specific content is relevant for their own students.

To help decide on relevant content for a new advanced subsidiary (AS) level course and textbook in the UK, *AS Science for Public Understanding* (Hunt and Millar, 2000), Millar analysed newspaper stories over a one-year period to determine what functional content informed citizens needed to know to understand those science-related stories (Millar, 2000). The main topics of that content turned out to be: health and disease, genetics, understanding who we are, our use of energy resources, the effects of radiation, and understanding where we are. This textbook illustrates excellent STS character by presenting the social and technical information required to comprehend what people will read or hear in the media, by making ideas about science (the nature of science) explicit to students, and by treating the canonical science content as reasonable "explanations."

It is interesting to note the similarities among the topics that emerged from the projects mentioned above, in spite of the fact each project evolved independently of each other. But they all considered relevancy defined by: "need to know" science, "enticed to know" science, and "have cause to know" science (Fensham, 2000). One conclusion seems clear, Portuguese innovators should consider incorporating various types of relevance into any new school science content which is dedicated to scientific literacy for an informed public.

Hansen and Olson (1996) and Bingle and Gaskell (1994) point out that many educators narrowly conceive of STS science content as dealing with social issues that connect science with a societal problem. Ziman (1984) reminds us, however, that there are two types of social issues in STS science: (1)
social issues *external* to the scientific community (science and society topics, for example, genetically modified organisms, population growth, or pollution); and (2) the social aspects of science -- issues *internal* to the scientific community (the sociology, epistemology, and history of science, for example, the nature of scientific theories, or how the concept of a sun-centred solar system evolved).

Once the STS content and the canonical science content are generally agreed upon, the next task is to integrate the two types of content: STS science content is a combination of canonical science content and STS content. But how much canonical science content is integrated with STS content? and How is this integration accomplished? To answer this question, Aikenhead (1994d, 2000b) devised "Categories of STS Science," a descriptive scheme with eight categories that characterize STS science teaching. The eight categories of STS science provide a language for discussing various structures for STS curricula, classroom materials, and teachers' instruction.

The task of how to integrate the two types of content is often helped by deciding what sequence the content should appear in. Eijkelhof and Kortland (1987, 1988) devised the following sequence: social content technology content canonical science content advanced technology content advanced social content. This sequence has great merit, I submit, for a textbook, for a chapter, and for an individual lesson. Although teachers may spend the majority of their instruction time on the canonical science content (for instance, 70% of instruction time), the Eijkelhof and Kortland sequence ensures that this canonical science content will be contextualized in a relevant way for students (Aikenhead, 1994a).

In summary, the first product towards developing an STS type of science curriculum is curriculum policy. Curriculum policy has a function, content, structure, and sequence, as well as a process for determining that policy; a process that will reflect the unique political protocol followed in each country. To develop a curriculum policy, educators should consider using the process of deliberation, in which many stakeholders are involved in the decisions that formulate policy (Aikenhead, 2000b; Hart, 1989; Orpwood, 1985; Roberts, 1988). Aikenhead (2002b) has described some of the political pitfalls involved in the Canadian experience of producing an STS science curriculum.

Canada inaugurated its first national framework for science education in 1997, the *Common Framework of Science Learning Outcomes*, developed by the Council of Ministers of Education of Canada (CMEC, 1997). This pan-Canadian protocol for school science established a science-technology-society-environment (STSE) approach to achieving scientific literacy in Canada. The publication is a curriculum policy document and not a curriculum per se. It represents a type of STS science education that may be attractive to STS educators elsewhere.

Classroom Materials and the Process of Research and Development

The second product required in the renegotiation of the culture of school science consists of classroom materials that support and guide STS instruction and assessment. Conscientious teachers require professional guidance on a daily basis to help them fulfill a new curriculum policy. These teachers
deserve suitable classroom materials (for example, practical teacher guides, examples of how to assess students, student booklets, resources, and textbooks). Without suitable materials, an STS science curriculum will not be achieved.

From country to country, cultural conventions differ over how textbooks and teaching materials are developed. The vested interests of the traditional textbook establishment (authors included) can undermine attempts at changing the science curriculum. If STS curriculum developers are to be successful, therefore, alternative processes for developing classroom materials may be needed. The most promising process is research and development (R&D).

There are differences between an R&D study and a typical research study normally reported in the research literature. In an R&D study, data are not collected to inform a theoretical model or to assess a program in any summative way. In an R&D study, research is undertaken and data are collected to be fed directly into improving the product of the study (or improving practice related to the product). This goal resembles formative assessment and action research. For example, R&D studies in science education were used in the 1970's and 1980's by a physics project that produced science-technology-society (STS) modules in the Netherlands (Eijkelhof and Lijnse, 1988). Aikenhead (1994a) employed an R&D study to produce the STS textbook *Logical Reasoning in Science and Technology*. His project was informed by the research literature on student learning, teacher practical knowledge, and STS content itself, and by the developer's earlier experiences producing STS materials (Aikenhead, 1979). This R&D project followed a multistage sequence that took place in various classrooms, collaborating with students and teachers. By engaging students in tasks in the natural setting of their own classroom, he was able to attend to information that spontaneously emerged during instruction, or to information that thoughtfully evolved from informal discussions with students.

Although a full R&D process may not be feasible in Portugal, the process might guide some of the smaller tasks needed to pilot early versions of the teaching materials.

Teacher Understanding and the Process of Implementation

Teacher understanding is a major component in the successful development of an STS curriculum. The intended curriculum must be interpreted into the translated curriculum before student learning occurs. Teacher understanding is arguably the most crucial influence in this transformation. Curriculum developers must negotiate with teachers.

Prior to implementing a new STS curriculum policy, science teachers will have their own ideas about what constitutes appropriate content, instruction, and assessment. These views will be diverse. For instance, a few teachers' preconceptions will already exemplify the new curriculum policy. Some teachers will be timid about change but will be ready to try an innovation on a small scale to see what happens. And other teachers will be steadfast in their preconceptions and little can be done to change these.
Teachers' previously held conceptions are usually constructed during their pre-service education experiences and from their teaching experiences (Aikenhead, 1984; Duffee and Aikenhead, 1992). Their conceptions fulfill many practical purposes, such as coping with, and surviving in, a wide range of classroom contexts and community situations. An in-service program associated with a new STS curriculum is only a tiny increment in a wealth of past experiences that have shaped a teacher's understanding of science teaching. Thus, a simple in-service intervention by itself holds little promise for altering a teacher's acceptance of STS science. Teachers' preconceptions will not likely change unless those teachers are able to influence their teaching contexts and are able to envision the practical consequences of a new curriculum. In other words, teachers must have a role in the negotiation of a new culture of school science. Rational arguments do not change deeply held values, but some teachers will be impressed by the positive reaction of their students to STS instruction and they will consequently rethink some of their teacher practical knowledge. In other words, teacher understanding of a new curriculum policy comes during, not before, the process of implementing that new policy. Implementing policy in a thoughtful way is a negotiation strategy worth considering.

I would like to identify one major problem and then suggest some general plans of action that we in Canadian have found successful in producing STS science curricula. When studying science at university, teachers experience a process of socialization into a discipline (Ziman, 1984). During that experience, teachers develop deep-seated values about science teaching (Aikenhead, 1984; Pedretti and Hodson, 1995). Many science teachers have been socialized into believing that they too have the responsibility to socialize their students into a scientific discipline (that is, science-centred instruction, not student-centred instruction). The most powerful self-image for many teachers is the image of the "little professor" initiating students into the culture of his or her scientific discipline. From a teacher's point of view, the best way to initiate students into a discipline is the same way the teacher was initiated (Aikenhead, 1984). STS science, with its goal of scientific literacy for an informed public, challenges the conventional goal of preprofessional training and the initiation of students into a scientific discipline (Hurd, 1975). Therefore, to renegotiate the teacher's contribution to the culture of school science successfully (that is, to implement an STS science course successfully) is to change the deep-seated, personally cherished values of a number of teachers (Aikenhead, 1984; Hughes, 2000); for example, their image of themselves as initiating students into a scientific discipline. Teachers' practical knowledge must go through a Kuhnian paradigm shift (Kuhn, 1970). Paradigm shifts are difficult to achieve. They involve knowledge, values, assumptions, loyalties, and self-images; and therefore they require more than rational arguments and simple in-service programs.

Because science teachers have been socialized by university science professors, then one successful plan for negotiating change has been to involve the scientific community -- the community responsible for shaping a science teacher's values in the first place, and a community with academic credibility. A cadre of enlightened scientists, carefully selected from industry, government labs, and universities, must relieve science teachers of the burden of socializing students into a scientific discipline. In addition, these same experts may be helpful in determining relevant science content -- the "have cause to know" science. Enlightened scientists, often parents of high school students disenchanted with their science courses, will likely support an STS curriculum policy even more if those scientists were involved in the
deliberation process that produced that policy in the first place.

In addition to changing deep-seated values and images of teaching science, teachers must add new methods to their repertoire of instructional strategies. A new routine of instruction is best learned from fellow teachers -- the people who have practical credibility. A successful plan of action will involve a few cleverly selected teachers chosen to go through an intense in-service experience. These teachers then become in-service leaders in their own regions of the country, passing on their leadership expertise to other teachers who repeat the in-service process in their own communities.

One needs "technology transfer" in-service programs, characterized by materials and know-how being transferred from experts to others who work in different locations. Educators could benefit from adopting technology transfer methods from industry. For instance, transfer of expertise requires practical on-site experience and a network of participants. In education this would mean that science teachers who are novices with respect to STS science would spend time in the classroom of an "expert" teacher -- one who is implementing an STS course. Technology transfer can serve as one useful method for the process of implementing an STS curriculum.

Student Learning and the Process of Instruction/Assessment

Curriculum policy, classroom materials, and teacher understanding, all lead to student learning -- the ultimate product of an STS science curriculum. Instruction and assessment are the obvious processes that nurture student learning in the formal setting of schools.

Teachers and parents often express the fear that students will not learn as much canonical science content from an STS science curriculum. Their fears are largely unwarranted. Research into student learning shows that spending time on new topics and activities (not normally considered canonical science content but related to that content, for example, STS content) is not detrimental to student achievement on traditional science content tests or to careers in science and engineering (Aikenhead, 1994b; Champagne and Klopfer, 1982; Yager and Krajcik, 1989). Therefore, a high school STS science curriculum will not necessarily be detrimental to student achievement in their first year university courses, provided that students have a facility in quantitative problem solving (Aikenhead, 1994b). For students not expecting to enrol in university science courses, the preprofessional training function of school science vanishes.

Scores on international tests are often used politically to support a conventional position during science curriculum debates. Science educators must vigilantly challenge the validity of these assessments and the politics of their interpretation (Fensham, 1998; Jenkins, 2001). For example in Saskatchewan, our Department of Education was under intense pressure to participate in national and international testing programs. Its policy to be low key on this issue was recently supported dramatically by a Scientific American article entitled "The False Crisis in Science Education" (Gibbs and Fox, 1999). The authors had conducted thorough journalistic research in three cities: Amarillo, Texas; Saskatoon, Canada; and
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Umea, Sweden. The original agenda for the journalistic research was to identify the reasons for TIMSS (Third International Math and Science Study) scores being highest in Sweden, high in Canada, and low in the USA. In the article's title, the phrase "false crisis" harboured two different meanings. In the first sense of false crisis, it was argued that the highly publicized test-score crisis advanced by status quo protagonists was largely an emperor without clothes. The *Scientific American* researchers learned to distinguish between "statistical significant differences" and "educational significant differences" in test scores (Gibbs and Fox, 1999, Figure 1). Thus, the first false crisis was attributed to a narrow interpretation of the assessment data. A second sense of false crisis was discussed more thoroughly in the article. In Saskatoon, Gibbs noticed and documented a quality of teaching (an STSE approach to school science) that he had not found in either Amarillo or Umea. He concluded that the curriculum objectives assumed by TIMSS were false with respect to our current understanding of scientific literacy (school science for an informed public). The article's second sense of false crisis, therefore, was the falsity of the teaching objectives subscribed to by the protagonists for a conventional science curriculum. Such a high profile endorsement of STSE science from a *Scientific American* article was read in educational and political circles throughout the province. One lesson to take away from this experience is this: any proposal for developing a new type of science curriculum should have high profile endorsements designed into the proposal. Endorsements will strengthen one's negotiating position.

Although relevant STS science instruction and assessment increase student interest, students tend to experience difficulty when mentally moving between their everyday world of commonsense concepts -- characterized by social interactions and consensus -- and the theoretical world of pure science concepts -- characterized by logical reasoning with evidence (Hennessy, 1993; Lijnse, 1990). If STS science teachers expect students to learn the canonical science content in enough depth to use it in everyday situations (rather than to memorize it for an examination), then STS science teachers have taken on a much more rigorous task than conventional science teachers. This in-depth learning contrasts with making a political difference to students' lives by passing tests that artificially open doors to social opportunities (for example, attending university), but without achieving any meaningful learning of the science content (Aikenhead, 2000a; Costa, 1997).

Because STS instruction aims to make a real difference to a student's everyday life, STS science teachers run the risk of judging their own success by a much higher standard than teachers who subscribe to the goal of getting students through their course. In this sense, then, conventional science instruction and assessment can be viewed as "soft" and superficial, while STS science instruction and assessment can be thought of as "hard" and rigorous. For instance, memorizing how to solve heat transfer problems is superficial. On the other hand, explaining how the conceptual invention of energy changed scientists' ideas about heat transfer is rigorous. The assessment of student learning can be superficial or rigorous.

One way to help students move back and forth between their everyday world of commonsense and the abstract world of science is to treat science from the point of view that most students hold: science is a foreign culture (Aikenhead, 1996, 2000a). This "cross-cultural" approach to STS science instruction is gaining international attention as educators focus on students' "border crossings" between their home/peer culture and the culture of science (Aikenhead and Jegede, 1999; Jegede and Aikenhead, 1999).
Instructional strategies for STS science were first addressed systematically in 1980 by Ziman in his book *Teaching and Learning about Science and Society*. Solomon's (1993) *Teaching Science, Technology and Society* is an excellent current resource for technology transfer programs for STS science teachers. In an article entitled "How to Make Science Relevant," Byrne and Johnstone (1988, p. 44) concluded, "It is the achievement of interactivity, rather than the exact format, whether it be simulation, group discussion or role playing." Interactive learning approaches are often identified with STS science instruction. Byrne and Johnstone's research suggests the following:

1. In terms of learning canonical science content, simulations and educational games can be just as effective as traditional methods. In terms of developing positive attitudes, simulations and games can be far more effective than traditional methods.

2. In terms of attitude development, the strategies of role playing, discussion and decision making can be highly effective.

3. "Group discussion can stimulate thought and interest and develop greater commitment on the part of the student." (p. 45)

4. In terms of promoting an understanding of the processes of science, an analysis and evaluation of historical case studies can be effective.

Champagne and Newell (1992) point out that certain educational jurisdictions demand that assessment be simplistic, competitive, and unidimensional in order to distinguish winners from losers. Tests are designed "on the assumption that knowledge can be represented by an accumulation of bits of information and that there is one right answer" (p. 846). On the other hand, "alternative assessment is based on the assumption that knowledge is actively constructed by the child and varies from one context to another" (p. 847). For successful STS science courses to succeed, the latter position must be supported by curriculum policy, classroom materials, and teacher understanding (Aikenhead, 2000b). Part of renegotiating the culture of school science is to have assessment practices in place that harmonize with the curriculum policy of scientific literacy for an informed public. The American innovation SEPUP excels at this (Thier and Nagle, 1994).

Today we recognize that learning will be more effective when classroom activities serve both instructional and assessment functions (Bell and Cowie, 2000; Black, 1997; Gallagher, et al., 1996). As a result, formative assessment techniques that accumulate data during instruction (for example, quizzes, check lists, portfolios, concept maps, posters, and self-assessments) are thought to be both instructional strategies and assessment techniques. In the classroom, greater learning takes place when instruction and assessment are integrated.

**Summary**
The purpose of this paper was to clarify some key ideas and issues that Portuguese science educators should consider as they renegotiate the culture of school science in Portugal. Educators must reach a consensus on their own meaning of scientific literacy for an informed public, and they must plan to translate that meaning into classroom practice. This translation takes place when one negotiates a new science curriculum, develops new teaching materials, negotiates an enriched teacher practical knowledge, and nurtures teachers' capacities to instruct and assess. In a cursory way, I have illustrated these ideas with examples of STS curriculum policies and STS teaching materials from other countries. Although these policies and materials cannot be transported from one country to another without considerable cultural disruption, the policies and materials may inspire Portuguese science educators to creatively innovate within their own educational jurisdictions.

References


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