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Science | Environment | Health

Towards a Renewed Pedagogy for Science Education

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Introduction

Albert Zeyer and Regula Kyburz-Graber

Health and the environment are important learning areas in science education, and they are growing in importance. Not only do they have high social relevance, but also they are close to students' interests and needs. They provide an opportunity to open up science to individually relevant questions and to promote both boys' and girls' commitment to science education.

The structure and content of this book emerged from a conference held at the University of Zurich, Switzerland, in August 2010. The aim of the conference was to bring together professionals in education, health, and environment in order to reflect on science education. The conference provided a platform for keynote lectures by researchers who are prominent in the field, as well as a variety of workshops, where both advanced and young researchers presented their research studies for in-depth discussions. This book contains a selection of papers, which have culminated from the activities at the conference, organized and reviewed by the editors.

The book's core idea is to present well-founded perspectives on how science education may benefit from challenges of both health education and environmental education. Specific reasons concerned with why these areas are particularly legitimized to challenge science education and with their potential impact on a revision of science education are discussed and evaluated. The book title is inspired by a suggestion that **Justin Dillon** makes in his contribution. He uses the term science|environment|health to refer to the potential mutually beneficial relationship between the three fields in a revised science pedagogy.

The challenge for science education is at least twofold. Firstly, and quite obviously, the inclusion of health and the environment in science education has implications for the classroom. This comprises considering curricular aspects, the educational

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reconstruction of health and environmental topics, problems of teacher education, and other issues of both theory and practice.

Second, and perhaps even more important, is the challenge that arises when integrating health and environment related issues and topics within science education. These issues are often complex and intertwined with social and societal questions. They are, by their very nature, interdisciplinary and include elements of critique, of empowerment, of informal reasoning and value judgment, etc. In other words, these are socio-scientific issues! The teaching of socio-scientific issues extends beyond the transmission of canonical science in a traditional way. Indeed, while challenging traditional knowledge transmission in science education is not new, health and environmental issues might work as catalysts in the transformation of science teaching in a way that has been sought by science education researchers for many years.

This book is divided into two parts. In the first part, the challenges are introduced and discussed. This part is followed by another in which suggested responses are outlined. The opening chapter is written by **Peter Fensham**. Fensham starts by evoking the grand challenges and opportunities of the twenty-first century. The very fact that issues of environment and health are so prominent in these may be understood as an urgent call for education, in particular science education, to help foster a public climate in which related difficult political decisions are allowed to be made. The introduction of the Cynefin Framework, which stems from complexity theory, is central to Fensham's argument since health and environmental issues are mostly complex and therefore uncertain and loaded with high risk. To address the challenges, Fensham concludes that a focus on socio-scientific issues is required as well as traditional school science.

Regula Kyburz-Graber, basing her argument on critical theory and the concept of socio-ecological education, quite similarly points out in her chapter that environment and health are more than just interesting and socially relevant learning areas in science education. Rather, through these areas modern society and scientific communities are urged to learn that scientific knowledge does not provide the certainties that are frequently sought when it comes to identifying solutions for newly arising problems. Indeed, our current view of science might be challenged more by the inclusion of health and environmental issues in science education than by most other topics.

This argument directly leads onto the third chapter in the first section that is written by **Rodger Bybee**. This chapter is centered on the concept of scientific literacy. Bybee supports a vision of scientific literacy in which learning science is emphasized in the context of life situations which include science and technology. Bybee agrees with Fensham and Kyburz-Graber that the inclusion of health and environmental contexts in science education provides a chance to foster this vision of scientific literacy. Based on the results of PISA 2006, Bybee proposes a curriculum which should be guided by the "Sisyphean question": given a life situation that involves health or environmental issues, what should citizens know, value, and do?

In the following chapter, **Peter Schulz** and **Kent Nakamoto** introduce the concept of health literacy in terms of a competence with increasingly complex skills. In their chapter, they discuss the measurement of this competence and the role of knowledge and judgment within it. Based on the results of a case study on the use and misuse of antibiotics in Switzerland, they conclude that basic reading and writing skills are not sufficient to face future challenges in the field of health. As a result, they explain that an urgent need exists for a considerable amount of declarative and conceptual health knowledge, which must be combined with an adequate level of judgment skills. Schulz and Nakamoto discuss what they, as researchers in the field of health promotion, would expect from school curricula.

The second part of the book also consists of four chapters. **Justin Dillon**, in the first of these chapters, emphasizes that the growing dissatisfaction with the existing science curricula in many countries provides an opportunity to consider a radical reform that includes health, environmental education, and science education as partners. Based on existing research results and concepts, Dillon describes possible outcomes of a new curriculum that should be diverse and more personalized and local than is currently the case. He describes many concrete aspects and desirable features of such a curriculum.

In the subsequent chapter, **Paul Hart** explores how perspectives from environmental education have worked to accommodate socio-ecological, political, and, more recently, cultural issues in ways that broaden conceptions of what counts as school science. Hart argues that these perspectives have the potential to change thinking about how school subjects can deepen student engagement with meaning and understanding through construction of subjectivities. Implicit in this discussion is a change in how young people's engagement with school science can be reconceived within expanded notions of what counts as curriculum and pedagogy.

Alla Keselman, Savreen Hundal, and **Catherine Arnott Smith** review research studies suggesting that when it comes to daily life and social action, students would benefit from a deeper understanding (than what is currently taught) of biology and environmental factors that impact health. The educational interventions that are reviewed in this chapter are those in which deep conceptual understanding and informal reasoning and argumentation skills are emphasized and which have been shown to improve students' ability to reason about personal and socio-scientific health issues. The authors conclude that science education which is likely to promote scientific literacy emphasizes reasoning and argumentation about general and environmental health and is situated in the context of realistic situations and socio-scientific dilemmas. This process can then encourage informed citizenship and enlightened personal choice concerning health.

Albert Zeyer proposes a framework model of health literacy in his chapter. In doing so, he has two intentions. One is to show explicitly that health literacy is inherently knowledge-based and that this provides a strong link between scientific literacy and health literacy. In his view, there is a win-win situation between these two fields that has not yet been fully exploited. His second intention is to facilitate a systematic approach to the research, development, and teaching of these issues in the context of science education. Using several examples, Zeyer demonstrates how the systematic analysis of health issues through this framework model may reveal the potential of health issues for meeting the challenges identified in part one of this book. Zeyer also stresses that health literacy refers not only to the field of good health in its narrow sense, but also to the field of diseases and to medicine, which opens up a whole range of topics, which may be interesting and relevant to students.

In the final chapter of this book, the editors **Albert Zeyer** and **Regula Kyburz-Graber** bring together and discuss the preceding chapters, which inevitably contain a variety of perspectives, styles, attitudes, and intentions. However, all the contributions are strongly framed by conceptual standards, which reflect the state-of-the-art in the field. As a result, the contributors produce some key arguments, add profound new perspectives to each topic, and sometimes take quite controversial standpoints. The aim of the last chapter is to gather together the concepts and arguments in the book and to use them to form an overall picture.

A new pedagogy for science|environment|health that yields interesting and relevant science education for students and teachers and addresses the grand challenges of this century: what an attractive and rewarding project indeed! We hope that this book will motivate teachers, teacher educators, and science education researchers to take part in this ongoing project.

Part I
Challenges of Health and Environment Education to Science Education

Preparing Citizens for a Complex World: The Grand Challenge of Teaching Socio-scientific Issues in Science Education

Peter J. Fensham

The dawn of the twenty-first century encouraged a number of scientific and technological organisations to identify what they saw as 'Grand Challenges and Opportunities' (National Research Council 2000). Issues of environment and health featured very prominently in these quite short lists, as can be seen from a sample of these challenges in Table 1. Indeed, the first two lists of challenges in Table 1 were identified as for the environment and for health, respectively.

The prominence of environmental and health issues in these lists stems from the fact that examples of society's need for their solution are now regularly brought to public and political attention via the mass media. Furthermore, these issues have the potential to seriously impact on humanity's personal, social and global patterns of behaviour in the coming years. This priority attention means governments and the international community are caught between delaying decisions, or attempting to make them, before these complex issues are fully understood scientifically, socially or economically. Governments everywhere are now including specific ministers for energy, global warming and water, as well as ones for the longer recognised health and environment. Ministries of education are thus under pressure to respond to these challenges lest they be accused of selling short their students as future citizens.

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Table 1 Organisations listing grand challenges for science and technology in the medium term future

Professional organisation	Year	Grand challenges and opportunities
National Research Council, USA	2001	Bio-geochemical cycles, climate change, biological diversity, hydrologic forecasting, infectious diseases
The Gates Foundation	2003	Improve childhood vaccines, control insect transmission of disease, improve nutrition, minimise drug resistant organisms
National Research Council, USA (Chemical Industry)	2005	Carbon management, renewable fuels, green chemistry and engineering, life cycle analyses
American Association for the Advancement of Science	2006	Global warming (sea levels, etc.), burning coal cleanly
National Academy of Engineering, USA	2008	Solar electricity, manage nitrogen cycle, advance health informatics, access to clean water, carbon sequestration, secure cyberspace, prevent nuclear terrorism, fusion energy

These grand challenge issues do all depend on science and its applications in technologies for their study and resolution. With sufficient support, progress towards scientific understanding and courses of action could be made, but they are, however, not purely scientific issues. Their multi-faceted character involves several scientific disciplines, and each has features that bring in social sciences such as economics, sociology, social philosophy and ethics. The national and global political will that will be needed would demonstrate an unusual level of cooperation and sacrifice of existing priorities. A number of leading scientists are pessimistic that this will be achieved. For example, Martin Rees (2003), the president of the Royal Society, suggested in a recent book, **Our Last Century,** a probability of 50:50. His, and similar gloomy predictions, add an urgency for education about these issues that will create the public climate that will enable the difficult political decisions about them to be made.

The grand challenges are spectacular examples of a much larger class of real world issues confronting citizens that involve science and technology (S&T). They are commonly referred to as socio-scientific issues (SSIs), and it is this whole class of issues that presents the grand challenge to science education.

Part I of this chapter considers some key features of science's relationship with society in the twenty-first century and what this means for the science of SSIs in particular. These features have, as yet, been largely ignored by the still prevailing conceptions of science in school education. Complexity theory offers both ideas and a tool that provide a basis for this comparison. In Part II, a number of innovations in both public and school science education are reviewed to suggest how science teaching can contribute to citizens' and students' confidence and knowledge as they meet these challenges.

1 Part I

1.1 Science/Technology/Society and Complexity Theory

The 2007 World Conference on Science and Technology Education in Perth, Western Australia, brought a number of these grand challenge issues to the attention of the international school science education community. Its keynote speakers, Lord Robert Winston (*health*), Graham Pearman (*global warming*), Howard Gardner (*multiple intelligences*) and Ian Lowe, (*energy and conservation*), described issues they saw as societally urgent ones for science and technology teachers to heed and respond to in their classrooms.

In the same year, Roberts (2007) directed the attention of science educators to two different visions for scientific literacy (SL) and the consequences these have for teaching and learning science. Vision I SL derives its meaning and content for learning by looking inward at the canons of the natural sciences, particularly biology, chemistry, earth sciences and physics. Vision II SL derives its meaning from real world situations students are likely to encounter in their lives that have a scientific component. The SSI situations that provoked the grand challenges, and many less grand ones, are examples of the situations referred to in Vision II.

In suggesting school science could shift its focus to Vision II scientific literacy, Roberts rightly identifies real world situations involving science and technology as the basic units of such a science curriculum. He may, however, have insufficiently recognised that it is the technologies involved that provide citizens, and hence students, with the personal and social encounters that make these situations cogent and relevant. The term 'socio-scientific' to describe these societal issues also tends to obscure the technological aspect. The interrelation between a technology and the scientific knowledge that may be involved needs to be seen as an essential aspect of school science for Vision II scientific literacy. The development in the 1990s in many countries of 'Engineering' or 'Technology' as a school subject is a positive recognition of technology's prominence in society, but much still needs to be done to make the curricula for these two subjects optimally complimentary.

Gardner (1994, 1995) has discussed in detail the changing historical relationship between science and technology. For much of human history, society's technological advances were independent of the explanatory science that underpinned them. In many cases, the engineers or technologists responsible for their use in society developed an alternative, more pragmatic theory to guide their use and improvement of a technology. This continues today and constitutes the modern field of engineering as a field of human knowledge and practice that is distinct from, albeit related to, science. In the twentieth century, a much closer relationship developed between advances in science and their applications as technologies that bring changes to society.

Gibbons et al. (1994) extended this progression by providing a neat summary of these historical changes. Initially, technology set a society's agenda. As modern science developed in the seventeenth century, the relationship changed to one in which science set the agenda of society. Now in the twenty-first century, it is society that is setting the agenda of science, and increasingly so, due to the speed of interactions that the technologies of the information society now make possible. The emergence of complexity theory in the 1990s has, to a considerable extent, been due to these radically changing relationships between science, technology and society.

The grand challenges are a reflection of this change, in which national societies, and the global society itself, are now asking the scientific and technological communities for answers to their urgent problems. The now required criterion of 'likely impact' for gaining research funds is another manifestation of Gibbons' third relationship, as is the loss in the last decade of the superior status the natural sciences had in schooling during much of the twentieth century society. Students are demanding evident relevance and obvious personal worth from their science education.

C.P. Snow's Rede Lectures in 1959 (Snow 1959) drew public attention to the problems that arise when scientific knowledge is separated from, and given status relative to, other ways of knowing. Nevertheless, the separation was reinforced in the second half of the twentieth century by structures and practices of schooling. The abstract emphasis in the science curriculum spread, in these years, downwards from the upper years of schooling to its earliest years. This made the learning of science difficult for many students, thus creating a myth of superiority about scientific knowledge. Science was increasingly taught as conceptual knowledge that provided generalised principles which, by bringing together otherwise different phenomena, provided a simplified and powerful, but abstract picture of the natural world.

In contrast to this view, Nowotny (2005) has pointed out that science and technology, respectively, offer knowledge and tools that can be applied in society's interactions with nature. These offer the possibility that humanity can reduce some of nature's complexity. This same knowledge and tools may, however, also increase the complexity beyond that which is offered in nature. When the latter happens, society has to embark on another round in which it uses a new or modified form of these powers to reduce the complexity we ourselves have engineered. Humanity is now locked in a complexity race—building an ever more complex human world by intervening and manipulating nature—while seeking to find ways of reducing the increased levels of complexity we thus encounter.

The fields of medicine and the environment are replete with examples of this complexity race. What seemed to be a great simplifying solution has often turned out to introduce its own more complex problems. The introduction and control of rabbits, European types of agriculture in an essentially dry country, and the use of the cane toad as a control in sugar plantations are now well-known follies of S&T in Australia. The disastrous oil leak in the Gulf of Mexico in 2010 began as a technological process that simplified the extraction of oil beneath the seabed, but when the process broke down, a litany of new complexities has continued to emerge for the ecosystems of the Gulf on which so many, animals, plants and humans depend for existence.

1.2 Politics, Science and Science Education

Conflict between political and scientific perspectives is now common. The failures of the Inter-governmental Copenhagen Conference on Climate Change in late 2009 still resonate around the world. Constructive agreement between the scientific reality presented by the International Panel on Climate Change and the social, economic and political priorities of nation states was not possible.

Making decisions about scientific issues has been a politically supported aim of school science education since the mid 1980s. This suggests a naivety among political leaders that the rationality they perceived to be present in science will, through its study, supplant the seemingly irrational and negative reactions they often encounter among their public to science-based initiatives. The evidence from the Eurobarometer studies suggests that more science education makes citizens more discriminating about which science-based initiatives they will support and which they will oppose (Papacostas 2005).

In Part II, decision making in school science will be found to be a process that involves much more than scientific information.

1.3 Uncertainty, the Precautionary Principle and Science

The scientific community has a long history of being cautious in interpreting scientific data and evidence (see, e.g. Harremoës et al. 2002). More recently, in 1999, the World Conference on Science decided that a more formal articulation of this caution was needed for situations where possible consequences of action or inaction pose risks to the well-being of human society and of the environment. Recognition of these risks should have higher status in social and political decision making involving science and technology. The World Commission on the Ethics of Scientific Knowledge and Technology (COMEST) was asked to develop such a definition. In 2005, it presented a report on **The Precautionary Principle** that recommends a distinct shift from post-damage control to a pre-damage control of these risks and their underlying source in uncertainties, ignorance and indeterminacies. The central tenet is that ‘when human activities may lead to morally unacceptable harm that is scientifically plausible but uncertain, actions shall be taken to avoid or diminish that harm’ (UNESCO 2005, p. 14).

‘Morally unacceptable’ was defined in this UNESCO report as a risk of harm to humans or to the environment that is:

- Threatening to human life or health
- Serious and effectively irreversible
- Inequitable to present and future generations
- Imposed without adequate consideration of the human rights of those affected

Table 2 Comparison of the features of the science of the grand challenge issues with traditional school science

Science of socio-scientific issues	Traditional school science
Interdisciplinary	Discrete disciplines
Multi-disciplinary, including non-science aspects	Non-science aspects used only for motivational purposes
Some knowledge is uncertain	Knowledge is firmly established
Scientific perspectives alone can distort the reality of the issues	Science knowledge alone needed for idealised or contrived situations
Possibilities and probabilities are solution goals, not a single, correct solution	Problems have a single correct answer, often involving reproduction of static knowledge and simple applications of established principles
Uncertainty introduces the ideas of risk, trust of source and argument as a reasoning features of solutions	Scientific reasoning has a rationality that does not include risk and probability. Trust of source and argument are non-features

A number of the regularly publicised socio-scientific issues are readily associated with one or more of these grounds for moral unacceptability. Some of these, like the steady development of public constraints on tobacco smoking because of its social consequences fall within the ready experience of the students in science classrooms. The Precautionary Principle would be a helpful basis for teachers attempting to engage them with these issues.

In summary, the Precautionary Principle's four criteria for 'morally unacceptable' can be used by science teachers and their students to develop the idea of possible social and environmental harm in relation to SSIs where there are scientific uncertainties.

1.4 The Science Involved in SSIs

When socio-scientific issues are considered from the point of view of the science involved, a number of common features emerge that contrast quite starkly with traditional school science (see Table 2).

From his studies of public understanding of science, Wynne (1993) also compared the uncertain science in a socio-scientific issue with the certainty that pervades most school science; Wynne (1993) listed four differences:

- Risk: parameters for action are known, but outcomes involve risks with assigned probabilities
- Uncertainty: some important parameters of the system are known, but not their probabilities
- Ignorance: some other unrecognised parameters may be important
- Indeterminacy: some causal chains or processes are open and thus defy prediction

To include even some of these differences in school science would mean a less confident and rational nature of science than has hitherto been taught in most science curricula.

In one sense, the differences in Table 2 between the range of scientific knowledge in socio-scientific issues and the limited range usually presented in science classrooms are so great that science teachers would face a new paradigm if they are to teach students about these issues. Most science teachers will not, in their own science education, have encountered such a different view of scientific knowledge.

In calling for this paradigm shift, Jenkins (2000) argued that the 'world proves to be much more complicated, uncertain and risky than school science encourages students to believe' (p.211). He went on to point out that failure to engage students in school science with the uncertain science of contemporary issues will leave them with two conflicting visions of science. One is constructed as certain knowledge and institutionalised in a school curriculum, while the other is less certain and yet engages with students' own growing experience of the real worlds they inhabit beyond school. This was a foretelling of Roberts' two visions of scientific literacy and a foreshadowing of a paradigm shift for school science education that this chapter can now outline in some detail.

In another sense, Table 2, Wynne's list and Jenkins' 'armageddon' present too much of a difference. It is only some of the science of SSIs that is uncertain. Much of the science in an SSI is well established and already included in the science curriculum of most countries. Hence, the teaching emphasis requires the lesser change of drawing students' attention to its significance and worth in real world SSIs of interest rather than to the context-free examples so common in textbooks.

1.5 Complexity Theory, Science and Science Education

In complexity theory, socio-scientific issues are considered differently, depending on their degree of uncertainty. The uncertainty can arise from:

(a) The science itself, either because of the intractable nature of some of the phenomena involved or because their scientific investigations are incomplete before political decisions have to be made about them.
(b) The multi-disciplinarity of these SSIs create further uncertainty since expertise and knowledge from a number of scientific and non-scientific disciplines are involved and decisions have to be made on information that is all relevant but incommensurable.

Kurtz and Snowden (2003) invented the *Cynefin Framework*[1] as a helpful heuristic in comparing a variety of cases that share a common element but differ in their complexity.

[1] *Cynefin* is a Welsh word meaning *the place of our multiple affiliations.*

Established Laws Hold	**Uncertainty Holds**
simple cases **a broken arm** risk zero or very low	*complex cases* **AIDS** risk high
complicated cases **a heart by-pass operation** risk low to medium	**CHAOS** a **pandemic of AIDS** very high risk out of control

Fig. 1 A basic form of the Cynefin Framework with medical examples

In this chapter, it is used to compare the science of socio-scientific issues with the science of current science education and to highlight directions that are needed if school science is to include the new paradigm.

The Framework takes the form of a 2 by 2 matrix as shown in Fig. 1. The two sectors in the left column are for cases and phenomena for which well-established laws hold, together with their assumptions about order, rational choices and agreed intent. The two sectors in the right column are for cases and phenomena in which a degree of uncertainty holds and for which there are consequences of incomplete order, choices that are not merely rational and where agreed intent is lacking. When these latter characteristics fail to be controlled, the outcome of a case becomes CHAOS. For each type of case, there is an associated level of human risk that increases from zero or very low in the simple cases, through intermediate levels in the complicated cases, to the complex cases where risk is high and, under some conditions, can become very high and uncontrolled.

The examples of medical cases examples illustrate the Framework's differentiation.

A broken arm is a *simple case*. It is fully understood why bones break and how to set them so that they will restore themselves, and this operation has very low risk.

A heart bypass operation is today a complicated case that was impossible 60 years ago. When these operations began 30 years ago, they were *complex cases* due to uncertain aspects and the associated high risk. Medical science now fully understands how to detect the condition of blocked arteries and how to remedy it with bypass arteries, justifying an expensive and extended but essentially routine open-heart operation. This example of a heart bypass operation illustrates the dynamic character of the Cynefin Framework. As more becomes known about a case, its classification in the Framework can change between its sectors.

AIDS is a complex medical case, still not understood or fully curable after more than 20 years of intensive study. This condition has a high associated risk despite some progress having been made in controlling its spread and its rate of onset after infection by drugs. To maintain this control, big changes in social behaviour are involved as well as regular application of costly drug treatment. In some countries, these controls have been established too late, or are not possible, and the illness has become pandemic, properly locating in the CHAOS sector.

Natural Laws of Science Hold	**Uncertainty Holds**
simple case SSIs **Single science discipline(direct applications of established knowledge)** risk: zero or very low	*complex SSIS* **Multi-disciplinary SSIs (The Grand and other Challenges)** risk: high
complicated SSIs **Inter-science disciplines (technological applications of established knowledge from several science disciplines)** risk: low to medium	*CHAOS* very high risk: out of control

Fig. 2 The disciplinary nature of the science in socio-scientific issues and their relative associated level of social and/or environmental risk

1.6 Socio-scientific Issues in the Cynefin Framework

When applied to socio-scientific issues, the two sectors in the column under **Established Laws Hold** allow for a differentiation between *simple cases* of SSIs that involve a short sequence of well-established science principles and *complicated cases*, where the SSIs require principles from different sciences to be applied and where their sequencing may have options. In the column under **Uncertainty Holds,** SSIs that are located in the upper sector are designated as *complex cases* because of their uncertain science or not completely understood character, and their multi-disciplinarity. This uncertain character leaves open the extreme possibility that can lead the SSI to fall into the lower CHAOS sector. Socio-scientific issues, depending on their location in the Framework, have varying degrees of social and environmental risk consequence, and this risk becomes an important feature when social and political decisions have to be made about them (see Precautionary Principle above).

The disciplinary nature of a socio-scientific issue is an important factor in its location in the Framework as indicated in Fig. 2, and this factor requires particular consideration when SSIs are to be included in the teaching of school science education (see discussion in Part II).

Modern society is replete with countless examples of direct applications of the established knowledge from each of the science disciplines. Heating and cooling, making shelters, and food preparation and consumption, are just a few aspects of living for which this disciplinary knowledge has made positive differences to personal, social and global well-being. Sometimes, these applications do, however, have unanticipated negative consequences for human society and for the environment, becoming broader issues and requiring their science to be revisited. The use of DDT as a miracle insecticide is just such an apparently simple case that became so complex that it had to banned.

In the *complicated cases* of SSIs, established disciplinary principles still hold, but their formulation and application is more complicated. In addition, the interdisciplinarity leads to the definition and use of new concepts. For example, to measure tissue damage from ionising radiation, it was necessary to introduce the *sievert* as an interdisciplinary unit measure, beyond the mono-disciplinary sense that the units of rad or curie provided. Internal and external interactions in these *complicated SSIs* need to be heeded in applying established principles and can give rise to more alternative solutions.

The progression in the mechanics and realisation of rockets/unmanned satellites/manned satellites/a human round trip to the moon illustrated what, at one end, is an application of simple physics and, at the other end, is a highly complicated application of interdisciplinary sciences. Until the uncertainties in the science of the complicated end stages were much reduced, it could not be undertaken.

As indicated in Fig. 2, many SSIs and certainly the Grand Challenges of Table 1 are contexts of sufficient complexity and uncertain science that they locate as *complex cases* in the Framework. An example close to me as an Australian is recurring forest fires. These present complex, multivariate socio-scientific situations about which the science is not fully understood. They pose high risk to human life, but knowledge of them is usually enough to provide some control, but not long-term solutions. In the combination of conditions on February 7, 2009 in Victoria, control was lost, thousands of properties were ravaged, 200 human lives and many more livestock and native fauna were lost. The forest fire issue tipped that day into the lower right CHAOS sector

Global warming is now a generally familiar example of an SSI with uncertainties in its science knowledge and so locates as a *complex case* in the Framework. Some scientists, however, believe that the warming is advancing so rapidly that 'tipping points' like affecting the Gulf Stream cannot now be avoided. If they are right, the effects of global warming would move to the CHAOS sector. The people of some Pacific nations—the Solomons, Tuvalu and Kiribati—are already teetering on this intersection to CHAOS.

1.7 Traditional School Science and the Cynefin Framework

The teaching of science in schools has historically been developed over the twentieth century in terms of single science disciplines. In many countries, these disciplines are separate subjects within the total curriculum, and even in those countries where 'science' is a single subject, the organisation of the intended knowledge is usually still in single disciplinary blocks.

When this detailed content for science learning is related to the Cynefin Framework, almost all of it locates in the *simple cases* sector of the Cynefin Framework. For some curricula, perhaps up to 10% locates in the *complicated cases* sector. There are, however, increasing reports in the research literature of the pilot teaching of science

Natural Laws of Science Hold	**Uncertainty Holds**
simple cases **90+% of school science (established mono-disciplinary knowledge)** **contexts:** idealised and contrived with directed laboratory exercises **learning:** *one correct answer (knowledge from established science)*	*complex cases* ***pilot teaching of S&T projects and SSIs (inter-disciplinary science and other knowledge disciplines)*** **contexts:** real world, in- and out-of-school projects including uncertain science and argumentation) **learning:** *possibilities & probabilities (balancing uncertainty in knowledge and its interactions)*
complicated cases **≈10% of school science (interdisciplinary science knowledge)** **contexts:** real world involving established science and open-ended laboratory exercises) **learning:** *one or more correct answers (knowledge from several sciences)*	***CHAOS***

Fig. 3 The location of school science and science education for socio-scientific contexts issues in the Cynefin Framework

topics, which can, because of their openness for other reasons, properly be located in the complex sector. As yet, this type of science education is, however, initiated by individual teachers or is research-initiated, rather than curriculum-required. Figure 3 presents this location of school science, together with the disciplinarity, the type of context with which it is associated and how its learning is assessed, in place of the risk indication.

Prior to the 1980s, the single disciplinary character of most school science and the introductory nature of its concepts and principles located it in the simple cases sector of Fig. 3, and this was reinforced by teachers and the use of textbook applications in ideal or contrived contexts that ignore the complicated and complex realities of the real world. In such contexts, the established principles and laws of science hold and can be directly used to pose assessment questions that do just have one correct answer.

The Science Technology Science (STS) movement among science educators in the later 1980s provided strong arguments for teaching science that involved technological applications of science. It recognised the importance of engaging students by using topics and contexts that had real world meaning for students. Such contexts are rarely mono-disciplinary. The exemplary materials for this STS teaching illustrated this more interdisciplinary approach in school science (Solomon and Aikenhead 1995). These STS innovations thus would be located in the lower left sector of the Framework although they were never sufficiently established as mainstream to indicate what new modes of assessment their learning needed.

During the 1990s, the new curricula for school science did not follow the STS direction, not least because of the emergence of Technology as a new and separate school subject. Instead, the mono-disciplinary science strands of secondary schooling were extended to include the early years of schooling despite the very limited human and technical resources that were usually available compared with those at the secondary level. The science in these curricula was still located in the simple cases sector of Fig. 3, and their mono-disciplinary definition of subject content and usual assessment practices (reinforced internationally by the I.E.A's TIMSS project (Beaton et al. 1996)) meant that their focus was firmly on Roberts' Vision I for scientific literacy.

The inability of these curricula to interest students in science and in scientific careers then began to be apparent (Millar and Osborne 1996) with calls for school science to re-engage with technological applications in real world contexts, that is, to include in school science education contexts that would locate in the complicated sector of the Framework. In response to this challenge, exemplary teaching and materials have been developed for what was increasingly being identified as, not STS reborn, but context-based or humanistic science education (e.g., Aikenhead 2006; Tytler 2007). It is interesting to note that these approaches powerfully build links between science concepts and their contextual origins and meaning, but also they require a greater recognition of the nature of science, an interest quickly taken up among science education researchers (Flick and Lederman 2004). In Part II, the role of the OECD's PISA project in encouraging these changed emphases through authentic assessment is discussed.

Some context-based science teaching can be seen as on the threshold of SSI teaching, but most of it has not moved to a location in the complex sector of the Framework. Mostly, it is confined to the established S&T aspects of a context, and there is only passing recognition that other knowledge dimensions are important. Recently, reports in the research literature are, however, appearing that describe science classroom initiatives that do bear the hallmarks of the complex sector—arguing about the science, recognition of risk and the moral aspects of SSIs. These exciting developments are introduced and described in Part II.

2 Part II: Taking Up the Challenge of SSI Teaching

2.1 Public Understanding of Science

The challenge of teaching SSIs was first taken up with members of the general public rather than in schools. Unlike the captive classes of students in schools, adult citizens are only interested in learning some science because they need it to deal with an SSI in which they are personally involved. Layton et al. (1993) worked with small groups of citizens in a range of socio-scientific situations. The situations included parents of Down's syndrome children, elderly persons and domestic heating, and residents living near nuclear processing plants. In each situation, the individuals had a strong sense of need-to-know. The findings highlighted the 'fragility of much of the available science and its inability to provide unambiguous answers to the questions asked' (p.118). The use of 'inarticulate' in the title of the report of these studies, **Inarticulate Science**, refers not to these citizens but to the inaccessibility of the technical language of science for these citizens and to its need of 'translation' into language that communicated. These studies also raised issues in decision making about the trustworthiness of the sources of scientific information, its reliability and how it can be weighed against other relevant social knowledge.

Irwin and Wynne (1996) echoed these findings in nine other cases of public involvement with science-related issues. Arguments about the science (even when presented as if it was value free), played an important role in the way these cases were framed for discussion by the participants. Rather than value free, this scientific information was found to be determined by social as well as technical factors. Furthermore, many participants did not share the presenters' assumption of the superiority of scientific knowledge at the expense of social knowledge with which they are more familiar and confident (Wynne 2001).

Five features stood out as important from these case studies of public understanding of SSIs:

- A strong sense of 'need to know'
- Only specifically relevant science knowledge
- Science knowledge required 'translation'
- Trust in the science knowledge source
- The weighting of science knowledge against other knowledge

The extent to which these features have importance for the teaching of SSIs in school will be considered later in this chapter.

Studies of public understanding of prominent socio-scientific issues in the areas of health and environment, involving larger numbers of the public in Australia (Bulkeley 1997), New Zealand (Hipkins et al. 2002) and the United Kingdom (Tulloch and Lupton 2002; Shaw 2002; Duggan and Gott 2002; Petts et al. 2003), have all found that the level of risk involved was an important missing factor in these persons' decision making. The features of balancing risk from the associated probabilities and the precautionary principle, thus, need to be added to the above list (Christensen 2009). Recent natural disasters in New Zealand Australia and Japan have projected the meaning of risk to a centre stage of public attention that is not captured in these controlled studies. It has become clear in these instances that the socio-political construction of risk plays a large part in which SSIs become key and which can be ignored.

Ryder (2001) analysed 31 studies of public understanding of science (some with well-established science and some with contested science) in order to develop a framework for teaching *functional scientific literacy* in schooling that recognises science education as having a concern with citizenship. Knowledge of science content was obviously important, but not as central to decision making as was knowledge about science. The six categories of knowledge he argues for as necessary for engaging with SSIs are *science content knowledge, the collection and evaluation of data, interpreting data, modelling in science, uncertainty in science* and *science communication in the public domain*. Where there is uncertainty in the science, he concluded risk understanding is fundamental, that is, knowing that decisions need to be made on the basis of risk estimates and recognising these estimates sometimes may not be available.

2.2 Decision Making and Science

The response of the public in these studies is consistent with the findings of Tversky and Kahneman (1974) who analysed human decision making and found that, far from applying normative utility theory, people commonly apply heuristics and biases, both individually and socio-culturally derived. These biases are not necessarily irrational or detrimental, as people making decisions pursue a variety of objectives that can frame the same problem in different ways. Most approaches to remove bias involve consideration of alternative perspectives that can minimise the initial framing effects.

As indicated earlier, *decision making* is now a regularly stated aim of the school science curriculum, although remarkably little guidance has, as yet, been provided for teaching these personal and social processes. Ryder's analysis shows it is naïve to assume that all that is needed for making decisions about an SSI is the usual school level knowledge of its science and some rational use of scientific reasoning. Even when the science of the issue is clear and definitive, decision making by human beings involves more than just science knowledge, and everything becomes even more complicated when the science aspects themselves have a degree of uncertainty.

3 Teaching Complex Socio-scientific Issues

Science teachers, for teaching socio-scientific issues, will need to learn to differentiate between the variety of issues they may wish, or be required, to include in their teaching. The Cynefin Framework's location of SSIs in Fig. 3 as *simple, complicated* and *complex cases* can be helpful here since it relates to their disciplinarity, the uncertainty of the science involved, and how important it is to include a treatment of risk in the teaching.

Issues that locate in the simple cases sector involve the least challenge. Here, what is required is a shift to acknowledge the technology and science involved and to the use of engaging pedagogies rather than the common transmissive one. The science knowledge is disciplinary, but its significance is now determined by the SSI to which it relates rather than by its traditional place in developing the logic of the discipline. The change in pedagogy is discussed in more detail below.

For issues in the complicated cases sector, a science teacher will need to develop established knowledge from the several sciences on which the technology depends, together with the appropriate interdisciplinary concepts, to lead to the alternatives about which decisions need to be made. Again, interactive pedagogies are essential. Aikenhead's (1991) curricular example of science teaching about the issue of car driving and drinking alcohol is a classic example of this type of science education.

For socio-scientific issues that locate in the complex cases sector, science teachers should be wary of embarking too facilely alone on the task of teaching them. This may come as a relief to many science teachers who are reluctant to extend their teaching beyond the simplicity of disciplinary ideality. Few science teachers are equipped to do justice to the multi-disciplinary aspects of these issues. Attempting to do so can lead students to see the issue as essentially a technical or scientific one, for which the societal solution is in the hands of scientists or engineers.

Nevertheless, the urgency and responsibility of including key socio-scientific issues that relate to social and environmental health in school science is so great that they cannot be avoided on these grounds. Rather, new ways of teaching need to be explored that assist science teachers to acknowledge the importance of the other dimensions of socio-scientific issues—ethical, social, economic, etc.—while fulfilling their primary role of providing deep understanding of the scientific and technical dimensions.

3.1 New Pedagogies and Conditions for Teaching SSIs

Several ways to do justice to the non-science dimensions have been suggested. In *Rich Tasks*, a recent curricular innovation for middle secondary students in Queensland, Australia, teachers from different subject areas separately addressed their aspect of the same issue (e.g. a biotechnological process with local social and ethical dimensions). These aspects are then brought together in a shared forum of the teachers and students. The mix of pedagogical styles from the different subjects enriched the students' engagement with the issue (Education Queensland 2004). A second approach is to plan an 'educational event' over one or more days. This requires more organisational adjustment, particularly for secondary schooling, but provides a rich learning opportunity. Teachers plan together how to introduce their differing disciplinary perspectives on the chosen issue. Students in small groups then engage in extended activities that develop these perspectives in more detail. Finally, the students feed the alternative dimensions into the whole class to see what coherence can be reached about the issue and the possibilities for decision making or resolution. Educational events like these have been described by Bev Farmer (1994) and Léonie Rennie (2007) for in-school and out-of school learning, respectively. While this type of cooperation and planning is unfamiliar to many science teachers, it is similar to that which is involved in taking classes on field trips, and on visits to museums and science centres, etc. In primary schooling, teachers who are accustomed to an integrated approach to teaching find these 'educational events' a relatively simple extension of their practice.

3.2 An Exemplary Approach

Sadler and Zeidler (2008), together with local teachers, have developed an approach to the teaching of socio-scientific issues in terms of the psychological, social and emotive growth of the student as person, ensuring that these multiple dimensions are considered. For them, SSIs are:

- Social issues or problems with conceptual or procedural ties to science
- Have solutions that are under-determined by scientific data but are informed by evidence-based reasoning
- Require some element of moral reasoning
- Contain multiple perspectives with ethical, political, and/or economic implications
- Personally relevant, meaningful and engaging to students

They already have a number of teaching and learning modules in the general area of health that have been tried in middle secondary science classrooms.

For example:

- *Terri Schiavo and the definition of 'alive'* (nervous system)
- *Bird flu pandemic and vaccine development* (lymphatic/immune system)
- *Tattoos* (integumentary system)
- *Tanning beds and skin cancer* (integumentary system)
- *Fast food diets and increased heart disease* (cardiovascular system)
- *Safety of second-hand cigarette smoke* (respiratory system)

The evaluation by the students of these teaching modules has provided a number of interesting insights into some generic features of classroom teaching of SSIs. These parallel quite closely the five features (listed in the first section of Part II above) that were important in the public understanding studies.

Students typically only think about topics that are personally relevant, how they could be affected and what other people like their peers think—paralleling the need-to-know feature. When a strong sense of 'need to know' has been achieved among the majority of students, any specifically relevant science knowledge will be readily received, even knowledge of a depth that would not normally be taught in school science. This is similar to the 'only relevant knowledge' feature in the public studies.

The 'translation' of formal science that was a needed feature in the public studies was not so evident in the classroom, probably due to a flow of alternative meanings being available in the discourse between the teacher and the student peers. Students became aware that, beyond the competing scientific knowledge claims, there were 'other knowledge' claims (e.g. social and moral ones), again a feature in the public studies.

The notion of 'trust' to resolve ambiguity, whether as anomalous data or as conflicting scientific views, was a novel and unexpected feature for the students, whereas it was more familiar in the public studies. Nevertheless, the students found the experience of arguing about the science of an SSI a positive one and recognised it as a preparation for later citizenship. In considering the mix of scientific and popular reports about these SSIs, the teachers and students found examples of faulty arguments and *inadequate sampling of evidence.* These served to assist teachers to handle the untraditional discourse of argument that SSI teaching in school classrooms requires, opening up the 'trust' feature in the public studies,

A negative evaluation was the ease with which students can easily go off task if the SSI is not well focussed and extends too long and the intended outcomes are not clear. Similar findings have been reported in other studies of context-based science teaching.

3.3 Pedagogies for SSIs

Equipped with new awareness of socio-scientific issues and the sense that science has a key role, but not a dominant role, science teachers will then need to develop competence in new pedagogies. These must be consonant with the nature of the uncertain science and the risk and trust that are characteristic of this new paradigm for science education. The old transmissive pedagogy that seemed consonant with the authority of established science knowledge will need to give way to sociocultural approaches in which discussion about ambiguity and uncertainty are encouraged and tolerated. Large-scale evaluation of the UK national curriculum *Core Science* (UYSEG and Nuffield Foundation 2007), which is based on contemporary socio-scientific issues, has confirmed the need to develop new science teaching skills if reforms of science education towards the goal of citizenship are to proceed effectively.

Kolstø (2000, 2006) in Norway proposed a 'consensus model' based on adult community consensus conferences that are now common for local issues in several countries. Students work in groups, each group researching a knowledge aspect and a values perspective of the issue. These 'expert' groups then report to and are questioned in a whole class event by a 'lay' group who listen to the varying perspectives and work towards a consensual opinion on the issue. This teaching approach assumes that decision making should be both values-based and knowledge-based.

Some practical pedagogies tried by Ratcliffe (1997) in UK and by Dawson (2001) in Australia include classroom debates, forums, hypotheticals, drama, simulation games, seminars, role plays and activities outside of school. These authors have found it necessary to develop some agreed ethical principles to assist students to deal with the complexity of issues. They also advocated the use of an explicit decision-making approach, such as cost-benefit analysis. Each of these pedagogies allowed students' voices and opinions to be aired, challenged and changed, and contrasted with the absence of opportunities for students to participate opinions in traditional science classrooms. This lack has been identified by them as a major ground for their dislike and disinterest in school science (Lyons 2006).

These pedagogies will be new procedures for many science teachers. Cross and Price (1996) studied Australian science teachers' initial experiences of dealing with socio-scientific issues. They needed help with clarifying the purposes the new pedagogies were to serve and with managing the discussion in the classroom, particularly the non-science dimensions. Levinson and Turner (2001) in England and Bryce and Gray (2004) in Scotland found similar reactions from science teachers.

3.4 Theoretical Pedagogical Models

Parallel with these more practical studies, some theoretical pedagogical models for SSIs have been suggested by Oulton et al. (2004). They argued that an important basis for the new pedagogies is an understanding of the nature of controversial issues by both students and teachers. They defined *controversy* by differences in value judgements, seeing bias as an essential part of controversy. The teacher's task then becomes the development of the students' capacity to be critically aware of bias—a kind of 'critical science literacy' advocated earlier by Lemke (2002). Oulton et al., however, pointed out that teachers' fear of being accused of bias is currently one of the barriers to effective teaching of controversial SSIs.

Levinson (2006) used the nature of controversies to develop an elaborate framework for including them in pedagogy. This consists of three strands—categories of reasonable disagreement, communicative virtues, and narrative and logico-scientific modes of thought. The categories of disagreement describe scenarios where the roles of evidence and social dimensions vary in their capacity to resolve the issue. Levinson suggests that articulating these categories of disagreement can show students how the strong socio-political disagreements about current issues arise from the varying interplay of evidence, values and worldviews. The narrative mode is important as an opportunity for students to convey meaning to the science of the issue and to stimulate further questioning—a classroom counterpart to the important 'translation' feature that was so important in the early studies of public understanding described at the beginning of Part II above.

From just such a theoretically based approach to the role of argument in science, Driver et al. (2000) pioneered some studies of teaching about this feature in science classrooms. As other studies of argumentation followed, a strong case has been built for argumentation to have a quite central place in the emerging interest in curriculum debates of what 'knowledge-about-science' students ought to expect from their science education.

Brown and Renshaw (2000) introduced a pedagogy called 'collective argumentation', based on Bereiter's (1994) idea of science as progressive discourse, to assist students to develop confidence in dealing with issues involving uncertain or controversial science. It was based on 'more diverse communicative spaces in the classroom', that is, 'spaces where students can speak and engage together in ways that differed from the typical science classroom format where teachers do the majority of talking and thinking' (p. 53). In collective argumentation, students establish and follow rules of discourse for discussing the novel and complex problems that SSIs present.

3.5 Assessment of SSI Learning

Developing a sense in students of what they have learnt is an essential element in any teaching and learning. In the case of formal schooling, there is also a wider sense in which the learning that is taking place has to be assessed and accounted for publicly. In the case of science, there is, thus, a need for formative assessment which involves means that make clear to students where they are in their learning, and there is a need for a summative assessment that enables individual achievement to be compared with wider samples of other students, both in-school and beyond. The performance of students in practical work is an example of science learning that Black (1997) and Yung (2001) have argued can only really authentically be done by class teachers supported by peer-moderating that gives them the sense of what quality learning in this task can mean. Accordingly, the specific contextual nature of SSI teaching, and the importance that social participation has in its classroom discourse means that aspects of SSI teaching and learning such as *explicating* the interacting features, *arguing* about the reports of scientific evidence, and *the making* of *moral decisions* will only be amenable to assessment by the classroom teacher.

Science teachers do not mind being encourager and judge of learning when it is formative assessment. They are less comfortable about having these roles in relation to summative assessments, particularly one that carries high-stakes future implications. If educational authorities are serious that science teaching should include the SSI paradigm, they will need, as in the case of developing and assessing students' investigative skills in science, mechanisms such as teacher/teacher monitoring that not only reassure and support teachers about these roles but also provide them with very good professional development.

Sadler and Zeidler have, nevertheless, suggested four practices from their experience of specific SSI teaching that seem to have more general applicability. These are:

(a) Appreciating the inherent complexity of an SSI
(b) Analysing it from multiple perspectives
(c) Recognising the need for information about the uncertain nature of the science
(d) Employing scepticism in the review of information provided by parties with vested interests

Despite their generic worth, it is not easy to conceive how portable instruments could be developed that would enable large-scale external assessment of the learning of any of these practices.

Instruments for assessing some components of SSI learning can be developed for external use, nationally and internationally. The two currently used international tests of science learning contrast this possibility. The IEA's ongoing Trends in International Mathematics and Science Study (TIMSS) began in 1994 and exemplifies a basic assessment of science learning that would locate in the simple cases sector of Fig. 3 (Beaton et al. 1996). Its science items are presented as isolated pieces of scientific information related to a single disciplinary science topic, and each has just one right answer. This project continues every 3 years and essentially measures students' recall of science content that is commonly taught to 8- and 14-year-olds across many countries. Only a small fraction of this scientific content knowledge is relevant to the teaching and learning of SSIs.

The Programme of International Students Achievement (PISA) (launched by the OECD in 1998) set out to measure the science learning of 15-year-olds, but with a very different charter from TIMSS. It was to provide countries with information about how well students were *prepared in science for twenty-first century life*. PISA was to establish measures of how well students could *apply* their science knowledge, *wherever learnt*, to real world situations involving science and technology (S&T). This prospective view of science learning contrasted strongly with the dominant, retrospective view of learning taken by national testing authorities and by TIMSS.

After some exploration of its task in 2000 and 2003, the PISA project defined five scientific competencies (three cognitive and two affective) for which paper and pencil items could be developed. The scientific competences, *identifying scientific issues, explaining phenomena scientifically* and *using scientific evidence* phenomena, involved both content knowledge of science and knowledge about science. The project's test items for these competences are notably pro-active in comparison with mere recall. In the PISA Science test, students are asked to respond to these items as presented in relation to a set of novel real world S&T situations. The science in these situations is interdisciplinary, and items with more than one right answer were common (OECD 2006). The items in the PISA test locate regularly in the *complicated cases* sector of Fig. 3. Although a number of the PISA presenting situations could be located as SSIs in the *complex cases* sector of Fig. 2, the PISA project's constraints to assess only their scientific dimensions and, for 2006, to essentially only consider established science, meant its test items rarely strayed into the *complex cases* sector of Fig. 3.

Sadler and Zeidler (2009) complimented the PISA project's Vision 2 scientific literacy for its daring to pioneer, internationally, a form of science testing that few countries have yet emulated. They are, however, critical that its items do not link sufficiently to the presenting contexts and fail to pursue the non-science dimensions, particularly the moral dimension. These authors are currently experimenting with new approaches for assessing SSI learning outcomes. These include students' *reflective judgement*—a construct that represents an individual's perspective on knowledge and justification of knowledge. King (2008) has produced a computer-based form for assessing this construct via the Reasoning about Complex Issues (RCI) Test.

4 Conclusion

Modern societies are now regularly confronting issues about health and environment for which applications of science and technology are both contributing factors and essential elements of their resolution. It is in these societies that the lives of current and future citizens have to be enacted. Rather than becoming simpler, these societies are increasingly concerned with issues that are 'complex' in the way this term is defined in this paper. The science schooling of future citizens cannot responsibly ignore the challenges these science- and technology-based issues pose.

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Socio-scientific Views on Environment and Health as Challenges to Science Education

Regula Kyburz-Graber

Environment and health are interlinked areas that are generating increasing interest and relevance in view of achieving a sustainable society. This is the main argument for increased emphasis on environmental and health issues in science education. However, beyond this foreground goal, environment and health problems provide a background of opportunities to ask questions about the nature and role of science in society. From a positivist technical perspective, environment and health are well-defined measurable resources or states that can be controlled by well-educated individuals. Environmental and health education and related research approaches have, for a certain time, followed this line. From a socio-scientific perspective, the potential of environmental and health issues lies in searching beyond the surface: What notions of environment and health can be identified, how are they represented in society, and how are they represented in science? How do members of society, such as citizens, politicians, and scientists, come to know about what matters in current and future environmental and health developments? And what concepts do people have about how environmental and health problems might be approached? Such questions illustrated by examples and related research approaches are challenges for a socio-scientific orientation in science teaching.

Environment and health are areas of major concern in various life situations. Health touches the individual directly and usually quite obviously; the environment, in contrast, has–at least in the way people are aware of–more indirect impacts on individuals and societies. However, both the environment and health are directly and obviously relevant to everyone, more than other areas of science. This statement may directly lead to the argument that environment and health should be given priority in science education in order to motivate and raise interest in socio-scientific issues for students.

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In this chapter, it will be argued that environment and health are more than interesting and socially relevant learning subjects in science education. Environmental and health problems challenge modern societies and scientific communities to learn that scientific knowledge does not provide the certainties that democratic systems tend to ask for in order to make the "right" decisions for solving newly arising problems. It will be shown that health and environment are spheres that, maybe, challenge our view of science more than any other scientific topics. These challenges, it is argued, should not be concealed from young people as teachers sometimes do, aiming at protecting students from uncertainties and doubts. To the contrary, uncertainties rising from environmental and health issues may illuminate science as a sphere of human action with strengths and weaknesses, possibilities, and limits.

Though we are well aware that environment and health issues are by far not limited to the natural sciences, the questions we raise in this book focus on potentials of environment and health in science education, not least to explore what effects those areas actually have on established concepts of science teaching. Thus, the approach here is not so much to ask what environmental and health education can directly contribute to improve environmental and health situations in our societies; the perspective is more ontologically and epistemologically oriented, in the sense that we are asking what makes environmental and health problems particularly relevant for a critically relational view of science and science teaching.

The first section addresses the question: What arguments basically support a predominant and challenging role of environmental and health questions in science education? A particular focus is given to the "nature of science" subject in science teaching. A second section presents a socio-scientific approach to science teaching, one inspired by socio-ecological education.

1 Arguments Supporting the Growing Predominance of Environment and Health in Science Education

Let us begin with a view on how environment and health can be conceived as learning fields in science education. Arguments for environment and health as main contexts for present-day science in education may be addressed from the following perspectives.

1.1 The "Improving Society Through Changing Behavior" Argument

Certainly, one important argument is the social relevance of environment and health and its meaning regarding future human and nonhuman life on earth. In this perspective, environment and health are, to a substantial extent, seen as areas of science education in which individuals can learn about how to describe, control, and improve the various human action fields through appropriate awareness, behavior, and action. Environmental and health education have, for some time, followed this line driven by the UNESCO documents of environmental education and education for sustainable development (UNESCO-UNEP 1977; UNESCO 2005), and a number of concepts implemented in schools still do so. This view follows a positivist approach to environmental questions and assumes that scientific research will principally provide the knowledge needed as a basis for appropriate decisions and actions. Robottom criticizes this position, arguing that environmental education should be located within a social rather than a scientific discourse (Robottom 2003). In an exclusively scientific discourse, usually the outreach and the epistemological basis of scientific knowledge on environmental problems are not questioned, nor the psychological and sociological knowledge base on how people come to act in the way they do, or how they come not to act even if they know that they ought to. This perpetually experienced reluctance of people to act in an expected way in spite of knowing better may lead to a basically skeptical attitude on what education might cause or not. It is not the question here, whether education has any effects on human responses at all, which it certainly has. It is more a question of whether, in education and specifically in science education, we sometimes deem teachers to have control over what learners do with what they have learned, for instance, on environmental questions. The fact that knowledge does not necessarily lead to actions intended by those who have provided this knowledge makes us thoughtful, cautious, and careful about expectations on directly visible educational effects.

Over years of coaching teachers in environmental education practice, it can be noticed that teachers are often driven by the idea of changing children's attitudes and behavior toward a "better" sustainable world, suppressing thoughts of the complexity of causes and reasons guiding human behavior and acting. Some teachers eventually, after a couple of years teaching in such ways, choose to drop environmental education more or less out of the science curriculum because, as those teachers argue, they did not achieve the effects in young people they had worked toward (Schlüter and Kyburz-Graber 2000).

The fact that teaching scientific environmental knowledge does not have the expected direct impact on environmental behavior engaged many researchers to explore reasons and more appropriate teaching designs (see, e.g., Hines et al. 1986/1987; Sia et al. 1985/1986; Hungerford and Volk 1990; Heimlich and Ardoin 2008). An informative insight in the German tradition is given in the Environmental Education Research special issue (Seybold and Nikel 2006).

Cornelia Gräsel has widened the perspective on environmental knowledge and action with her research on the concept of ecological competence (Gräsel 1999, 2009; Bilharz and Gräsel 2006). She empirically showed that ecological competence is more than scientific environmental knowledge; according to Gräsel, ecological competence embraces three kinds of knowledge (situational knowledge, conceptual environmental knowledge, ecological action knowledge) as well as three kinds of skills for the evaluation of action effects (evaluation of increased environmental quality, evaluation of the practicability of the environmental action, evaluation of effects on oneself). Both knowledge and evaluation skills are embedded in the ability of self-reflection. Gräsel concludes that if a person is ready and willing to deal with various aspects of environmental acting in a self-reflective process, the person will interact with a challenging environmental situation in an appropriate way.

Albert Zeyer shows in his contribution to this book how the ecological competence concept can also fruitfully be developed for health education in science education. Thus, the competence concept integrates various kinds of knowledge as practical action knowledge and conceptual knowledge as well as knowledge generated in a specific situation, as well as the ability of evaluation and reflection including affective dimensions of learning.

The competence model promises to be a useful concept for approaching complex aspects of acting in environmental and health situations (cf. the action competence model of Jensen and Schnack 2006). Yet, the competence concept adopts an exclusively individual psychological view on environmental questions and disregards the political, economic, and cultural dimensions. In regard to the "socio-ecological approach to environmental education," we attempt in our research studies to focus on an environmental learning process that is a more critical inquiry on conditions, frameworks, causes, effects, and side effects of human actions (Kyburz-Graber et al. 2006, 1997).

Environmental and health education do not really challenge science education if they are reduced to a "changing behavior" concept. Taking shortcuts in environmental education may cause disappointing learning effects and antagonism from the students. If environmental and health education is broadened into learning arrangements, inviting learners to explore not only foreground phenomenon but also analyze and discuss the background of environmental and health issues, it can provide a more critical perspective on science as embedded in society.

1.2 The "Awakening Interest for Science" Argument

Another argument for integrating environment and health as main areas in science education is the awakening interest argument. Here, the argument centers on concerns that directly touch individual's lives, sometimes also described as the external and internal environment relevant in everyone's life. A broad literature recording research on students' interests and motivation indicates that environment and health provides topics that may awake interests in students on scientific issues (see, e.g., Elster 2005; Jones et al. 2000). In this sense, the "awakening interest for science" argument follows, similar to the "improving society" argument, more or less an instrumentalist perspective on education: Young people ought to learn what is necessary for them throughout their life. There is no question that each education and training is seen from the utility perspective, not only by those responsible for education but also by the target groups. For example, teacher students want to learn what they can use as professionals and in their personal lives. This argument for environment and health in science education is limited. Who can tell what people will need in 5, 10, or 30 years? And will the situation then be the same as today with respect to environmental and health states, scientific knowledge, social and individual needs, and economic possibilities?

1.3 The "Promoting Scientific Literacy Through Environment and Health Topics" Argument

A third argument for integrating environment and health as the main conceptual areas in science education is in order to attain scientific literacy.

Meaningful goals of science education are seen in the knowledge that individuals need to understand and handle issues that are relevant in and for their lives. Within the science literacy concept, this relevant knowledge is described as knowledge of basic scientific concepts, scientific thinking, and methods, and the ability to use knowledge to identify scientific questions, to explain scientific phenomena, and to draw evidence-based conclusions (see the contribution of Rodger Bybee in this book).

In traditional German and Swiss science education, the pragmatic conception of scientific literacy is accepted as a kind of general education in science ("naturwissenschaftliche Grundbildung"). But beyond this, particularly in the pre-academic track of upper secondary education, science education ("naturwissenschaftliche Bildung") emphasizes much more discipline-specific scientific knowledge about concepts and principles in biology, chemistry, physics (Strobl 2008), and knowledge about means of generating scientific knowledge. This embraces systematically observing and collecting data, formulating hypotheses, conducting experiments, and analyzing and interpreting data. On the other hand, discourses and reflections on the nature of science including ontological and epistemological questions have less tradition in science education in German- than in English-speaking countries. Yet, these aspects in science teaching seem to be growing: In a recently published report from Zurich, with recommendations for improving science teaching, the overall goal for science teaching is described as "to enable students to draw on basic scientific concepts to explain processes in the animate and inanimate world and predict incidents. This includes familiarity with scientific ways of thinking and researching and an awareness for possibilities and limits to scientific findings" (ZHSF 2009, translation RKG). Another document with recommendations for biology teaching to improve the transition between gymnasium and university in Zurich recommends that "The innovation process in the gymnasium has to adequately consider important challenges of the twenty-first century, such as maintenance of life basics, sustainable use of natural resources, discussion of the desirability and of forms of using biological and medical possibilities, and health questions (…). The search for solutions to the problems of the twenty-first century presupposes solid basic knowledge to which all nature science branches make substantial contributions, and it calls for interdisciplinary and international cooperation of science, technology, economy, politics, education and culture" (HSGYM 2008, p. 77, translation RKG).

If these questions are seriously incorporated into science teaching, they will touch on philosophical, historical, and sociological aspects that address questions such as the following: What is desirable? How is the concept of nature conceived? What counts as scientific knowledge? How is scientific knowledge embedded in historical contexts? Under what social (e.g., economic, political, cultural) conditions do scientists produce and interpret scientific findings?

We might now argue that environment and health fit optimally to the scientific literacy concept. This argument leads to the statement that environment and health ought to be broadly integrated in science curriculum or even build up the main conceptual structure for science education because they offer a bundle of interesting and engaging examples to all relevant aspects in the scientific literacy concept. This is certainly a strong argument for focusing on environmental and health issues in science education. However, environment and health in science education can go beyond this: Environment and health, as spheres of science, have the potential to open up a perspective on science beyond their traditional position, which is often linked to science education. It is a perspective that may reveal its educational potential across any instrumentalist functional claims for science education. This will be demonstrated in the "critical approaches to science" argument.

1.4 The "Critical Approaches to Science" Argument

A wider perspective on environment and health in science education is grounded in critical approaches to what science can contribute to future developments in our societies and where it has to accept limits and adopt a humble position in democratic processes aimed to improve human living conditions.

Stevenson (1987, 2007) distinguishes between a conservative form of environmental improvement and a radical form, based on different perspectives of the root causes of environmental problems. The conservative form is concerned with finding quick solutions through technologies implemented in existing decision-making structures without addressing the structure of social and economic institutions. The radical form is based on the critique of the dominant role of economic growth and the unequal distribution of resources; hence, also a critical perspective is given on the role science is attributed in society. Stevenson claims that students should be exposed to the plurality of environmental ideologies and "through a process of inquiry, critique and reflection develop their own sets of values and beliefs" (Stevenson 2007, p. 143). Environment and health issues in the context of science education are fields of inquiry that can enable students to critically analyze and reflect on the role and nature of science as ingredients in social processes of environmental change.

A critical perspective on science in terms of the "nature of science" may start with questions like: What notions of environment and health do people have, and how are those notions represented in society and in science? Is the environment conceived as a resource for technical development or as a source for life? Lucie

Sauvé has raised such questions in the context of UN documents on environment and development (Sauvé et al. 2003). Further questions may be how do members of society (citizens, politicians, scientists, and particularly students) come to know about what matters in current and future environmental and health developments? It makes a difference if students learn from science textbooks, or if they learn from current environmental problem situations, conducting their inquiries on the multiple perspectives of causes, values, and interests, and what concepts people have about problem-solving approaches. A critical inquiry includes exploring the role of science in problem-solving attempts, the way science generates knowledge in a specific context, and the potential and limits of scientific findings.

Inquiries made by such questions will evoke more thoughtful reflections on reasons behind developments in society and how changes may happen, and in favor of whom. Students will perhaps come to develop a critical attitude toward any kind of short-term solutions that do not take into account long-term effects.

Two examples illustrate the relevance of these questions mentioned above. The examples indicate how environmental and health questions specifically have the potential to raise awareness in people that science does not provide any definite truths and certainties. We do not claim that environment and health issues are the only spheres in science that can open up a critical view on the interpretation of scientific findings. But environment and health offer highly interesting and relevant perspectives on scientific findings and interpretations.

2 Example 1: Climate Change

Climate change is an increasingly widely agreed phenomenon, as was just recently stated in the article "A Scientist, His Work and a Climate Reckoning" by Justin Gillis in the New York Times (Gillis 2011). Climate change is explained by scientific facts such as the greenhouse effect and natural climate variations over thousands of years (Pfister 2010a). There are also increasingly more observable short-term changes in the environment such as floods, hurricanes, melting glaciers, unusual changes in weather, etc. What makes these scientifically observed and analyzed phenomena environmental issues?

It is about a couple of questions linked to the phenomenon: Is the current observed climate change really caused by human lifestyle and use of the environment? To what extent is the human contribution to the causes for climate change estimated? Which scientific findings on climate changes are judged to be reliable and why? Is the climate change a severe environmental problem or not? In his article in the New York Times, Gillis states, "perhaps the biggest reason the world learned of the risk of global warming was the unusual personality of a single American scientist" (Dr. Charles David Keeling) (Gillis 2011, p. 4).

Keeling began taking precise measurements of carbon dioxide in the atmosphere in the 1950s in California and later on in Hawaii. The "Keeling curve" shows that the amount of carbon dioxide rises over time.

In parallel, it was shown that carbon dioxide emissions continuously increased. Depending on how the environment is seen as a utility to exploit to the benefit of parts of the world or as the basis for sustainable life on earth, necessary measures for retarding climate change processes are seen over a spectrum, from doing nothing up to substantial changes in energy production and use. The climate change problem is likely to be a political rather than a scientific question. As Gillis states, "But as action on climate change began to seem more likely, the political debate intensified, with fossil-fuel industries mobilizing to fight emission-curbing measures. Climate-change contrarians increased their attack on the science, taking advantage of the Internet to distribute their views outside the usual scientific channels" (Gillis 2011, p. 4).

What makes the climate change thematic specifically remarkable is the recent communication disaster about the careless use of information by communication of so-called scientific findings through several steps of unapproved mediated information. Pfister, an environmental historian, calls it a "climagate" and explains it with the acrimonious battle between scientists supporting anthropogenic causes of climate change and climate-change contrarians both fighting for the intra-scientific control of leading journals and the interpretation primacy of public media (Pfister 2010b). Pfister demonstrates, by referring to the study "Entdeckung der Eiszeiten – Discovery of the glacial periods" by Tobias Krüger (2008), that stealing data and personal feuds are historically not regarded as new occurrences. Pfister argues for a more active role of human and social sciences supporting scientists to present adequate and open-minded information. This is exactly what makes environmental questions challenging issues for exploring how the public comes to know about them and how the so-called facts are interpreted and changed via communication transmittance and mediation.

In fact, these communication processes are not specific to environmental questions; they happen to any scientific findings. But environmental and health issues provide an area of controversial interests and concerns opening doors to critical inquiries on multiple assumptions and claims.

Referring to the four arguments supporting a predominant environmental and health issues role, science educators can choose different approaches to the climate change problem: (1) Following the "improving society through changing behavior" argument would mean that students learn about scientific facts of climate change and possibilities of environmentally sound behavior to individually contribute to the reduction of greenhouse gases. (2) The "awakening interest for science" argument would mean that teachers use the climate change problem in order to spark students' interest in chemistry, geophysics, or thermodynamics. (3) The "promoting scientific literacy" argument would mean focusing on scientific knowledge on climate change and how scientific conclusions can be drawn. Possibilities and limits of scientific knowledge would be discussed. (4) Following the "critical approaches to science" would lead students to explore the climate change issue from the scientific perspective of knowledge generation and its limits as well as from a socially critical perspective, for example, on controversial interests, political and economic influences on scientific findings and interpretations, the role of media, problem-solving (or preventing) strategies, and the use of science as reference for truth.

3 Example 2: Food and Nutrition

Another example, linking health and environmental questions, is the "food and nutrition" perspective. The very traditional way of treating this topic in science teaching is to explain the organs and the process of digestion. A wider perspective on the topic would be to explore cultures and habits of nutrition, the ways of food production, geographical regions and conditions of production and transport, the green revolution and questions of global food distribution logistics, trade and storage, environmental disasters, and their impact on the global food market.

Current research fields concern genetic engineering for food production, effects of food components on the human body, such as the recently found effects of trans fats, or health problems caused by nutrition defects. Other investigations focus on how people deal with so-called healthy food, the difference between tastes of young and adult people, fast food, convenience food, and functional, slow, "sustainable," and "healthy" food. Recently, a number of these issues concerning food and nutrition were the focus of an interdisciplinary research program with numerous researchers (Häberli et al. 2002).

Food and nutrition are an integral aspect of everyone's life. However, science teachers may place different priorities on different aspects. (1) Following the "improving society through changing behavior" argument, a teacher would focus on scientific knowledge on food production and healthy food. Students will discuss which products best meet criteria such as environmentally adequate production and transport, and individual health. (2) The second argument, "awakening interest for science," would probably start from questions about good and healthy food and how science can provide answers to those questions, followed by introductions into organic food production and analysis of food components. (3) Referring to the "promoting scientific literacy through environment and health" topic, a teacher would use the "food and nutrition" topic to teach basic scientific topics, such as food chain, cycle of materials, enzymes, or others. Students can learn what questions science can answer and how to draw evidence-based conclusions from scientific findings, for example, food effects on health. (4) The "critical approaches to science" argument may be induced by teachers or learners. For sure, young people have critical questions in the context of food and nutrition that they want to explore. Their questions may not be the tactic that science teachers would choose to address food and nutrition. The learners' questions may concern images of "healthy" or "natural" food, and conditions of food production, genetic engineering, or global nutrition. A critical approach will question, for example, the political, economic, and social conditions of food production, storage, promotion, and consumption, including the role of science in those processes.

As the two examples suggest, learning science includes asking questions that touch socially relevant problems in the context of science and scientific research. Furthermore, it includes learning about how knowledge is generated and communicated in specific situations by scientists, interest groups, and media, and critically analyzes what science can tell within its epistemologically set framework and what is explored and interpreted beyond the scientific framework when scientific findings are used in public discourses.

4 A Socio-scientific Orientation Challenge Toward Environmental and Health Education Science Teaching

Environment and health education will always evoke utilitarian views on what people ought to learn in order to improve life conditions. These goals are fundamentally linked with environment and health issues. And they are also common in science teaching. But beyond these views, environmental and health topics can open up a critical stance on "what it is all about," on how we come to know what we think we know, and what makes people act as they do: While exploring the dimensions of environmental and health questions, it is helpful to widen the field of scientific inquiry and learning, distinguishing spheres directly or indirectly relevant for individual knowledge and action. Every environmental or health question in real-life situations can be investigated across at least three main spheres as we have outlined in the socio-ecological approach toward environmental education (Kyburz-Graber et al. 1997, 2006):

1. The sphere of the individual assigned as the field of individual knowledge, beliefs, and behavior regarding environmental and health questions
2. The sphere of institutions and social groups that help to better understand the social contexts that influence what individuals know and do in real-life situations
3. The sphere of the natural and social environment providing the basis and framework in which human action takes place, which helps understand and critically reflect the conditions in which people live and act

Exploring and learning in these interrelated spheres may lead to generating knowledge on:

- Life situations with their interrelations among the three spheres
- Beliefs, values, interests, and meanings that are relevant for individuals and groups
- Scientific ways of knowledge production, findings, and explanations, and research conditions
- Knowledge and beliefs about science and scientific contributions to life situations
- Notions and concepts relevant for explaining life situations and conditions

Related approaches to science teaching have been described within the socio-scientific issues framework (Ratcliffe 2009; Zeidler et al. 2009, 2005; Simonneaux 2007; Albe 2007; Osborne et al. 2004; Stein 2001). Challenges from environmental and health education to science teaching support the socio-scientific issues concept. This can be shown by research questions corresponding to socio-scientific approaches to science teaching.

Research questions that matter to participants in the field, that is, teachers and students, will be more contextual and specific instead of large-scale inquiries on overarching questions of learning concepts. Teachers might perhaps like to learn more about epistemological aspects of conducting science: what kind of questions students ask when they are subsequently approaching life situations and how they try to find answers to those questions, or how students explain in their own words what they learned through their own inquiries and how they were able to critically reflect on their approach to research questions and how they can be supported in their reflections. Teachers and researchers might be interested in exploring how students handle information on scientific findings and what kind of questions they ask to understand the background of scientific research.

Another strand of research questions on science education might follow an ontological perspective: What do students assume concepts such as "nature," "ecological circles," the notion "natural," or "ecological balance" to be? Or how do students reflect on the nature of science?

Answers to these research questions will not tell science teachers how to teach general concepts in science education or how to reach environmentally sound behavioral changes in students or improve awareness of health risks. They may, however, open windows to meaningful thoughts and perhaps challenge students to more critically reflect on why things develop as perceived and how they could change. There is no certainty in this, no defined ends and no guarantee that defined goals will be reached, but this is perhaps what we mean when we claim critical approaches to science.

Critical socio-scientific approaches to science go beyond changing curriculum topics. Methods of teaching and learning have to be examined as well. The dominant practices of passive assimilation and reproduction of factual knowledge in schools are challenged, as well as teachers' presuppositions about knowledge and teaching (Stevenson 1987, 2007). As Osborne states about science teaching, "Considerable evidence exists that the lack of space for critical engagement with the ideas of science and their implications is what alienates many students. In addition, the foundationalist basis of many traditional science courses means that the underlying coherence and the major explanatory themes of science are only grasped by those who stay with the course to the end" (Osborne 2007, p. 109). In order to engage students in reflection, teachers themselves ought to be able, according to Osborne, to engage in reflective meta-commentary. Furthermore, Osborne sees the traditional role concept of teachers as science teachers in a critical way: "In addition, teachers commonly operate as if they are dispensers of knowledge rather than facilitators of learning" (Osborne 2007, p. 109).

Levinson (2007) has explored in interviews how teachers experience the teaching of socio-scientific issues. He came to the conclusion that teachers should focus on specific case studies and be encouraged to explicitly draw on student narratives and to educate students in the communicative virtues.

In a current research project, we explore how such learning processes can be initiated and engaged with students of upper secondary level. For this research study, an example from science history was developed that demonstrates, as example, how scientific research is embedded in a historical cultural and social context. The research project is presented as a vignette in this chapter to make it more visible and engaging.

Vignette

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DINOS: Discussing the Nature of Science: A Video-Based Research Study on the Process and Content of Students' Small-Group Discussions in Specific Learning Arrangements

The Subject of DINOS

The subject of this research study is teaching and learning about the nature of science (NOS) in upper secondary science classrooms in Switzerland. One main focus of the study is the content and process of students' small-group discussions. The overall objective is to provide an empirical knowledge base about teaching, learning methods, and content material that are supportive of the development of more informed views on NOS among students. Results shall be incorporated into teachers' preservice training and continuing professional development.

Posing the Problem

The theoretical background of the research is twofold. Firstly, addressing the NOS topic, according to shifts in the international science education discourse, science education has to develop from advocating scientific knowledge transmission to promoting an understanding of science referred to as scientific literacy. This entails not only knowledge of science, i.e., the contents and methods of science, but also knowledge about NOS, i.e., the epistemological underpinnings of the activities of science and hence also the "unavoidable characteristics" of scientific knowledge (Lederman 2006). Currently, with regard to teaching about NOS, the most influential definition of the concept holds that scientific knowledge (1) is *tentative* (i.e., subject to change); (2) is *empirically based* (based on and/or at least partially derived from observations of the natural world); (3) is *subjective* (theory-laden, involving interpretation by an individual or a group); (4) *necessarily involves human inference, imagination as well as creativity* (e.g., the invention of explanations or the design of experiments); and (5) is *socially and culturally embedded* (i.e., influenced by the society/culture in which science is practiced) (Lederman 2006, p. 304).

Secondly, the constructivist concept of the social learning arrangement needs to be considered. According to the current debate on educational objectives of upper secondary schools, the curriculum has to be reconsidered so as to allow young people to learn to use methods of self-directed and cooperative learning.

Educational researchers such as Lederman (2006) or Hofheinz (2008) showed that within an explicit and reflective approach, cooperative learning and especially small-group discussions are particularly suitable when it comes to learning about NOS. On this point, our two theoretical approaches are linked. The aim of such an explicit and reflective approach is to make students aware of the various aspects of NOS, which might be best achieved by student-centered, problem-based, reflective discussions with and among students about the practice of science (see Lederman 2006, p. 312).

Methodology and Research Design

In the past, empirical research on teaching and learning about NOS mainly focused on finding patterns in students' and teachers' views on NOS by using quantitative instruments of analysis. Such approaches, however, fail to provide an in-depth view of students' discourses and reflections on NOS questions. Hence, this study strongly focuses on the reconstruction of the processes of communication and interaction by which students put forward and negotiate their views about NOS. In order to better understand these processes, not only are classroom activities videotaped and interpreted, students' and teachers' perspectives are also included by means of interviews and questionnaires.

The project is designed as a two-stage multiple-case study, of which the later stage is built on the previous, and staggered over time. In the first stage, the research team and two biology teachers participating in the project cooperatively developed curriculum material on the NOS topic. The learning unit was then implemented in three different classes with students aged 17–19: The 1st lesson introduced students to the NOS topic. The 2nd lesson was based on self-studying material, which the students evaluated in a short questionnaire. In the 3rd and 4th lessons, selected groups of students (i.e., the cases of our study) were videotaped in two small-group and two whole-class discussions. These discussions built the main data source for case analysis as well as cross-case comparison.

Data analysis combined top-down and bottom-up qualitative procedures that focused on students' NOS views emerging from the discussions, the processes of communication and interaction in which students developed their ideas about NOS, and teachers' and students' judgment of the learning arrangement. Based on the analysis outcome, the learning arrangement will be modified accordingly and then implemented in new classes in the second stage of field research, employing a similar procedure as in the first stage.

In order to allow for data triangulation, multiple sources of evidence were used. Data were collected by videotaping the NOS lessons, through semistructured interviews with students and teachers, student feedback forms on the teaching material, and worksheets completed by students during lessons. Additionally, in order to gain insight into the stability and/or change of students' views on NOS, pre- and posttests using selected items from the "Views on Nature of Science Test"(Lederman et al. 2002) are conducted.

Findings of the first stage are discussed with teachers, and the outcomes are used as guidelines for adjusting the learning arrangement. The revised arrangement will be implemented in stage 2 of the project, and discourses in student groups will be analyzed.

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5 Concluding Reflections on Possible Pedagogical Implications on Science Teaching

Environmental and health education do not only challenge science teaching aspects by focusing on socio-scientific issues but also challenge means of teaching, shifting from a transmitting school science pedagogy approach to a scientific inquiry pedagogy, questioning scientific research conditions, and reflections on scientific findings. Such approaches will put less emphasis on:

- Fixed sets of concepts that are detached from contexts but more emphasis on inquiries in authentic life situations with multiple perspectives
- Fully predefined learning arrangements but more emphasis on openness to what students really want to find by themselves
- Quantity in science curriculum but more in-depth investigations and reflections on ontological and epistemological questions

A shift in established ways of teaching and learning requires more than revising the existing curriculum. It requires a paradigmatic change, which needs revising suppositions and beliefs that guide the science education curriculum and practice. In the focus of changing endeavors are the teachers and their teaching conditions. As Stevenson states, treating the existing practice of teaching as problematic asks for a new definition of the role of teachers and for changes in the organizational conditions (Stevenson 1987, 2007). The very key of the challenge is presumably the experiences and beliefs held by teachers of how science teaching and learning works and which scientific knowledge counts as legitimate and assessable.

Stevenson (2007) argues for professional teacher communities where a new discourse of professional learning can develop. In these communities, a participatory curriculum revision might be envisioned where teachers can, among themselves and together with learners, critically reflect on science education aims and methods of addressing them.

Building communities for professional learning and development within the current conditions of teaching seems unrealistic. Looking merely at the time needed for professional discourses one would agree. But beyond this time argument, there is evidence that teachers working together in professional communities feel supported, engaged, and encouraged for their work as teachers. This benefit as a long-term effect probably will compensate the time-consuming short-term efforts.

What questions might be discussed in professional science teacher communities?

One important step will be that teachers will become aware of their own learning experiences with science. They may share questions, problems, and situations that challenged their interactions with science when they were students, teacher students, or as teachers. Sharing these experiences and discussing specific inquiries and subjective approaches to scientific knowledge that had impacts on how they constructed science knowledge may lead to increased sensitivity for students' interactions with science.

Another field of inquiry in teachers' professional communities may be a critical approach toward scientific knowledge: In the course of their science education, did teachers learn about historically and socially contextualized knowledge in science? Do they know examples that allow for a critical analysis of different avenues of interpretations and communication of scientific findings? How did they experience the discourse on controversial perspectives on scientific facts?

Further inquiries may lead teachers to explore learning experiences of their students, their concepts and images of science, and how they come to critically reflect on the interface of science and society.

A further step will be to develop a curriculum offering learning arrangements that are open and challenging enough to engage students in critical inquiries and reflections. Closely linked with the learning process is the question of how to assess the learning outcomes. Teachers will have to discuss in what ways they expect students to express and document their knowledge and abilities and how students will be able to reach their fullest capabilities. Discussions will lead back to the question of what kind of knowledge counts as scientific knowledge and how may students' critical interactions with multiple perspectives be supported.

This outline of possible questions and discourses in professional communities may give an idea of how teachers can become researchers in science education and thus contribute as actors to a science curriculum transformation and science teaching and learning. In these transformation processes, socio-scientific approaches to environment and health issues will play a major role as outlined in this chapter.

Socio-scientific approaches in science education will probably not lead to recruiting more potential scientists, but perhaps they will contribute to better addressing questions raised by young people in a wider scientific context, such as those concerning the role natural sciences play in modern society, with all their opportunities, contradictions, uncertainties, and unexpected side effects. Teachers, students, researchers, and teacher educators ought to have the courage and be empowered to drive science education into these directions.

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Scientific Literacy in Environmental and Health Education

Rodger W. Bybee

1 Introduction

The grand challenges of our age consistently incorporate issues directly and indirectly related to the environment and health. Examples of contemporary challenges directly related to environment and health include:

- Environmental quality and the need for responses to global climate change
- Health maintenance and the need to reduce preventable diseases

Other socio-scientific challenges indirectly related to environmental and health issues appropriately should be added to this list. For example:

- Energy efficiency and adequate responses for a carbon-constrained world
- Resource use and the need to address continuing conflicts over limited natural resources
- Natural hazards and mitigation of severe weather, earthquakes, fires, and droughts

One must ask, "What is important for citizens to know, value, and be able to do relative to contemporary challenges related to the environment, health, and science-related issues?" Asking this question introduces the theme of scientific literacy.

This chapter begins with a discussion of scientific literacy. The orientation for this discussion of scientific literacy and the environmental and health theme is PISA 2006 Science. The results from this international assessment serve as a basis for describing policy implications for education.

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The PISA 2006 Science survey provides a significant foundation for the entire chapter and extends discussions of related themes from earlier works. Here, I acknowledge references to several of those publications (see, e.g., Bybee 1979a, b, c; Bybee 1991, 2008, 2010; Bybee et al. 2009; Bybee and McCrae 2011). PISA 2006 provided an opportunity to survey the scientific literacy of 15-year-olds in 57 countries, the total of which constitutes approximately 90% of the world economy. The next sections introduce PISA and place emphasis on the linkage between scientific literacy and issues related to the environment and health.

2 PISA 2006 Science: A Brief Introduction

The Program for International Student Assessment (PISA) is sponsored by the Organization for Economic Cooperation and Development (OECD), an intergovernmental organization of 30 industrialized nations based in Paris, France. The PISA survey is conducted by the Australian Council for Educational Research (ACER) in Melbourne, Australia. In 2006, 57 countries participated in PISA and included 30 OECD countries and 27 non-OECD countries. PISA measures 15-year-olds' competencies in reading literacy, mathematics literacy, and science literacy every 3 years. Each 3-year cycle assesses one subject in depth. The other two subjects also are assessed, but not in the same depth as the primary domain. In 2003, mathematics was the primary subject assessed, and in 2006, it was science. PISA also measures cross curricular competencies. In 2003, for example, PISA assessed problem solving and in 2012, it will survey financial literacy.

2.1 Scientific Literacy

The term scientific literacy has been used since it originated in the 1940s and over time has increased clarity especially in terms of national standards, curriculum, and assessment (Bybee 1997; Fensham 2000). With time, scientific literacy has acquired a broad meaning associated with the purpose of science education. The general use has the advantage of unifying the science education community by centering on what is perceived to be the goal. The disadvantage of using the term is the loss of its specific meaning which was an understanding of science and its applications to social experiences. Because science and technology have such a significant role in society, economic, political, and social discussions could not be made without consideration of science and technology (Hurd 1958). This view has personal, national, and global perspectives.

Osborne (2007) and Roberts (2007) have described critical distinctions relative to use of the term scientific literacy. Osborne argues that contemporary science curricula and practices are primarily "foundationalist." They emphasize educating for future scientists versus educating future citizens. Roberts describes two continuing political and intellectual perspectives in science education. One perspective emphasizes learning subject matter, including major concepts and processes of science. The second perspective emphasizes learning science in the contexts of life situations that include science and technology. Roberts refers to the curriculum designed to answer the first perspective as Vision I; the latter he refers to as Vision II. Vision I looks within science, while Vision II uses external contexts, such as environment and health, that students will encounter as citizens. PISA 2006 Science represents an assessment emphasizing Vision II.

Most school programs emphasize fundamental knowledge and processes of the science disciplines. These science programs are intended implicitly to provide students with the foundation for professional careers as scientists and engineers. With the centrality of science and technology to contemporary life, full participation in society requires that all adults, including those aspiring to careers as scientists and engineers, be scientifically literate.

For many with responsibility for national standards, curriculum materials, and assessments, the distinction between "Vision I" and "Vision II" is blurred. The dominant perceptions about the content and learning outcomes are Vision I; the exclusive emphasis is on science knowledge and methods. An often unstated assumption is that if students understand science concepts, they will apply that knowledge to the personal, social, and global problems they encounter as citizens. I question that assumption. I argue that school science programs should incorporate Vision II clearly, consistently, and continually. Individuals should have experiences where they confront appropriate socio-scientific issues and problems within meaningful contexts, such as the environment and health. PISA 2006 Science provided an assessment model for this view of scientific literacy.

2.2 Scientific Literacy and PISA 2006

The PISA 2006 Science assessment focused on scientific competencies that clarify what 15-year-old students know and are able to do within appropriate personal, social, and global contexts.

In PISA 2006 Science, scientific literacy referred to four interrelated features that involve an individual's:

- Scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomenon, and to draw evidence-based conclusions about science-related issues
- Understanding of the characteristic features of science as a form of human knowledge and inquiry
- Awareness of how science and technology shape our material, intellectual, and cultural environments
- Willingness to engage in science-related issues, and with the ideas of science, as a constructive, concerned, and reflective citizen (OECD 2006, 2009)

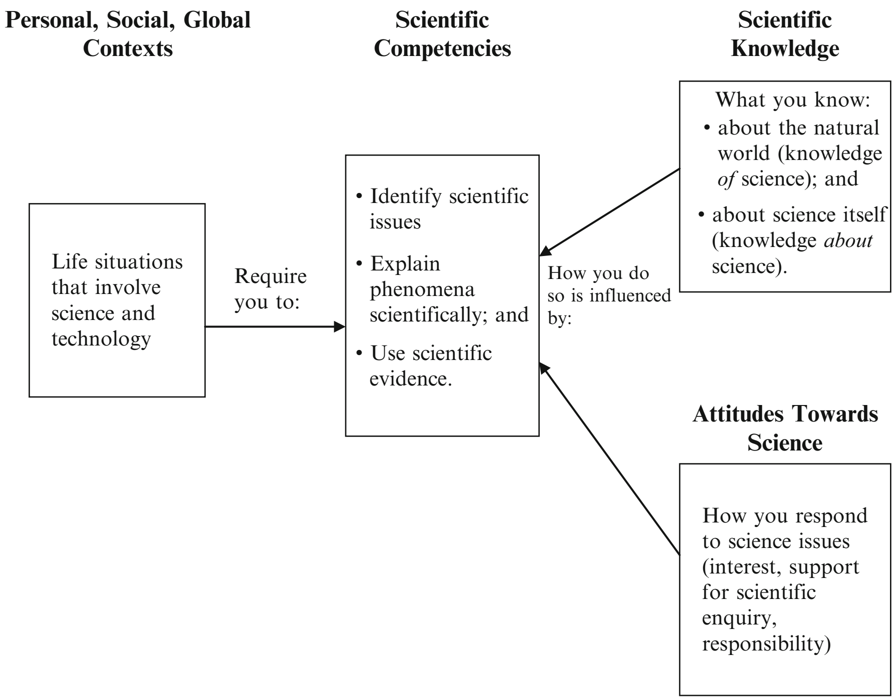

Fig. 1 Framework for PISA 2006 science assessment

PISA 2006 Science implemented the definition of *scientific literacy* and its science assessment questions using a framework with the following components: *scientific contexts* (i.e., life situations involving science and technology), the *scientific competencies* (i.e., identifying scientific issues, explaining phenomena scientifically, and using scientific evidence), the domains of *scientific knowledge* (i.e., students' understanding of scientific concepts as well as their understanding of the nature of science), and student *attitudes toward science* (i.e., interest in science, support for scientific inquiry, and responsibility toward resources and environments). These four aspects of the PISA 2006 conception of scientific literacy are displayed in Fig. 1.

Although PISA 2006 Science was not designed with an exclusive focus on environmental and health contexts, the survey did include a number of test items and survey questions that provide insights into students' understanding and interests relative to these domains. The reason for this centers on the fact that health and the environment include many life situations that present opportunities for assessment.

The PISA 2006 survey used both a student questionnaire *and* contextualized questions in test units to gather data about students' attitudes. The inclusion of contextualized items added value to the assessment and provided data on whether students' attitudes differed when assessed in and out of context, whether they vary

Interest in Science

- Indicate curiosity in science and science-related issues and endeavours.
- Demonstrate willingness to acquire additional scientific knowledge and skills, using a variety of resources and methods.
- Demonstrate willingness to seek information and have an ongoing interest in science, including consideration of science-related careers.

Support for Scientific Enquiry

- Acknowledge the importance of considering different scientific perspectives and arguments.
- Support the use of factual information and rational explanations.
- Express the need for logical and careful processes in drawing conclusions.

Responsibility towards Resources and Environments

- Show a sense of personal responsibility for maintaining a sustainable environment.
- Demonstrate awareness of the environmental consequences of individual actions.
- Demonstrate willingness to take action to maintain natural resources.

Fig. 2 PISA 2006 science attitudinal dimension

between contexts, and whether they correlate with performance at the unit level. One aspect of students' *interest in science* (namely, their *interest in learning about science*), and students' *support for scientific inquiry*, was assessed in the test using embedded items that targeted personal, social, and global issues.

The student questionnaire gathered data on students' attitudes in all three areas: *interest in science, support for scientific inquiry,* and *responsibility toward resources and environments* in a non-contextualized manner (see Fig. 2).

Of significance to this discussion, *responsible attitudes toward resources and environments* is an international concern. In December 2002, the United Nations approved resolution 57/254 declaring the ten-year period beginning on January 1, 2005, to be the "United Nations Decade of Education for Sustainable Development" (UNESCO 2003). The International Implementation Scheme (UNESCO 2005) identifies *environment* as one of the three spheres of sustainability (along with society—including culture—and economy) that should be included in all education for sustainable development programs. The UNESCO declaration provided a rationale for including questions about students' responsibility toward resources and the environment.

3 Students' Attitudes Toward Selected Environmental Issues

The following discussion is based on students' responses to the questionnaire that accompanied the test. Questions were sequenced to identify students' awareness, concern, optimism, and responsibility toward selected environmental and resource issues. The sequence of questions and environmental issues were influenced by an

Table 1 Students' awareness of selected environmental issues

Environmental issue	Percentage of OECD students who are familiar with or know something about this environmental issue
The consequences of clearing forests for other land use	73
Acid rain	60
The increase of greenhouse gases in the atmosphere	58
Nuclear waste	53
Use of genetically modified organisms (GMOs)	35

earlier international survey of science education (Bybee and Mau 1986). The design of questions provides more detailed insights about how attitudes and interests may be realized in actual science-related situations that individuals will encounter as reflective citizens. To be clear, these questions and students' response are only a proxy for the connections between attitudes (interests) and actual behavior.

In the survey of students' awareness of environmental issues (see Table 1), the majority of students in OECD countries are aware of selected environmental issues. The one exception was use of genetically modified organisms (GMOs). Data from the survey indicate that students' level of awareness of environmental issues is strongly associated with their scientific knowledge. However, some countries with lower mean scores, the United States, for example, did have students who were aware of environmental issues. Nevertheless, lower individual understanding of science may result in environmental issues being ignored or dismissed by students and eventually by citizens.

Students from more advantaged socioeconomic backgrounds reported higher levels of awareness of environmental issues. Twenty-five of 30 OECD countries had significant gender differences, with boys scoring higher than girls on their awareness of environmental issues.

Beyond awareness, one can ask about the level of students' concerns about environmental issues. The questionnaire for PISA 2006 asked students to report whether or not selected issues were a concern. Students are, in general, concerned about global issues. As you can see in Table 2, the percentages are highest for air pollution (92% on average for OECD) and lowest for water shortage (76% for OECD). Based on these data, students have remarkably high levels of concern about environmental issues.

In contrast to students' awareness, level of concern does not have a strong association with students' performance on science test items. Further, students' level of concern is not strongly associated with socioeconomic background. That is, students from less-advantaged backgrounds are equally if not more concerned about environmental issues. That said, it also is the case that they are less able to explain the issues from a scientific point of view. Finally, there is a significant gender difference in 29 of 30 OECD countries, with girls indicating greater concern than boys about environmental issues.

Table 2 Students' level of concern regarding environmental issues

Environmental issue	Percentage of OECD students who believe the following environmental issues to be a serious concern for themselves or other people in their country
Energy shortage	82
Water shortage	76
Air pollution	92
Nuclear waste	78
Extinction of plants and animals	84
Clearing of forests for other land use	83

Table 3 Students' level of optimism regarding environmental issues

Environmental issue	Percentage of OECD students who believe the following environmental issues will improve during the next 20 years
Energy shortage	21
Water shortage	18
Air pollution	16
Nuclear waste	15
Extinction of plants and animals	14
Clearing of forests for other land use	13

Are students' optimistic regarding environmental issues? To judge students' optimism about the future, PISA 2006 used the same environmental issues as presented for concern and asked if they thought the problems would improve during the next 20 years (see Table 3). Only a minority of students in OECD countries thought the various environmental issues would improve within the next 20 years. Students are most optimistic about shortages of energy (21%) and water (18%). But more than three quarters are pessimistic about these two issues. Their optimism about other issues is even lower. Unfortunately, the association between science performance and optimism is weak to moderate. There is a negative correlation between knowledge of science and optimism about future solutions to socio-scientific issues. That is, the more students know about science, the less optimistic they seem to be. These results are similar to those found in the ROSE study (Schreiner and Sjøberg 2004).

Students from more disadvantaged socioeconomic backgrounds tend to be more optimistic about the improvement of these environmental issues within the next 20 years. Quite strikingly, girls are significantly less optimistic in 28 of 30 OECD countries.

If 15-year-old students express generally high levels of awareness and concern, yet indicate significant pessimism about environmental issues, it seems reasonable

Table 4 Students' responsibility for sustainable development

Statements describing possible policies on student questionnaire	
A	Industries should be required to prove that they safely dispose of dangerous waste material
B	I am in favor of having laws that protect the habitats of endangered species
C	It is important to carry out regular checks on the emissions from cars as a condition of their use
D	To reduce waste, the use of plastic packaging should be kept to a minimum
E	Electricity should be produced from renewable resources as much as possible, even if this increases the cost
F	It disturbs me when energy is wasted through the unnecessary use of electrical appliances
G	I am in favor of having laws that regulate factor emissions even if this would increase the price of products

Abbreviated policy statements indicating students' responsibility	**Percentage of OECD students who strongly agree with the statement**
A (Require safe disposal of waste)	92
B (Laws to protect endangered species)	92
C (Regular checks on car emissions)	91
D (Minimize use of plastic packages)	82
E (Produce electricity from renewable resources)	79
F (Waste of energy through unnecessary use of appliances)	69
G (Laws to regulate factory emissions)	69

to ask about their sense of responsibility for sustainable development. PISA 2006 presented students with a sample of seven possible policies for sustainable development and asked them to respond by indicating the degree to which they agreed or disagreed with the policies (see Table 4). Students who indicated they agreed or strongly agreed were deemed to express a sense of responsibility for sustainable development. The strongest sense of responsibility was expressed for laws to protect endangered species (92% for OECD), followed by regular checks on car emission (91% for OECD), and safe disposal of dangerous waste material (92% for OECD).

Again, higher science performance is associated with a stronger sense of responsibility in all OECD countries. In general, students from more advantaged socioeconomic backgrounds tended to indicate a higher sense of responsibility for sustainable development. Very interestingly, girls show significantly more responsibility than boys in 20 of 30 OECD countries.

In conclusion, the results from PISA 2006 suggest that, in general, students with a greater understanding of science also are more aware of environmental issues. They also have a deeper sense of responsibility for sustainable development. However, these same students are not optimistic about how selected environmental issues will improve during the next 20 years. Within this conclusion, boys tend to be more optimistic and girls tend to be more concerned and responsible about environmental issues.

4 Students' Interests in Selected Health Issues

This section begins with a general discussion of students' interest in science. The PISA 2006 survey of science incorporated a unique approach to assessing students' interest. The survey asked students about science in a student questionnaire and also asked them, in the course of the assessment, about their interest in specific contexts used as the basis for the assessment units.

The survey's attention to attitudes toward science was based on the belief that a person's *scientific literacy* includes certain attitudes, beliefs, and interests which influence decisions and actions.

The PISA 2006 Science survey contained 37 units, comprising 108 cognitive items and 32 attitudinal questions (18 questions on *interest in science*). A form of the Rasch model was used in a similar manner to the processing of achievement data to produce an *interest in learning science topics* scale from student responses to each of the parts of the *interest items.*[1]

Table 5 shows the *interest in learning science topics* mean scale scores[2] for a selection of countries. The countries are arranged in decreasing order of PISA 2006 Science scale scores. The countries listed in the top half of the table were the highest performing countries in science. The countries listed in the bottom half of the table were the ten lowest performing countries in science.

Results from PISA 2006 indicated a tendency for students in low-performing countries to show relatively high levels of interest in science, with students in high-achieving countries showing relatively lower levels of interest. For example, Colombia had the highest mean score on the *interest in learning science topics* scale, but its mean achievement score was significantly higher than only two (Qatar and Kyrgyzstan) of the other 56 PISA 2006 participants. Finland, the country with the highest mean science achievement score in PISA 2006, was the lowest scoring country on the interest scale.

The negative correlation between student interest and performance *at the country level* is consistent with the findings of the Relevance of Science Education (ROSE) project. The ROSE survey is an international comparative study of 15-year-olds' interest toward science and technology. The pattern arising from ROSE data is that "The more developed a country is, the less positive young people are towards the role of science and technology in society" (Sjøberg and Schreiner 2005, p. 14). In related research, Shen and Tam (2008) analyzed TIMSS data from 1995, 1999, and 2003 and found a negative relationship between self-perceptions and achievement at the country level.

There were gender differences in interest. On average across the OECD countries, males scored significantly higher than females on the *interest in learning*

[1] An earlier version of the following analysis can be found in McCrae (2009).

[2] PISA scales are constructed with a mean of 500 and a standard deviation of 100.

Table 5 *Interest in learning science topics* mean scale scores

		Interest in learning science topics scale score			
Country[a]	Science score	All students	Males	Females	Difference[b](M – F)
Finland	563	448	445	451	**–7**
Hong Kong-China	*542*	*536*	*547*	*525*	***22***
Canada	534	469	471	467	4
Chinese Taipei	*532*	*533*	*542*	*524*	***18***
Estonia	*531*	*502*	*500*	*504*	*–4*
Japan	531	512	518	505	**13**
New Zealand	530	461	464	459	5
Australia	527	465	467	463	4
Netherlands	525	452	458	445	**13**
Liechtenstein	*522*	*504*	*502*	*506*	*–5*
Montenegro	*412*	*561*	*551*	*571*	***–20***
Mexico	410	611	607	614	**–7**
Indonesia	*393*	*608*	*600*	*616*	***–16***
Argentina	*391*	*567*	*562*	*572*	***–10***
Brazil	*390*	*592*	*588*	*596*	***–8***
Colombia	*388*	*644*	*633*	*652*	***–19***
Tunisia	*386*	*590*	*588*	*593*	*–5*
Azerbaijan	*382*	*612*	*609*	*615*	***–6***
Qatar	*349*	*565*	*568*	*562*	*6*
Kyrgyzstan	*322*	*580*	*571*	*588*	***–17***
OECD total[c]	491	507	510	503	**7**
OECD average[d]	500	500	501	491	**2**

[a]Non-OECD countries are indicated with *italics*

[b]Values in **bold** are statistically significant at the 5% level

[c]The OECD total is a weighted average in which each country contributes in proportion to the number of 15-year-olds enrolled in its schools

[d]The OECD average gives equal weight to each country (i.e., it is the average of the country averages)

science topics scale. Finland and the Czech Republic were the only two countries with mean science scores above the OECD average for which females scored significantly higher than males. However, males significantly outscored females on the interest scale in only eight of the 30 OECD countries in total, while females outscored males in seven of them. Furthermore, for the 27 non-OECD participants in PISA 2006, males significantly outscored females on interest in only four countries while females outscored males in 12 countries.

The PISA 2006 student questionnaire asked students how much interest they had in learning about the following eight broad science areas: topics in physics, chemistry, the biology of plants, human biology, astronomy, and geology, the ways scientists design experiments, and scientific explanations. Relative to the theme of health, human biology attracted most interest from all the tabulated countries except Azerbaijan; students in 52 of the 57 participating countries were more interested in learning about human biology than any of the other broad topics.

Table 6 The ten topics in which students showed the *most* interest

OECD rank	Non-OECD	Question label	Topic (*How much interest do you have in the following information?*)
1	**1**	Fit for drinking QNc	Learning which diseases are transmitted in drinking water
2	**2**	Sun and health QNa	Knowing how sunlight causes skin cancer
3	**5**	Physical exercise QNa	Understanding better how exercise affects your muscles
4	**4**	Good vibrations QNa	Knowing your own hearing sensitivity by having it checked
5	**3**	Physical exercise QNb	Learning how your body controls your breathing rate during physical exercise
6	**18**	Airbags Q9Na	Knowing why airbags can be dangerous in some accidents
7	**7**	Good vibrations QNb	Knowing how your hearing is damaged by loud noise
8	**9**	Alex's band QNa	Understanding how loud music can damage your hearing
9	**6**	Mousepox QNc	Understanding better how the body defends itself against viruses
10	**11**	Tobacco smoking QNc	Learning how the body recovers after stopping smoking

A review and analysis of field test items reveals a deeper understanding of health-related contexts and the interest of students. During 2005, about 260 science items (70 units) were field tested for possible inclusion in the 2006 survey. An *interest* item was included in 44 of these units. As mentioned in the context of the main survey, scaling of the field trial data also revealed that students from non-OECD countries exhibited a significantly higher average interest in scientific contexts than OECD students, but were less discriminating in that OECD students had a wider range of interest. Females exhibited higher average interest than males in OECD and non-OECD countries, but much less so in the OECD countries. Females had a much wider range of interest in the topics than males in both groups of countries.

The ten topics in which subgroups of students showed the most and the least interest are shown in Tables 6 and 7.[3] There is general agreement between the highest and (to a lesser extent) lowest preferences of OECD and non-OECD students, especially when issues that generally affect each group differently are taken into account. For example, it is not surprising that students from non-OECD countries were more interested in "knowing how water is tested for bacterial contamination"

[3] Topics are ranked according to how difficult it was for students to express interest in learning about them. Often, however, there was no significant difference in the difficulties of two or three items that have successive ranks.

Table 7 The ten topics in which students showed the *least* interest

OECD rank	Non-OECD	Question label	Topic *(How much interest do you have in the following information?)*
1	**3**	Green parks QNb	Knowing more about the design of experiments to test the effects of fertilizers
2	**1**	Plastic age QNc	Understanding how the molecular structures of various plastics differ
3	**2**	Hot work Qna	Understanding how the shape of the cup influences the speed at which coffee cools
4	**4**	Health risk QNa	Knowing about the chemical composition of agricultural fertilizers
5	**9**	Green parks QNa	Learning how fertilizers affect different plants in different ways
6	**5**	Hot work QNb	Learning about the different arrangements of atoms in wood, water, and steel
7	**19**	Experimental digestion QNa	Knowing about the work of other pioneers in the study of digestion
8	**10**	Cooking outdoors QNa	Understanding how propane is produced
9	**27**	Wild oat grass QNb	Understanding how scientists accurately identify plants
10	**8**	Cooking outdoors QNb	Knowing about other fuels that are used in portable stoves

than "knowing why airbags can be dangerous in some accidents." It should be noted that both of these topics relate to health and safety. There was more variability in the preferences of males and females, in both OECD and non-OECD countries.

In general, students expressed most interest in learning about health or safety issues that they might encounter personally (e.g., "learning which diseases are transmitted in drinking water") and least interested in learning about abstract scientific explanations (e.g., "understanding how the molecular structures of various plastics differ") and how scientific research is conducted (e.g., "knowing more about the design of experiments to test the effects of fertilizers"). The trend of decreasing interest as the topic moves further away from personal experience and immediate relevance is consistent with the finding of Osborne and Collins (2001) that students are most interested in the aspects of science that they perceive as being relevant to their lives, and least interested in topics that they perceive as being of little personal relevance. It also is consistent with the preferences PISA students expressed for learning about broad topic areas, where the highest rating was given to "human biology."

Students' interest in topics of personal relevance adds support to the general theme of scientific literacy and the specific inclusion of topics related to the environment and health. This observation connects to the earlier discussion of Vision II for scientific literacy (Roberts 2007).

4.1 Enhancing Scientific Literacy Using Environmental and Health Contexts

Scientific literacy would be improved through educational experiences that involve environmental issues and health concerns that have personal meaning for students. This discussion is based on an adaptation of the PISA 2006 framework for the purposes of design and development of curriculum and arguments for teaching science within real-world contexts (Fensham 2009). The themes for this curriculum emphasis are contexts, competencies, content, and attitudes. These themes were described in Fig. 1.

Although I stated this earlier, I want to be very clear about the emphasis and orientation for the proposed curriculum I am describing. The curriculum emphasis is scientific literacy as described in frameworks for PISA (OECD 2006, 2009). I can paraphrase the Sisyphean question to clarify the curriculum emphasis for this discussion. Given a life situation that involves health or environmental issues, what should citizens know, value, and do? The orientation I have outlined directly contrasts with the responses that students first need to learn life, Earth, and physical science concepts and processes. If students have learned this basic knowledge, it is assumed they will respond appropriately to life situations concerning health or environmental issues.

Because most school science programs emphasize the life, Earth, and physical sciences, teachers rightfully can ask, how can I introduce life situations that involve health and/or environmental issues? This is a reasonable question and deserves an answer. Science teachers in discipline-based courses could keep life situations in the background of their instruction and as appropriate briefly bring them to the foreground as examples, interesting applications, and meaningful connections to the primary subject. Think of this as shifting socio-scientific issues related to health and/or environment from background to foreground to background of instruction. There is not a need to persist on the socio-scientific issue, but the teacher can continuously integrate those situations in a low-level, consistent, and continuous manner. This approach to integrating the different environmental and health topics requires little time, i.e., they would be like short commercials, and the impact on learning likely would accumulate and be a significant factor during a year.

In the alternative view, the design of curriculum I am advocating begins with contexts that align with life situations that are personally meaningful for students. For a more detailed discussion, see Fensham (2009). For this discussion, I use health, environment, and resources because the latter is so closely related to environmental issues. Including climate change as a global perspective for health, environment, and resources is intentional as I believe the causes and sequences of global climate change is the single most significant challenge of our era (Fig. 3).

The environmental, resources, and health contexts for school programs would vary with students' ages and grades. Recognizing the dynamics and politics of curriculum reform, it seems reasonable and prudent to recommend the curriculum materials emphasizing scientific literacy and contexts of health and environment

	Personal (Self, family and peer groups)	**Social** (The community)	**Global** (Life across the world)
Health	Maintenance of health, prevention of accidents, nutrition, diet	Control of disease, social transmissions, food choices, community health	Epidemics, spread of infectious diseases, influenza, bio terrorism, climate change
Environment	Environmentally friendly behavior, use and disposal of materials	Population distribution, disposal of waste, environmental impact, local weather	Biodiversity, ecological sustainability, control of pollution, production and loss of soil, climate change
Resources	Personal consumption of materials and energy	Maintenance of human populations, quality of life, security, production and distribution of food, energy supply	Renewable and non-renewable, natural systems, population growth, sustainable use of species, climate change

Adapted from PISA 2006 Science (OECD, 2006)

Fig. 3 Contexts for health, environment, and resources

(and resources) should be introduced in yearly units of 2, 4, and 6 weeks at elementary, middle, and secondary grades, respectively.

The second consideration addresses the issue of scientific competencies. Here, the learning outcomes center on the question, what should citizens be able to do when confronted with life situations involving health and the environment? The answer aligns with the scientific competencies displayed in Table 8.

The curriculum should provide students with experiences where they encounter real-world situations requiring scientific competencies. Clearly, they will need to apply scientific knowledge and consider the aforementioned values.

The scientific competencies can be illustrated with a contemporary example. Global climate change has become one of the most talked about and controversial global issues. As people read or hear about climate change, they must separate the scientific reasons for change from economic, political, and social issues. Scientists explain, for example, the origins and material consequences of releasing extraordinary amounts of carbon dioxide into the Earth's atmosphere. This scientific perspective has been countered with economic and political arguments. Citizens should, for example, recognize the difference between scientific and economic positions. Further, as people are presented with more, and sometimes conflicting, information about phenomena, such as climate change, they need to be able to access scientific knowledge and understand, for example, the scientific assessments of bodies such as the Intergovernmental Panel on Climate Change (IPCC). Finally, citizens should be able to use the results of scientific studies about climate change as they formulate an informed opinion about its personal, social, and global consequences.

Table 8 Scientific and technological competencies

Identifying scientific issues
Recognizing scientific issues that are related to health, environment, and resources
Identifying keywords to search for scientific information
Recognizing the key features of a scientific or technical response to the issue
Explaining phenomena scientifically
Applying knowledge of science in a given situation
Describing or interpreting phenomena scientifically or technologically and predicting changes
Identifying appropriate descriptions, explanations, and predictions
Using scientific evidence to support a decision or recommendations
Interpreting scientific evidence and making and communicating conclusions
Identifying the assumptions, evidence, and reasoning behind conclusions
Reflecting on the societal implications of science and technological developments

Adapted from PISA 2006 Science (OECD 2006, 2009)

The content of curriculum programs should include both knowledge of science and knowledge about science. The former includes basic scientific concepts, and the latter includes understanding the nature of science as a human endeavor. Given that the recommendation for curriculum emphasizing scientific literacy in the contexts of health and the environment only occupy a portion of the school science program (i.e., 2, 4, and 6 weeks at elementary, middle, and secondary levels), one can assume the majority of the program will place knowledge of physical, life, and Earth sciences in the foreground.

Giving knowledge about science an increased importance in the curriculum will be an innovation. The recommendation to educate future citizens about the nature of science as well as the concepts of science, however, is not new (see, e.g., DeBoer 1991; Duschl and Grandy 2008; McComas 1998; Flick and Lederman 2004).

Table 9 displays examples of knowledge about science. The first category, "scientific inquiry," describes the central process of science and various components of that process. "Scientific explanations" represents the results of scientific inquiry. The relationship between categories can be thought of as the means of science (how scientists establish evidence) leads to scientific explanations. The examples listed in Table 9 convey the general meanings of the categories. No attempt is made to list comprehensively all the processes of knowledge in each category.

Considering attitudes toward science and values that may be included in units of study about environment and health, underscoring content with personal meaning and incorporating activities and investigations will enhance students' interest, support for science, and responsibility for issues of personal, social, and global importance. In addition, including the values of beneficence and justice, prudence and stewardship, and cooperation and mutual regard will be important for the proposed curriculum units.

Turning to instruction, the BSCS 5E instructional model could be used for the proposed units (Bybee, et al. 2006). Table 10 describes this approach.

Table 9 Knowledge about science categories

Scientific inquiry
Origin (e.g., curiosity, scientific questions)
Purpose (e.g., to produce evidence that helps answer scientific questions, such as current ideas, models, and theories to guide inquiries)
Experiments (e.g., different questions suggest different scientific investigations, design)
Data (e.g., quantitative [measurements], qualitative [observations])
Measurement (e.g., inherent uncertainty, replicability, variation, accuracy/precision in equipment, and procedures)
Characteristics of results (e.g., empirical, tentative, testable, falsifiable, self-correcting)
Scientific explanations
Types (e.g., hypothesis, theory, model, law)
Formation (e.g., existing knowledge and new evidence, creativity and imagination, logic)
Rules (e.g., logically consistent, based on evidence, based on historical and current knowledge)
Outcomes (e.g., new knowledge, new methods, new technologies, new investigations)

Table 10 BSCS 5E instructional model

Engage the learners. Present students with a question or problem situation that has personal meaning
Exploration by learners. Ask the students what they know about the issue. What responses, decisions may be required? Why should they respond?
Explanation of the science and technology. Students learn scientific and technological explanations from their investigations, the teacher, textbooks, and the Web. Students seek answers to questions such as, what do scientists know about this? What could happen?
Elaboration by learners. Students apply what they have learned—the knowledge, values, and processes—to the life situation
Evaluation of learners. Students prepare reports, presentations, summaries, etc., as individuals or groups. They present the issue, identify the scientific and technological components of the issue, explain the scientific or technological aspects of the situation, and use the information, data, and values in an argument supporting a recommendation or decision

5 Conclusion

If one reviews various discussions about "grand challenges" of the early twenty-first century, themes related to environment and health are consistently listed (see, e.g., McCarthy 2009; Holdren 2008; Omenn 2006; Zhu 2010; Bloom 2010; Reid et al. 2010). Environmental and health concerns present citizens with a variety of issues at personal, national, and global levels (Goldman and Coussens 2004; Goldstein et al. 2003; Coussens 2009). Examples of environmental issues include energy efficiency and the consequences of climate change, and for health, concerns about the H1N1 virus, HIV/AIDS, tuberculosis (TB), and malaria. Further, almost without exception, discussion of environmental issues and health concerns include the role of education as a part of solutions.

Scientific literacy, as I have discussed, refers to an individual's scientific knowledge and use of that knowledge to *identify scientific questions*, to *explain scientific phenomena*, and to *draw evidence-based conclusions* about science-related issues. In addition, the definition includes the understanding of the characteristic features of science as a form of human knowledge and inquiry; an awareness of how science and technology shape our material, intellectual, and cultural environments; and a willingness to engage in science-related issues.

Scientific literacy is essential to citizens' full participation in society. The knowledge and abilities associated with scientific literacy empower citizens to make personal decisions and appropriately participate in the formulation of public policies that impact their lives. Statements such as these provide a rationale for establishing scientific literacy as the central purpose of science education. But the development of scientific literacy by students requires experiences with science in meaningful contexts. Educators could use issues that citizens daily confront, for example, personal health and environmental quality, as underlying contexts for science education programs.

The discussion in this chapter has pursued answers to a variation of the Sisyphean question in science education: What is important for citizens to know, value, and be able to do in situations involving the environment and health?

Policies for science education programs and instructional practices should emphasize learning outcomes that include (1) understanding and fulfilling basic human needs and facilitating healthy personal development, (2) maintaining and improving the physical environment, (3) conserving and wisely using natural resources, and (4) developing an understanding of interdependence and community among citizens at local, national, and global levels. These outcomes include the underlying values of beneficence and justice, prudence and stewardship, and cooperation and mutual regard.

In the early decades of the twenty-first century, the science education community must respond to citizens' requirements for broader and deeper levels of scientific literacy by including environmental and health contexts in educational programs and instructional practices.

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The Concept of Health Literacy

Peter J. Schulz

The issues of health and health care dominate social, political, and economic discourse around the world both because of their human impact and because of their enormous cost. According to the Organization for Economic Co-operation and Development (OECD), health-care costs represented 11.2% of gross domestic product (GDP) in Switzerland, 10.9% in Germany, and 8.5% in Italy in 2002. In the United States, for example, health-care costs in 2003 amounted to over 15% of the GDP ($1.7 trillion). From advertising for diet programs, exercise videos and equipment, nutritional supplements, and, in some countries, pharmaceuticals, to health promotion and social marketing campaigns launched by nonprofit and government organizations, people are inundated with information related to health and wellness. Moreover, as patients, people receive health information and recommendations from a variety of health-care professionals including physicians, nurses, social workers, occupational and physical therapists, and psychologists. Beyond Western medical regimens, consumers engage practitioners whose specialties include numerous alternative approaches such as homeopathic remedies, herbal supplements, acupuncture, yoga, and meditation to name but a few.

How do people cope with this plethora of health information? Addressing this question has been a focus of research on health literacy. The term "health literacy" was first used in 1974 in a paper calling for minimal health education standards for all grade levels in the United States (Mancuso 2009; Zarcadoolas et al. 2006.). Since the 1970s, a stream of descriptive research has sought to examine the concept of health literacy, its measurement, and the problem of low health literacy. In addition, a large body of research has been focused on the development of

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interventions to improve health literacy or to limit the problems posed for people with low health literacy. Most of the literature on health literacy focuses on education as a key to health promotion and disease prevention.

Health literacy has been variously interpreted to include a range of knowledge and skills exercised in a variety of settings. Considering the variety of conceptualizations of literacy, this is not surprising (Nutbeam 2009; Frisch et al. 2012). For example, the National Institute of Deafness and Other Communication Disorders (NIDCD), one of the National Institutes of Health in the United States, offers this description of health literacy: "Similar to our traditional understanding of literacy, health literacy incorporates a range of abilities: to read, comprehend, and analyze information; decode instructions, symbols, charts, and diagrams; weigh risks and benefits; and, ultimately, make decisions and take action. However, the concept of health literacy extends to the materials, environments, and challenges specifically associated with disease prevention and health promotion." Two widely used definitions of health literacy include, first, the one used by the American Medical Association (AMA); it defines health literacy as "a constellation of skills, including the ability to perform basic reading and numerical tasks required to function in the health care environment" in the Journal of American Association (JAMA 1999). The other definition stems from the Healthy People 2010 report: "The degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions" (U.S. Department of Health and Human Services 2000). Both definitions refer to what has been called "functional literacy" in the literature. A sizable body of work focuses on functional health literacy primarily in medical settings (e.g., Parker 2000).

This narrow view of literacy had been vehemently criticized long before it was introduced to the field of health. Pattison (1982) coined the term of the "mechanics of literacy," stating that it is based on the wrong assumption that somebody who learns to read and to write automatically becomes a citizen capable of making the choices that need to be made in a democratic government. Basically, the formation of reading and writing skills is useful for the transfer of written information. Or, as Pattison put it, when one gives "a man the tools of reading and writing, we expect him to become more efficient, not more intelligent" (1982, p. 174). Something similar could also apply to health literacy: By teaching a man to read and to write, he will learn mechanical skills, but the acquisition of these skills gives no special insight into the proper and advantageous use of these skills in the field of health. So neither is health literacy equivalent to skill in reading and writing nor does the conclusion hold that individuals who are literate by this standard are more cultured than those who are not.

Nutbeam (2000) broadens the narrow view of health literacy, both in terms of the range of skills and of settings. He identifies three levels of skill: functional literacy, interactive literacy, and critical literacy, which endow the consumer with increasing autonomy and empowerment. Functional literacy refers to basic reading and writing skills, and interactive literacy adds to the functional level the consumer's ability to "extract information and derive meaning from different forms of communication." Critical literacy invokes a consumer's ability to analyze information and to use

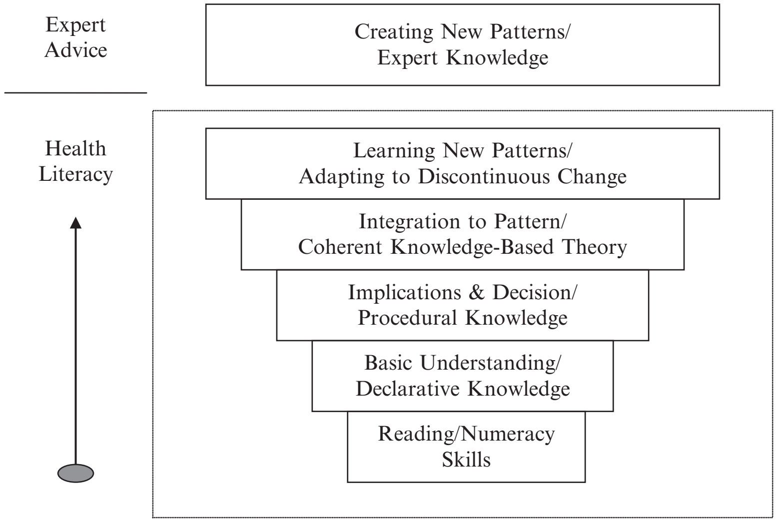

Fig. 1 Skill attainment view of health literacy

the analysis to gain control of and responsibility for his or her health. Based on Nutbeam's work, the World Health Organization (WHO) developed a definition that encompasses the elements of cognitive skills and behavior toward health: "Health literacy represents the cognitive and social skills which determine the motivation and ability of individuals to gain access to, understand, and use information in ways that promote and maintain good health" (WHO 1998).

In a previous article (Schulz and Nakamoto 2005), we sought to clarify the information and skills needed to attain these further forms of literacy. We suggested that health literacy might be viewed as competence with increasingly complex skills (Fig. 1). Certainly, traditional literacy abilities in terms of reading and numeracy form a base on which health literacy must be built.

Beyond these basic reading and numeracy skills, as Nutbeam suggests, health literacy involves the attainment of more "advanced" skills. Attaining these skills requires basic understanding of health-related material as declarative knowledge. Knowing, for example, that pain signals an abnormal condition or that prescription medicine is obtained at a pharmacy forms a base for understanding and interpreting health-related information. Thus, the component of declarative knowledge denotes all knowledge that patients or consumers could acquire via different information sources such as health professionals, mass media, colleagues, relatives, and friends. This type of knowledge is that which can be expressed verbally; it is "objectifiable" and is basic to learning how to approach a health condition.

Using such declarative knowledge to make informed decisions requires procedural knowledge regarding the appropriate application of health information. Procedural knowledge (or *know-how*) was first introduced by the philosopher

Gilbert Ryle, distinguishing between knowledge in the sense of “knowing that” and “knowing how” (Ryle 1946). As Ryle pointed out, know-how is akin to a person’s ability to conduct a certain activity. A similar distinction is drawn in the psychology literature as “declarative knowledge” versus “procedural knowledge” (Anderson 2005) and in a related vein as “explicit knowledge” versus “implicit” or “tacit knowledge” (Mandler 1984; Polanyi 1968), acknowledging that procedural knowledge cannot be recognized or verbalized. Declarative knowledge is stored in small packets and is consciously accessible, while procedural knowledge enables a person to use information in a specific context and governs the skilled performance of tasks (in this case, relative to the management of health conditions). For example, suppose a person has acquired a considerable amount of declarative knowledge about healthy food choices, the procedural knowledge would help him to use this knowledge across a wide range of situations. According to Anderson, knowledge compilation includes a progressive shift from the use of declarative knowledge to that of procedural knowledge. Speaking of a shift does not imply a hierarchical relationship between declarative and procedural knowledge. It is not that one is superior to the other; they are rather different forms of knowledge.

Partly, the skills in our model might correspond to Nutbeam’s integrative health literacy. The most complex levels of health literacy involve the integration of knowledge and the adaptation to changes in knowledge (cf. Nutbeam’s critical health literacy). These two components of the Skill Attainment View of Health Literacy, namely, “Integration to Pattern/Coherent Knowledge-Based Theory” and “Learning New Patterns/Adapting to Discontinuous Change,” both form together what we now call and label as “Judgment Skills”: Confronted with different or novel aspects that appear in everyday life, the patient or the consumer can manage them due to the acquired skills that allows him to make judgments on the basis of declarative knowledge. Thus he or she becomes autonomous in dealing with new situations. It goes without saying that this often requires practice, time, and also initial support from health professionals. For this reason, the patient’s progression in managing his disease is integral to our model. How do judgment skills relate to procedural knowledge? Procedural knowledge can be considered as a highly specific interpretation of declarative knowledge (Neves and Anderson 1981). For example, learning to perform a specific exercise to increase the mobility of a joint as part of managing arthritis would constitute a form of procedural knowledge of the (merely declarative) fact that the exercise would increase joint mobility (Schulz et al. 2007). Beyond this, however, different everyday situations require a judgment of which element of procedural knowledge is applicable to the situation. The problem on how to transfer declarative knowledge smoothly into procedural knowledge has to be faced within a framework that reaches beyond a merely knowledge-based concept of literacy and also includes patients’ empowerment. Health literacy theories that were partly introduced in the empowerment debate do not tackle this problem given that they mainly deal with reading and numeracy skills, that is to say: with skills that merely concern the declarative knowledge level. Implicit in the desirability of increased patient literacy is a critical assumption—that patient education (and thus literacy) will improve patient decisions.

This assumption implies that consumers and patients are motivated and empowered to participate as autonomous actors in making health-care decisions in a particular domain. This, however, might not always be the case. Think about people who are highly literate but lacking in psychological empowerment: They may choose to be highly dependent on health professionals despite their ability to make well-informed decisions for themselves. Alternatively, a psychologically empowered patient lacking adequate knowledge could well make dangerous choices that impede his or her health goals. Thus, the outcomes of autonomous patient participation will depend on both literacy and psychological empowerment.

It is critical, in addition, to recognize that health literacy has limits (Rubinelli et al. 2009; Schulz and Nakamoto 2011). We would not expect even a highly literate layperson to be able to discover and identify new patterns or develop new theories of health and disease. New knowledge of disease—mechanism, diagnosis, and treatment—is the domain of medical research. The application of such knowledge, for example, in the initial diagnosis of disease—for example, an initial diagnosis of diabetes—would not be an exercise in literacy. Rather, this would be a task appropriately performed by an expert—a physician—who has extensive training and experience in applying evidence-based tools and techniques to this task. One of the potential pitfalls of the skills conception of health literacy is the degree to which it leads to the portrayal of the health-literate person as a "pale shadow" of the expert.

One example of the difficulties that go along with the conception of a health-literate person as pseudo-expert is a mistaken vision of patient empowerment. Certainly, it is easy to argue that the caricature of the physician as autocratic and paternalistic dictator of health behavior is unacceptable but so is the conception of the patient as constant skeptic—doubting not only the judgment of the physician but also the value of his or her underlying knowledge. Beyond a vision of integrative medicine which seeks to involve complementary avenues to health, from improved nutrition to alternative treatment approaches (e.g., acupuncture), this overly skeptic patient feels empowered to denigrate the expertise of modern medicine altogether.

The health-literate person, then, occupies an admittedly ill-defined middle ground between a meek, ever-compliant patient who passively follows his doctor's orders and the self-assertive skeptic who challenges every word the physician says. However, we do expect a literate person to be able to recognize the need to consult an expert, not to become the expert. A fortiori, this means that literacy is not a function of ever-increasing amounts of content-specific (i.e., medical) knowledge. What sort of knowledge, then, is essential to health literacy? And how has health literacy been measured?

1 Effects and Measurement of Health Literacy

Beside the huge variety of concepts of health literacy, prior research has supported the association between literacy and disease knowledge, utilization of preventive services, hospitalization, overall health status, control of chronic disease, and mortality

(Mancuso and Rincon 2006; Schillinger et al. 2002; Wolf et al. 2005; DeWalt et al. 2004). In almost all of the studies, literacy was measured by the Test of Functional Health Literacy in Adults (TOFHLA) which is considered to be the most comprehensive among three reference standard tests. It measures comprehension of written instructions as well as numerical information (Parker et al. 1995). The test assesses reading comprehension by asking patients to fill in omitted words in prose passages. Moreover, it tests patients' numerical ability with respect to prescription labels, clinic appointments, etc. Given the length of the test—it requires up to 22 min to administer—a shortened and half as long version, the S-TOFHLA, was developed (Baker et al. 1999). The third standard test is the Rapid Estimate of Adult Literacy in Medicine (REALM), which assesses patients' ability to read and correctly pronounce 66 English medical words (Davis et al. 1993). While this test is easy to administer, it neither measures comprehension nor numeracy. Because the test is highly correlated with both the TOFHLA and S-TOFHLA, it is also often used in health literacy studies. Beside the TOFHLA and S-TOFHLA and REALM, in a few studies, single-item questions were used. A recent review came to the conclusion that single-item questions are capable of identifying patients with limited literacy. Particularly helpful are questions asking patients how confident they are filling out medical forms and how often they have someone help them read health information or demands to rate their own reading ability (Powers et al. 2010). Based on the three standard measurement tools used in more than 300 studies, a systematic review estimated that 26% of patients in the United States had inadequate literacy and additional 26% marginal literacy (Paasche-Orlow et al. 2005). Among elderly people enrolled in Medicare-managed care organizations, the estimate reaches 34% with inadequate or marginal literacy (Gazmararian et al. 1999).

So far, no validated instruments have been created to assess other dimensions of health literacy than simply reading and numeracy skills. However, what Nutbeam presents in his model as communicative or critical health literacy might have been studied under different labels. Ishikawa and Yano (2008) argues that other measurement tools such as the Patient's Confidence in Communication Scale (PCCS), which assesses patient's ability to list goals, barriers, and necessary skills for effective communication with a physician, do at least in part cover elements in Nutbeam's model. Similarly, other tools that test patient's level of confidence in participating in medical decisions do reflect parts of Nutbeam's concept of critical literacy (Arora et al. 2005). Based on these health literacy measurements, many studies were conducted that show that limited health literacy is related with several outcome measures such as limited knowledge regarding a specific disease (asthma, diabetes, hypertension, cancer screening et al.) or prevention (smoking), increased use of health-care services, as well as increased risk of hospitalization, health behavior, and poorer health status (DeWalt et al. 2004; Powers et al. 2010; Brown et al. 2011).

Several of these studies show the importance of baseline conceptual knowledge as a resource upon which individuals build their understanding of new health information. At the same time, it seems that most people have a poor understanding of science (Miller 1998). So far, there is no comprehensive instrument that would allow testing the general public's conceptual knowledge about health and illness (Baker 2006). Such an instrument would not only be helpful to plan health education programs, public health messages, and patient education. It would also allow to measure general health knowledge and to see how much should or could be included in school curricula. The question remains whether more than a solid conceptual and declarative knowledge should be conveyed in school. To address this question, we will shortly expand on the concept of knowledge in literacy.

2 Literacy and the Lived Experience of Health

Literacy in the traditional sense is understood as the ability to read and comprehend texts. Many authors appear to have translated this into health literacy as the ability to read and comprehend health-related textual material. While we recognize that these skills are foundational to a notion of health literacy, we believe that health literacy encompasses much more. As was argued, declarative knowledge, procedural knowledge, and judgment skills have to be considered, along with basic ability to read and write, as crucial elements of health literacy. In the following, we first describe the elements of procedural knowledge and judgment skills from a different angle and then argue that the combination of both has striking similarities with the classic concept of practical wisdom we have inherited from Aristotle.

Both functional health literacy and health-related declarative knowledge are epistemically objective concepts that can be taught and communicated straightforwardly, and also be measured in scores on a literacy scale or a knowledge measure. Considerations such as internalized ideas of good health, however, cannot be easily taught, communicated, or measured. They are inherently subjective. Indeed, a wider notion of health literacy can have no meaning separate from personal (internal) experience. This pertains to the notion of "knowing how" (Ryle) and to the conception of health literacy as an ability rather than a cognitive level, comparable to the skills of an experienced craftsman or businessman. The person who possesses experience is able, conjointly, to move about in his or her field of expertise with certainty and to adequately react to all situations he or she has to face. Traditionally, this type of knowledge has always been relegated to the categorical types of dispositions. Dispositions cannot be pinned down directly, although they are evident in their effects, without being totally manifested in these effects. In the wider concept we advocate, health literacy is, for instance, reflected in an individual's disposition to ask the right questions. This ability can be called experience, understood as a practical familiarity with things which fall into a particular area (health in our case). Whoever possesses experience has the ability to move about in a field of knowledge. The degree of experience shows up in the understanding of its possessor to rightly discern the things in this field. Due to its dispositional structure, "knowing how" or experience is a form of knowledge that is entirely "internal" to its owner. It is integral to the lived experience of the person; it almost is the person in an existential sense. Including experience into the concept of health literacy makes it a quality that is to a large degree internal to the individual and reflects the individual's understanding of the implications of health knowledge for his or her own good health.

This form of experience and understanding can be considered an aspect of practical wisdom. Following the tradition of Aristotle, practical wisdom (*phronesis*) is the ability to identify and use the right means to accomplish good ends. Whether somebody is able to do this depends in the ultimate instance on the accurate perception of what is required in the practical realities of a specific situation. According to Aristotle, as Kaldjian states,

> 'practical wisdom, acquired over time and through practice, functions as a disposition that motivates and enables a person to make good choices by responding in a proper way to a problem through clear perception and deliberation under given circumstances'.

Most importantly, the concept of practical wisdom includes as an ultimate end human well-being. And this ultimate end also provides the criterion by which one may choose among a given set of circumstances (Kaldjian 2010).

Health is undoubtedly a crucial aspect of human well-being. As we have argued above, increased patient literacy is usually considered a highly desirable goal. The critical assumption behind this is that more educated—more literate—patients make better health decisions. It follows that the more complex and demanding a patient's health condition is, the higher is the need for practical wisdom, the ability to choose among different treatment options and adapt them under given circumstances.

Generally, two elements of the traditional concept of practical wisdom are important for the discussion of health literacy and empowerment: First of all, the concept emphasizes the pursuit of worthwhile ends (goals) derived from a concept of human well-being and includes, therefore, a motivational aspect; secondly, it implies literacy aspects insofar as it requires the accurate perception of concrete circumstances. The comparison with practical wisdom shapes the vision of a concept of health literacy that includes the goal-directed activity underlying literacy.

Recognizing that experience-based knowledge is a crucial part of health literacy does not imply that declarative knowledge is unimportant to the concept. To the contrary, understanding health literacy as practical wisdom or experience highlights the importance of declarative knowledge. The concept may be, in Nutbeam's terms, "critical," and it is entirely legitimate for a literate person to weigh information in terms of his or her values. However, if literacy is to lead to better health outcomes and physical well-being, a person cannot be considered literate if he or she misperceives, distorts, or ignores relevant facts. To take but one example, not wearing a seatbelt while riding in a car because of a belief that being confined by the belt in an accident could increase the risk of injury (despite accident data to the contrary) is equivalent to ignoring the pertinent facts that should be considered. Access to information and the ability to acquire it belong as much to health literacy as individual processing, interpretation, and acceptance.

3 Health Literacy: The Case of Antibiotic Resistance

The following case study serves to illustrate the importance of including basic health information in school curricula together with emphasizing the knowledge-based fundamentals of health literacy. It is increasingly acknowledged that progressive resistance to antibiotics is due to their improper use. Previous research in the United States and European countries indicates that among the major factors promoting overuse of antibiotics is the lack of education which applies to both providers and patients (Levy 1998; Butler et. al. 1998; Britten 1997; Carbon and Bax 1998; Mainous et al. 1997; Seppala et al. 1997). Patients' lack of knowledge contributes on one side to increased demand for antibiotics and on the other side to their improper use. It is already known that patients' expectations have a significant influence on a doctor's decision to prescribe, even in cases in which antibiotics are not recommended (Macfarlane et al. 1997; Hamm et al. 1996; Britten 1997; Butler et al. 1998). Practitioners frequently acquiesce to misguided patients who demand antibiotics to treat colds and other viral infections that cannot be cured by the drugs, when they believe patients expect it (Hamm et al. 1996). But plenty of evidence also suggests that doctors overestimate patients' expectations: About one fifth of patients leave general practice consultations with prescriptions they did not expect (Britten 1995). In many countries, antibiotics are available only by prescription, but this restriction does not ensure proper use. People often fail to finish the full course of treatment for different reasons. Some get frightened by the side-effect descriptions listed on the package insert. Other patients terminate treatment after feeling better using less than the therapeutic amounts, which leaves quantities of the drugs for self-medication at other times. In both circumstances, the improper dosage will fail to eliminate the disease agent completely and will encourage growth of resistant strains. Although the reversibility of the current situation of resistance is uncertain, actions that could decrease the volume of antibiotic use without affecting quality of care should be considered.

It is presumed that awareness and knowledge regarding effects and possible risks of antibiotics are associated with proper use of antibiotics. But where do people learn about the problem of antibiotic resistance? One possible pathway of knowledge transfer might be the family context. To the best of our knowledge, there are no studies regarding the transfer of parents' knowledge regarding the antibiotic problem to their kids. But there is anecdotal evidence (Friedman et al. 2011) that parents who are aware of the problem are more likely to educate their children to be cautious with the intake of antibiotics. There are several other sources by which people are informed about the problem. Apart from the information patients could get from practitioners and at pharmacies, there are two other sources for learning about the appropriate use of drugs: the media, especially the press, and the package insert. For the former, reading and writing skills are not necessarily required, while for the latter, these basic skills are indispensable. In a study conducted in 2003, we observed whether and how basic information regarding antibiotics, their purpose and use indications, is given by physicians to their patients during medical consultations. Our research was based on qualitative data collected from 89 doctor-patient consultations in an Italian-speaking environment in Switzerland in a period from January to March 2003, when antibiotics prescriptions are more frequent than at other times of the year. All doctors who took part in the study—three general practitioners, three pediatricians, and three in internal medicine—had a relatively long professional experience. The consultations were audiotaped, with the patient's consent, when the doctor thought it probable for antibiotics to come up as a topic in the conversation. Only consultations with patients suffering from sinusitis, otitis, angina, bronchitis, or sore throat had to be recorded. All 89 interviews were transcribed verbatim and were verified comparing the audiotapes to the text. The analysis of the transcripts followed a content analytic procedure. Among the different themes we content-analyzed were the amount of information provided to patients regarding the difference between viral and bacterial infections, the proper way to take antibiotics, as well as the increasing problem of antibiotic resistance. Surprisingly, only in very few cases did the patients receive information regarding the difference between viral and bacterial infections as well as regarding the increasing problem of antibiotic resistance. And only sporadically did doctors inform their patients about the possible consequences of noncompliant behavior with respect to the antibiotic therapeutic regime.

Now, consider what people with sufficient reading skills could have learned from what is supposed to be the main information source in the field—the media and the patient package inserts (PPI). We analyzed articles from Swiss newspapers and magazines for a 4-year period (January 2001–December 2004), a census of 104 articles in 50 newspapers and magazines, to determine the extent to which articles presented information related to antibiotic resistance. Almost half of the articles analyzed mentioned the problem of antibiotic resistance but most did so attributing this to the use of antibiotics in animal nutrition. Out of 96 statements that explained the causes of antibiotic resistance, less than one quarter contained information on two key risk-reduction measures people can take to reduce the spread of antibiotic resistance: taking antibiotics only for bacterial infections and taking the full course of a prescription. Among the few times that human behavior was identified as a cause for increasing antibiotic resistance, the media blamed doctors' prescription behavior more than patients' improper use of antibiotics. These findings suggest that the print media were not relevant in increasing peoples' awareness of the problem.

PPIs, on the other hand, could possibly function as a means for raising awareness among the public about the problem of increasing antibiotic resistance, as well as for the related improper use of antibiotics. But an analysis of 67 antibiotic PPIs commonly prescribed in Switzerland for infections of the upper respiratory tract showed something different: (1) The problem of "antibiotic resistance" is very rarely mentioned (just 16 times out of 67 Swiss PPIs plus 20 synonyms and 16 times out of 46 Italian PPIs plus 18 synonyms) nor do they mention the difference between viral and bacterial infection. The information provided in this regard is far from being adequate. (2) In none of the PPIs was the resistance phenomenon explained as such nor was the therapy behavior ever connected to this problem. Therefore, increasing the basic level of the health literacy—that is, the reading and numeracy skills—could hardly resolve the problem in these cases.

At this point, the question arises whether people who are more aware and better informed (therefore have a more proper level of "declarative knowledge") regarding effects and possible risks of antibiotics are also less likely to improperly use antibiotics. People's knowledge of antibiotics and antibiotic use refers to how antibiotics work, such as whether they are useful against bacteria or viruses, or both. It also concerns matters of proper use, such as whether people are allowed to interrupt an antibiotics treatment when symptoms vanish. In addition, knowledge regarding antibiotics refers to whether people have heard of antibiotic resistance. In a representative survey we conducted among the Swiss resident population in April 2003 (Schulz et al. 2005), about one in six persons admitted to ever having interrupted an antibiotic treatment before the term indicated by their physician was completed. Among these, one third did so because of side effects, which cannot be considered misuse. Almost 11% of people terminated treatment prematurely for improper reasons. Two thirds of those who interrupted their treatment did not experience any negative consequences. About 4% of the Swiss population indicated they had, at least once in their lives, taken an antibiotic drug without having a prescription from a physician. One in ten Swiss people admitted to keeping antibiotic leftovers from previous treatments in their home pharmacy at the time of the interview. Table 1 shows the results and the precise question wording.

If terminating an antibiotic treatment prematurely and taking an antibiotic drug without prescription are considered actual improper use, then according to our survey, nearly 14% of people are improperly using them. As many people are aware of the impropriety of this behavior, we have to consider this figure as an underestimate of the real frequency of these behaviors. If storing antibiotics at home for use at a later time or simply throwing antibiotic leftovers away are counted as indicators of a propensity for misuse, 39% of the Swiss resident population in 2003 must be considered to show such propensity (Table 1).

Misuse and the propensity for misuse are lower in the German-speaking part of Switzerland and higher in the French- and Italian-speaking parts. A survey we conducted a year later clearly confirmed the more judicious (i.e., showing good sense, careful, mindful) use of antibiotics among the German-speaking Swiss population. It is not only misuse but also use in general that is higher in the Italian-speaking and especially the French-speaking part of the country. During the same time, awareness and knowledge of antibiotic resistance and antibiotics in general is lowest among the Italian-speaking Swiss, followed by the French-speaking. Among the German-speaking Swiss, both awareness and knowledge are highest. Overall, younger people show the highest level of misuse, although the respective questions are related to lifetime experiences. They also have a propensity for misuse that is almost twice that of the other age groups (30–65). The younger age group also knows less than the middle age group about antibiotics and antibiotic resistance.

Table 1 Misuse of antibiotics in Switzerland, April 2003, in percent

	Yes	No	Don't know, not applicable	Sum
Have you ever stopped an antibiotics treatment before term? I mean: Have you ever not taken it as long as the physician or the package leaflet said you should take it?	15.6	66.8	17.6[a]	100.0
Among these: Because I was feeling better	7.9			
Because of side effects	4.9			
Because I forgot	0.5			
Other reasons/Don't know	2.3			
Among these: Nothing happened	10.6			
Have you ever taken antibiotics without a medical prescription?	3.9	79.9	16.2[a]	100.0
In your chemistry at home, are there any antibiotics left from previous treatments?	10.0	87.6	2.4	100.0

N = 1,500
[a]Includes 16.1% who have never taken an antibiotic in their lives

Does knowledge affect the incidence of careless behavior toward antibiotics in the sense that those who know more are less likely to misuse antibiotics? Common sense would have us expect it, as would efforts to inform people about proper use. And there is some evidence for the correlation between both factors. For a general knowledge index, we calculated 11 knowledge items. It is indeed true that those who have not misused, and those who have no propensity for misuse, show somewhat higher knowledge levels than those who report to have misused antibiotics in the past and those who have a propensity to do so. Only in the case of propensity, however, does the difference reach conventional levels of significance. Similarly, application knowledge is related, but not significantly so, to misuse. Again, those who have not misused antibiotics in the past and those without a propensity for misuse know slightly more about the proper application of antibiotic drugs. The differences in both cases approach but do not quite reach the significance level of five percent (Fig. 2).

The results also suggest that merely increasing declarative knowledge of the proper ways to apply antibiotics is not enough. Antibiotic misuse in our sample is related to a number of attitudinal and behavioral precedents. One particularly interesting pattern for the purpose of the health literacy emerged from the data, namely, the well-educated, people with professional or high-level business occupations, and people with friends or relatives in the medical profession showed a below-average incidence of premature termination of antibiotic treatments but an above-average self-medication and above-average storage of antibiotics at home. This suggests that some misuse of antibiotics is due to readily available sources for this type of medication that people may have who are socially close to physicians, chemists, and other medical professionals. A less judicious use is correlated with some attitudes that signal a distanced view of medical personnel

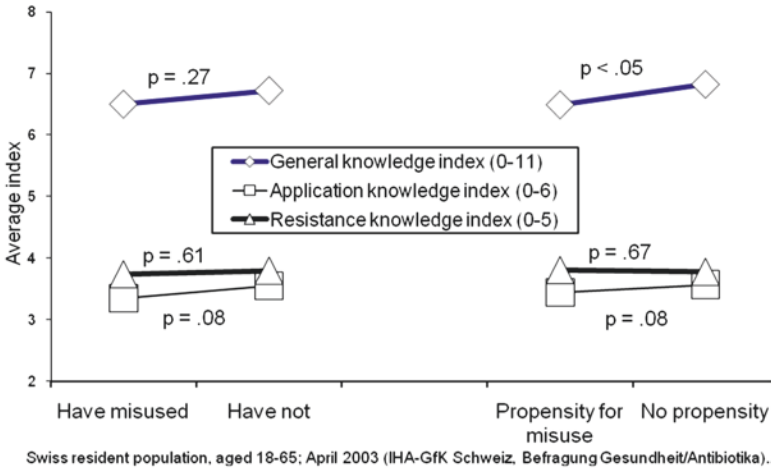

Fig. 2 Antibiotics knowledge and misuse

and institutions, such as avoiding to see one's doctor for as long as possible, expecting nothing but technical expertise from a physician, seeing physicians' prescriptions as being influenced by both the pharmaceutical industry and patients' demands, and not trusting health insurances as far as quality of treatments and/or doctors are concerned.

Several conclusions might be drawn from this case study. First of all, basic reading and writing skills are not sufficient to face important challenges in the field of health nowadays. Secondly, it cannot be taken for granted that important health issues are covered by media or other possible information sources such as the health professionals. There is an urgent need to teach this information in a school curriculum. Thirdly, a judicious use of antibiotics appears to go along not just with the indispensable amount of declarative knowledge but with judgment skills. Therefore, it would not be sufficient to provide students with proper knowledge regarding effects and possible risks of antibiotics but also the judgment skills regarding the proper use of antibiotics.

4 Conclusion

The instance of antibiotic resistance is a single case and can certainly not be generalized to other health issues with respect to the knowledge of the population or the information sources. However, it emphasizes that it is essential to understand which health concepts need to be taught more effectively at school—for example, not only the basic concepts of viral and bacterial infections but also the concepts of cardiovascular anatomy and disease that individuals are likely to encounter during their lifetime. Health literacy is a relatively recent focus of study and, as such, appears still to be in a developmental rather than a mature stage of analysis. Even at this stage, research on health literacy offers significant value and importance in understanding and promoting healthy choices, behaviors, and lifestyles. However, to capitalize on the potential of the concept of health literacy, we suggest there is a need to explore which health concepts need to be taught more effectively at school. In addition, we also need to expand our vision, especially the vision that highlights the ultimately subjective nature of a person's interaction with health information. As the research stream grows and matures, we believe it holds great promise, not only theoretically but also realistically, to provide information in health communication, provision, and policy.

Acknowledgments Practical wisdom has been recently linked to clinical judgments by Kaldjian (2010). This has inspired our line of reasoning. Also, some contemporary bioethicists discussed the importance of Aristotle's and Aquinas' concept of virtue to the practical wisdom of physicians (Pellegrino and Thomasma 1993; Beauchamp and Childress 2009). For a comprehensive treatment of the role of practical wisdom in everyday life, see Schwartz and Sharpe (2010).

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Part II
Responding to Challenges of Health and Environmental Education

Science, Environment and Health Education: Towards a Reconceptualisation of Their Mutual Interdependences

Justin Dillon

1 Introduction

The search for causality, while not exclusive to science, is certainly one of its fundamental characteristics. In Victorian times, as new technologies allowed scientists to widen the boundaries of their knowledge and understanding, the environmental causes of human diseases became increasingly clear. In 1854, a major outbreak of cholera killed 616 people in the Soho area of London. Using biological and chemical testing, the physician John Snow identified the likely source of the disease as a public well on Broad Street. This early epidemiological study challenged the miasmatic theory that held that disease was carried in air polluted by particles from decomposing matter—a theory that had held sway since Roman times. Even well-educated people believed the miasmatic theory in Victorian times because it seemed to explain their everyday experiences. New techniques and theories allowed scientists to offer more compelling explanations.

More than 150 years later, the links between the environment and health have been well researched, and our understanding has changed out of all recognition. That is not to say, however, that the public understanding of these links is particularly high. One reason for that poor state of affairs is that whereas science education is widely regarded as a core subject in the curriculum, health and environmental education are more likely to be seen as cross-cutting themes if they appear anywhere. Most current science curricula have relatively little health or environmental education in them and that is partly due to content overload which has been a feature of science education for decades.

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However, for a number of reasons, the situation is changing. One reason is that in recent times, significant efforts have been put into calculating the cost to society of a range of conditions from environmental pollution to alcohol abuse and obesity. For example:

> Scotland's obesity epidemic is costing the country around £450 million a year, according to a new Government study that predicts the bill could soar to £3 billion by 2030 if there is no change in the nation's attitude to food and exercise. (Gordon 2010)

Scotland has a population of just over 5 million people which puts the scale of the problem into some perspective. The sheer scale of the cost of these health-related issues has led policymakers to focus on strategies to change attitudes and behaviours. One of many policy responses was a pilot project, 'The Big Eat In', in Glasgow that involved pupils in 8 schools being encouraged to stay at school during lunchtime, eating healthily and taking part in activities (GCPH 2010). The success of the year-long project led to more schools getting involved in the scheme.

Schools are one of the main vehicles through which public attitudes and behaviours can be influenced although some might argue that legislation is more effective. The counterargument might be that without an educated public, it would be easier for opponents to regulation to thwart new laws. The recent UK Government Education White Paper notes that 'Good schools play a vital role as promoters of health and wellbeing in the local community' (DfE 2010, p. 28), adding:

> Children can benefit enormously from high-quality Personal Social Health and Economic (PSHE) education. Good PSHE supports individual young people to make safe and informed choices. It can help tackle public health issues such as substance misuse and support young people with the financial decisions they must make. (p. 46)

However, teacher training for PSHE, as it is labelled in the UK, is relatively brief and, consequently, not a good preparation for teaching about health issues (Walsh and Tilford 1998). To have any lasting impact on young people, the links between science, health and the environment need to be reflected in the core of the curriculum. Such a repositioning would require an overhaul of science education as we know it; however, there is a growing sense of frustration with the existing curriculum in many countries and resistance to change might be less of an issue than it has been in the past.

There is another reason why links between science, health and the environment are increasingly drivers for policy reform. The actual and potential impacts of climate change have caused a reconfiguration of policy agendas across the world. For many governments, the need for climate change mitigation and adaptation has already led to a range of new policies being implemented. Research into climate change education is increasing, and in 2009 NASA announced that it would be spending up to $8 million, funding 'projects designed to educate students, teachers and lifelong learners about global climate change' (NASA 2009). Climate change education will become a fixture in many education systems and, again, its most likely home is in the already crowded science curriculum.

So far, I have suggested that it is likely that links between science, health and the environment will increasingly be made in the school curriculum and that the most likely place for this to happen will be in school science education. In the next section, some reasons why this change is particularly timely will be explored.

2 The Problems with School Science Education

In 2008, the Nuffield Foundation published a report entitled ‘Science Education in Europe: Critical reflections’ (Osborne and Dillon 2008). The report emerged from two seminars, held in 2006, involving more than a dozen science educators and education researchers from a number of European institutions. The authors of the report identified why the seminars had been set up:

> Many countries are experiencing significant problems with engaging students with the advanced study of physical sciences. Where this is the case, it is a source of significant concern. However, this pattern is not universal across Europe and appears to be strongly correlated with the level of economic advancement in any given country. (Osborne and Dillon 2008, p. 13)

They noted, moreover, that ‘one area […] in which there is a common trend is in the decline of student attitudes to science’ (p. 11). This opinion is supported by data from the Relevance of Science Education (ROSE) survey which reported a ‘0.92 negative correlation between students’ attitude towards school science and the UN index of Human Development’ (Sjøberg and Schreiner 2005, p. 11). This negative association between student attainment and student attitude towards science also emerges from the Third International Mathematics and Science Study (TIMSS) which carried out a major comparison of students’ attainment and attitudes across the world in 1999 (Martin et al. 2000).

The Nuffield report contained a series of specific criticisms of science education which were thought to be common to many European countries. These included ‘a lack of perceived relevance’, ‘a failure to generate a sense of anticipation that accompanies an unfolding narrative’, ‘a pedagogy that lacks variety’, ‘a less engaging quality of teaching in comparison to other school subjects’, ‘content which is too male-orientated’ and ‘an assessment system that encourages rote and performance learning rather than mastery learning for understanding’ (Osborne and Dillon 2008: adapted from p. 15).

In terms of the lack of relevance of science education, the authors noted that:

> School science is often presented as a set of stepping-stones across the scientific landscape and lacks sufficient exemplars that illustrate the application of science to the contemporary world that surrounds the young person. (p. 15)

What, then, might young people think are relevant topics? One answer to that question comes from an analysis of the English ROSE data carried out by Jenkins and Nelson (2005). Students in the ROSE survey were given a list of 108 science topics and asked to rate their level of interest on a scale of 1 (‘not at all’) to 4 (‘very interested’). The results for the boys and girls were significantly different, as can be seen from Table 1 which lists the top five topics for each gender.

Table 1 The most highly rated science topic chosen by English boys and girls in the relevance of science education survey (Jenkins and Nelson 2005)

Boys	Girls
Explosive chemicals	Why we dream when we are sleeping and what the dreams might mean
How it feels to be weightless in space	Cancer—what we know and how we can treat it
How the atom bomb functions	How to perform first aid and use basic medical equipment
Biological and chemical weapons and what they do to the human body	How to exercise the body to keep fit and strong
Black holes, supernovae and other spectacular objects in outer space	Sexually transmitted diseases and how to be protected against them

Whereas the boys indicate an interest in topics involving weapons and outer space, the girls' interests are predominantly focused on health topics. The implications of this divide is that if health and environmental topics are to have a bigger role in the science curriculum, then girls will be interested but ways will need to be found to engage boys.

Osborne and Dillon concluded their report by noting that secondary science education was not fit for purpose:

> The irony of the current situation is that somehow we have managed to transform a school subject which engages nearly all young people in primary schools, and which many would argue is the crowning intellectual achievement of European society, into one which the majority find alienating by the time they leave school. In such a context, to do nothing is not an option.

Europe is not alone in possessing an inadequate science education system if the response to the publication of the Programme for International Student Assessment (PISA) 2009 study is anything to go by (see, e.g., Tse 2010). So, for many countries, doing nothing about the science curriculum is, as Osborne and Dillon argue, clearly not an option. The question, then, is what could and should be done?

3 A New Mutualism?

The issue of the relationship between science and environmental education has been discussed by Annette Gough (2002) among others. She notes that in the early debates about the issue, some authors (e.g., Fensham and May 1979) argued for the two subjects to be brought closer together, while others have provided counterarguments for their separateness (for example, Lucas 1980). The issue has continued to be debated, and Gough refers to Webster's comment that:

> Science, like economics, has been reformed through the promotion of investigative science and the contextualisation of science. The contexts are often social, utilitarian concerns: health, science in everyday life, a nod to environment, and industry. Content still dominates, as does experimentation. As in economics, the hidden values and assumptions about the way the world works remain largely unexplored. (1996, p. 82)

She concludes that it is timely to revisit the issue:

> If we are to achieve sustainable development then science education must have a role in encouraging ecological thinking (instead of being kept at a distance) and environmental education must move on from the insecure relationships that accompany the abstract arguments for it to adopt 'a holistic approach, rooted in a broad interdisciplinary base' (UNESCO 1978, p. 24). (Gough 2002, p. 1203)

Sustainable development is a highly contested term, but whether the desired goal is sustainability or survival, Gough's point is well made. Arguing for a new mutualism and noting science education's insecurities, she argues that 'science education needs environmental education to reassert itself in the curriculum' noting that it could do this 'by making science seem appropriate to a wider range of students and making it more culturally and socially relevant' (p. 1210). While, at the same time, she is of the opinion that 'environmental education needs science education to underpin the achievement of its objectives' and that it should 'provide it [environmental education] with a legitimate space in the curriculum to meet its goals because they are very unlikely to be achieved from the margins' (2002, pp. 1210–11). Not surprisingly, Gough suggests that this will not be an easy process.

So, extending Gough's argument to include the health dimension, how might science, environmental and health education come together in new ways that would add value to students' experiences in school rather than simply overwhelm them? A new curriculum would need to show that science is inherently political in terms of how it is funded and subject to commercial interest in terms of what research is favoured. Cancer, the second favourite topic of the girls in the ROSE survey mentioned above, provides an opportunity to look at how investments in prevention might be more effective than providing treatments. Cancer also provides an opportunity to examine issues of risk and probability, topics that do not often find themselves in traditional science curricula.

Recent events in Japan and their subsequent reporting in the media provide graphic examples of the need to educate people about topics such as the accuracy of predicting geological processes and the relative costs and dangers of different methods of power production. The engineering causes and the environmental, health and economic consequences of the Deepwater Horizon oil spill in 2010 provide other examples where a combination of knowledge and understanding is needed to make sense of major events in the world and of their implications for society.

One of the challenges that Gough identifies that any reformulated science education would need to take into account is 'critiques of traditional science education from cultural and constructivist perspectives' (p. 1211). In terms of identifying how science education might develop, it is instructive to consider what Aikenhead, writing from a cultural perspective, considers might constitute indicators of quality science teaching:

1. Acknowledgement of the degrees of cultural differences between students' cultural self-identities and the culture of their science classroom, and recognition that each student needs help when negotiating this cross-cultural classroom environment

2. An enacted curriculum predominantly comprised of relevant science content outside the category of wish-they-knew science, but not ignoring that category
3. An emphasis on the outcome: Teaching students *how to learn and use* science as the need arises in specific contexts
4. Student assessment formulated in terms of monitoring students' learning how to learn and how to use science and technology as needed (2011, p. 122)

As the main criterion for determining what might be taught in any future science curriculum, Aikenhead advocates 'educational soundness and relevancy' rather than political expediency (122–3). Such criteria would open the door for further inclusion of environmental and health education to be incorporated in science curricula.

The need for a less homogeneous version of school science curricula has also been identified by Jenkins (1999) who argued that 'curricula in different countries will show a greater degree of variety than is presently the case.' Jenkins uses the example of Bovine Spongiform Encephalopathy (BSE) in the United Kingdom to illustrate his point that:

> Not all science-related issues are global, and if the school science curriculum is to be sensitive to the interests of students, regional or other in-country variations will need to be accommodated. (p. 708)

This is an interesting point, and although much of the content of science—the laws and phenomena, for example—are clearly universal, their application is not. The question now is, what should be the purpose of this new curriculum? To answer that question, it might be useful to consider another of Gough's factors that any reconstructed science curriculum would need to attend to: calls for increasing the scientific literacy of the general public. Would this new vision of environmental/health/science education fit within a vision of scientific literacy?

4 Scientific Literacy

Although teachers might not use the term frequently, scientific literacy is relatively common in the lexicon of science education. Tracing its origins to the 1950s, McEneaney (2003) describes it as having achieved a 'worldwide cachet' and the concept underpins the Organisation for Economic Co-operation and Development's (OECD) Programme for International Student Assessment (PISA) study. However, the term is treated with scorn and distrust by some writers. Laugksch notes that 'scientific literacy is an ill-defined and diffuse concept' (2000, p. 71). According to Dillon:

> The longevity of the term scientific literacy relies on its ability to be seen as an umbrella for radically different philosophies of science education. However, the evidence suggests that when attempts are made to effect curriculum change to promote 'scientific literacy' the unreconciled philosophical clashes hinder progress. (2009, p. 202)

Some indication of the degree to which the philosophies clash can be gauged from this quote from Roth and Barton (2004):

> Conventional approaches to scientific literacy, knowing, and learning are based on an untenable, individualistic (neo-liberal) ideology that does not account for the fundamental relationships between individual and society, knowledge and power, or science, economics, and politics. (p. 3)

In an attempt to clarify what is meant by scientific literacy, Roberts (2007) identifies two ways of conceptualising science education's aims and purposes. He describes two 'visions' for generating conceptions of scientific literacy: Vision I and Vision II. Vision I 'looks inward at science itself—its products such as laws and theories, and its processes such as hypothesizing and experimenting' whereas Vision II 'looks outward at situations in which science has a role, such as decision-making about socioscientific issues' (Roberts 2007, p. 9).

Could the same set of visions illuminate what kind of literacies might be developed under the aegis of science, health and environmental education? Vision I would focus on a range of issues and topics such as climate change, environmental causes of cancers, and growth and reproduction. Vision II might focus on ethical issues concerned with stem-cell research, how climate change scientists work and at the role of pharmaceutical industry in drug research.

Grace and Ratcliffe (2002) note that environmental issues affecting society tend to be underpinned by value judgements. Such approaches would require teachers to focus on teaching about the values underpinning science, health, the environment and society. Again, the challenge of such a pedagogical shift must not be underestimated. There are many science teachers who might find it challenging to teach such topics. Science teachers cannot shirk their responsibility to teach about the issues that fundamentally affect people's health and the environment—to do so would be intellectually bankrupt and morally indefensible.

Gayford (2002) makes the point that teaching about climate change in school science might be problematic because teachers' understanding of such complex issues might be inadequate. While this change would make the new curricula more interesting and relevant, they might be difficult to teach because the border between 'scientific statements' and 'value statements' is often hard to see Oulton et al. (2004) found a serious lack of preparation to teach about controversial issues among science teachers in England resulting in some reluctance to use them in the classroom. One of Lucas's earlier concerns about teaching environmental education through science education was whether science teachers' 'worldviews as empirical experimenters [would] seriously distort the nature of historical understanding and aesthetic judgement?' (1980, p. 21). It is clear that any radical change to broaden the science curriculum would necessitate changes to initial and in-service teacher training as well as new resources for classroom and out-of-classroom use.

5 Health and Environmental Literacies

If Roberts's Vision I and Vision II for scientific literacy help us to reconcile some of the clashing philosophies that might impede curriculum change, do the notions of health and environmental literacy offer any opportunities to develop the mutual relationship between science, health and the environment? Nutbeam (2000) notes that health literacy is a relatively new concept, and for a long time it has tended to refer to the ability of patients to read medical information including labels on medicine bottles. However, as Nutbeam points out, this is a very narrow conceptualisation of literacy, and it ignores the growth in the study of literacy and literacies. Broader interpretations of the term do exist, and the World Health Organisation, for example, notes that:

> Health literacy means more than being able to read pamphlets and successfully make appointments. By improving people's access to health information and their capacity to use it effectively, health literacy is critical to empowerment. (Nutbeam 1998, p. 264)

Nutbeam himself derives a model of three levels of health literacy: formal, interactive and critical. The highest level, critical health literacy:

> [R]eflects the cognitive and skills development outcomes which are oriented towards supporting effective social and political action, as well as individual action. (2000, p. 265)

This approach to health education, he argues, can focus more on 'achieving change in the social, economic and environmental determinants of health which may benefit the health of whole populations…' (p. 265). Tones (2002, p. 289) argues that adequate theoretical frameworks already exist and that expanding the meaning of 'health literacy' is redundant. An example of such a theoretical framework that includes social capital and action competence can be found in Jensen et al. (2002). They advocate the development of:

> [P]upils' abilities to act at the personal and at the societal level […] If pupils have to contribute to the solution of today's health problems, it follows […] that they have to identify personal and structural causes behind the health problems and to develop their own possibilities to influence and change these conditions. (Jensen 1995, p. 6)

So, whether one takes the broader view of health literacy proposed by Nutbeam or sides with Tomes's view that critical approaches to health and environmental education already exist without recourse to the notion of literacy, then a new mutualism between science, health and environmental education should promote an educated citizenry able to critically examine issues of local importance and global significance in ways that they currently do not.

At this point, I should make clear that I have been eliding between two ideas. The first is that the science curriculum (strictly speaking, the science curricula) should be reconstructed to include more health and environmental education (I am avoiding using acronyms such as SHE and HES here—the failure of STEM has taught me to be wary of them). I am not advocating that health and environmental education should be swallowed up by science education (hence, the use of the term science/environment/health). There is a role for both beyond a reconstructed science education.

What I am doing in this chapter is to focus on what a reconstructed science curriculum might look like.

One aspect of environmental and health issues that is poorly addressed in any part of the curriculum is risk. This is a fundamental problem because we are increasingly being confronted by a range of 'soft disasters'—'environmental and political crises that emerge only slowly but at high cost to society, not least the erosion of public confidence and legitimacy' (ESRC Global Environmental Change Programme 2000, p. 3). Soft disasters include socio-scientific issues such as BSE, the GM food debate, HIV-AIDS and global climate change. These would seem to be just the sort of topics that might be studied in the science/environmental/health curriculum. To make sense of these complex issues, the public needs at least a basic understanding of risk assessment and management and some understanding of probability (Dillon and Gill 2001; Jenkins 2003).

6 What Might the Student Experience Look Like?

Some hypothetical topics for possible study in a science/environment/health curriculum were identified earlier. Examples of projects that might offer lessons about how to approach teaching the new interdisciplinary curriculum can be found in countries with particularly democratic education systems such as Denmark. Jensen describes Danish educational activities that he identifies as being action oriented:

> Such activities may consist of physical, chemical and biological investigations of a polluted lake or they may embrace social science oriented activities such as interviews or document-analysis. Such activities are obviously valuable and productive to the extent that they facilitate motivation and the acquisition of knowledge. But in order to be characterised as actions, they must be targeted at effecting real change regarding the environmental problem that is being worked on. (Jensen 1995, p. 326)

Such projects might not seem particularly novel given the long history of water quality monitoring projects; however, the focus on developing students' action competence and on empowering them to take political and social actions rather than simply learning content might be seen as a more radical approach to education. However, given that we do not have examples of the science/environment/health curriculum in operation, we can imagine that if they were realised then there would be almost limitless opportunities for local and regional projects on a wide range of topics.

Another dimension to the curriculum would be a commitment to:

> [F]ocus on helping learners deal with the sheer complexity and splendour of the environment as well as looking to use the local environment as a vehicle for developing understanding of the more mundane aspects of the science curriculum. (Dillon and Scott 2002, p. 1112)

In terms of outcomes, current science education tends to focus on a relatively small number, mainly related to knowledge and skills. However, the new curriculum might usefully take a much broader look at what benefits might emerge from a range of pedagogical approaches. We already know, particularly from primary education, that environmental projects can have a wide range of benefits to students, to teachers, to schools and to the wider community. For example, Maller (2005) identified a number of aims for engaging children in hands-on contact with nature:

> [T]o meet sustainability education, environmental education or science learning objectives. However, other reasons cited for the recent growth in these types of activities include beautification of school grounds, habitat restoration, and fostering qualities of stewardship and nurturing in children. (p. 16)

Maller's study showed that it is possible to identify science, environmental and health outcomes which were mutually reinforcing:

> The take-home message from this research is that hands-on contact with nature experienced via sustainability education is not only essential for protecting the environment, but it also appears to be a means of cultivating community and enhancing the mental health and wellbeing of children and adults alike. (pp. 21–22)

Other strategies to promote deeper understanding of science/environment/health links include public participation in scientific research (PPSR), sometimes known as Citizen Science. PPSR offers opportunities to develop a greater sense of how science works [Roberts' Vision II] in students and can encourage them and their schools to work collaboratively. In a review of PSSR projects, Bonney et al. noted that:

> Participants in many PPSR projects also gain knowledge of the process of science. Indeed, this is one area where PPSR projects have the potential to yield major impacts, particularly Collaborative and Co-created projects, which engage participants in project design and data interpretation to a significant degree. (Bonney et al. 2009, p. 12)

Such projects might involve the collection of environmental data, for example, of bird migration. Cowell and Watkins (2007) reported on a project that involved plants rather than animals. *Spring Bulbs for Schools*, a museum outreach programme, was set up in Wales in 2006. The project involved establishing 160 monitoring sites across the country. The project proved to be very successful as Cowell and Watkins report:

> Working with crocuses and daffodils made [participants] aware of the importance of bulbs in the life cycle of some plants. On a more general level, they become aware of the world around them and the idea that human activity can have noticeable effects, even on a local scale in the school garden. (2007, p. 27)

Again, the scheme demonstrated a range of environmental and science outcomes. The authors noted that 'the project enabled them to undertake pattern-seeking and observational activities—aspects of scientific enquiry that are often underdeveloped throughout the science curriculum' (p. 28). What might be a next step would be to focus on the health dimension of growing flowers outdoors.

One could argue that the curriculum should focus on the types of experiences that students should have during their schooling: museum visits, long-term experiments, visits to the countryside in all the seasons, visits to a farm, an opportunity to care for animals and plants over an extended period, visits to a hospital, time to discuss with scientists about what they do, etc. Such a curriculum might provide opportunities for children to have individual responses and personal outcomes rather than be pushed into the homogeneity of contemporary education.

7 Values and Controversy

A new science/environment/health curriculum, as described above, would necessarily involve teaching about values. Values are just one dimension of controversial issues such as growing GM crops or nuclear power. Traditionally, teachers have been recommended to adopt a neutral chair approach when teaching about controversial issue; however, Oulton et al. suggest that such an approach is unethical in that all pedagogic decisions would reflect the teachers' own position in some way and that it is better for them to be open about their position. Oulton et al. argue that teachers need to teach about controversial issues in such a way that the following points are made:

- Groups within society hold differing views about them.
- Groups base their views on either different sets of information or they interpret the same information in different ways.
- The interpretations may occur because of the different ways in which individuals or groups understand or 'see' the world (i.e. their worldview).
- Differing worldviews can occur because the individuals adhere to different value systems.
- Controversial issues cannot always be resolved by recourse to reason, logic or experiment.
- Controversial issues may be resolved as more information becomes available (2004, p. 420).

8 Theories of Learning

Underpinning the pedagogical approaches that would facilitate the new curriculum, there must be some theories of learning (Dillon 2003). Vosniadou's (2001) review of research provides a good starting point for a discussion of what we know about learning and thus allows us to see how it might be used to inform a new pedagogy to support a new curriculum and new assessment. Table 1 provides an overview of the key points:

Learning requires the active, constructive involvement of the learner.
Learning is primarily a social activity, and participation in the social life of the school is central for learning to occur.
People learn best when they participate in activities that are perceived to be useful in real life and are culturally relevant.

New knowledge is constructed on the basis of what is already understood and believed.
People learn by employing effective and flexible strategies that help them to understand, reason, memorise and solve problems.
Learners must know how to plan and monitor their learning, how to set their own learning goals and how to correct errors.
Sometimes, prior knowledge can stand in the way of learning something new. Students must learn how to solve internal inconsistencies and restructure existing conceptions when necessary.
Learning is better when material is organised around general principles and explanations, rather than when it is based on the memorisation of isolated facts and procedures.
Learning becomes more meaningful when the lessons are applied to real-life situations.
Learning is a complex cognitive activity that cannot be rushed. It requires considerable time and periods of practice to start building expertise in an area.
Children learn best when their individual differences are taken into consideration.
Learning is critically influenced by learner motivation. Teachers can help students become more motivated learners by their behaviour and the statements they make.

9 How Children Learn (Adapted from Vosniadou 2001)

Social constructivist theories of learning, based on the works of Piaget and Vygotsky in particular, would suggest that an effective pedagogy would involve the following characteristics:

1. Eliciting students' ideas about concepts and topics rather than assuming that they know nothing
2. The provision of concrete experiences supported by appropriate vocabulary so that learners become familiar with the subject matter
3. Choice of activities so that they feel in control of aspects of their learning
4. Cognitive challenge so that learners are presented with something which is challenging without being overwhelming
5. Plenty of time to discuss ideas with their peers and with adults
6. Feedback on their performance so that they know how to improve their work
7. Opportunities to practice operations so that they become confident in their skills
8. Time to engage with activities so that they have an opportunity to think about problems without feeling too pressured

As before, there are some teachers who might feel that the list above describes their existing pedagogy. If so, fine, it would show that it can be done within the constraints of current curriculum and assessment regimes. Nevertheless, for all teachers to be able to use this approach, it would require support in the form of pre-service and in-service training.

More radical approaches to earning are outlined by Wals and Dillon (forthcoming). They note that we can learn from nature itself about learning process and about sustainability. Ecosystems, they argue, provide evidence of resilience, and systems thinking allows us to examine how communities depend on each other to survive and to develop in the face of challenging circumstances.

They conclude that:

> Learning in the context of environment and sustainability then becomes a means for working towards a 'learning system' in which people learn *from* and *with* one another and collectively become more capable of withstanding setbacks and dealing with insecurity, complexity and risks. (Wals and Dillon, forthcoming)

Such a model of learning has substantial implications and would require a major shift in thinking about teaching students *how* to learn as individuals and groups rather than focusing on *what* they should learn.

10 Summary

The general sense of dissatisfaction with the existing science curriculum in many countries provides an opportunity to consider a radical reform based on Aikenhead's maxim that change must be based on 'educational soundness and relevancy' rather than political expediency (122–3). Gough's point that science and environmental education need each other and that there should be a new mutualism between the two disciples can be extended to include a third partner, health education.

The outcomes of the new curriculum should be diverse and more personalised and local than is currently the case. Students should be empowered rather than drilled to absorb information for the purpose of testing. In particular, students should develop an understanding of risk and probability and learn to appreciate the values implicit in a range of scientific, environmental and health issues.

Teachers need a pedagogy based on sound theories of learning and need to find out what students know, design activities to challenge students, provide opportunities for discussion and provide formative feedback. They will need to develop their skills and knowledge and they will need to be able to teach about values and about controversial issues openly.

There have been many calls for radical change to the way that the curriculum is organised. Now, however, the health and environmental challenges to society are of such a magnitude that we must rise to them otherwise we will be condemned to repeat the failures of the past.

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Creating Spaces for Rethinking School Science: Perspectives from Subjective and Social–Relational Ways of Knowing

Paul Hart

1 Introduction

In this chapter, I raise questions of possibility pertinent to (re)constructions of school science education. I begin by considering a question posed recently by Edgar Jenkins (2007) about whether school science itself is a "questionable construct" that ignores philosophical, conceptual, and methodological differences across the natural and social (or educational) sciences. My interest is in exploring ideas about what can count as school science in terms of how we come to know things and in putting those ideas to the test in relation to differences from fields such as environmental education. The overall aim of this chapter is to clarify and appraise the growth of dominant discourses at work in the practices of science education within broader questions of pedagogy from other forms of thought.

Through the discussion, I explore how perspectives from environmental education have worked to accommodate socioecological, political, and, more recently, cultural issues in ways that broaden conceptions of what can count as school science. I argue that these perspectives have potential to change thinking about how school subjects can deepen student engagement with meaning and understanding through construction of subjectivities. Implicit in this discussion is a change in how young people's engagement with school science can be reconceived within expanded notions of what counts as curriculum and pedagogy. Exploration of knowledge fields within environmental education is undertaken in an attempt to locate those discursive and material practices in terms of their fundamental assumptions about the role of identity construction in children's learning.

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Given the preeminence of science education as a privileged way of knowing within the dominant discourses of schooling, the introduction of ideas from environmental education, similar to ideas of wellness in health education, signifies a kind of critical frame change. Theoretically and pedagogically, serious consideration of how people learn implies changes from school science education heavily invested in rationalist–objectivist foundations to one that engages a range of personal sociocultural and political issues within a frame of multiple ways of knowing (see Jenkins 2007). This chapter considers whether the underlying post-foundational propositions from environmental education might provide guidance for critical reevaluation of what it means to do school science.

2 Science Education in Light of Environmental Education

Given the evolution of both science education and environmental education toward more accountable and globalized fields of education, questions of meaning have broadened in theory (e.g., Zembylas 2007), advocating more social and relational approaches, while becoming more constricted in practice. Less attention has been directed to processes of learning or to subjective capacities of learners to take and produce meaning (Hodson 1998b; Roth and Désautels 2002). In such cases, science provision has become more institutionalized, disregarding natural learning spaces beyond traditional classrooms. Policy demands of government have tended to override academic arguments for community spaces where meaning is less determinate and learning more embedded within the problems and issues of culture and environment. This theory–practice gap is the subtext of the arguments within environmental education for more critical approaches to pedagogy. There have been exceptions. For example, in the late 1960s or early 1970s, many science educators considered expanded notions of scientific literacy, informed by a science-technology-society(−environment) (STS(E) movement. Questions of disciplinary politics had rendered this field open to discourses and methodologies more attentive to the relevance and complexities of real world issues of society and environment. Yet during the 1990s, school science education, as an institution, retrenched itself in standards-based discourse.

Throughout these decades, given increasing public concern about environmental issues, voices from environmental education challenged dominant defining strategies of education (Buzzati-Traverso 1977; Fensham 1976; Robottom 1987, 1988). At the time, critical pedagogy was challenging education in terms of humanist accounts of subjectivity/agency.[1] A healthy skepticism toward education as reinscription

[1] Pinar et al.'s (1995) skepticism is in response to Kliebard's (1986) discussion of discourses on curriculum where "humanists" were characterized as guardians of an ancient tradition linked to the power of reason and elements of Western cultural heritage. This tradition is associated in American curriculum debates with "academic rationalists," a group quite distinct from the "reconceptualists" where, arguably, many critical environmental educators ground their curriculum theorizing (Apple 1975; Giroux 1981).

of dominant social values, called neoliberal, or humanist accounts of identity came into question (see Pinar et al. 1995). Impelled by social and environmental issues, such skepticism increasingly pressed on education systems for a different kind of accountability. Given the span of half a century, where dominant forms of education remain intact, questions are now being asked, within the texts of environmental education, about its actual impact on teaching and learning. Although critical and postmodern intellectual inquiry have intensified in the last twenty years, informed by multiple theoretical and methodological perspectives (that include gender, class, race, place, and environment/geography), questions remain about the impact of various social theories on schooling. In the face of a neoliberal/neoconservative agenda, in the interests of global competitiveness and corporate agendas, school systems remain preoccupied by forms of induction and arguments of rationally inscribed institutional practice. As Biesta (2006) indicates, it is naïve to think that education can locate itself outside ideology.

What is needed in such conditions is the construction of debates that can approach school science at the level of discourse that underpins institutional structure. Acknowledging past debates about such defining structures raises questions about what is different, this time. Several responses are possible, but post-humanist and post-foundational ideas related to discourses–practices that emphasize critical engagement with humanist modernity seem most promising (see Bonnett 2004; Stables and Scott 2001). These debates are part of a rigorous questioning of the defining structures underpinning current disciplines, including environmental education, defining structures that are evolving rather than fixed phenomena, and thus subject to disruption and discontinuity. There is evidence that such post-critical discussions in environmental education have been engaged recently, for example, in *Environmental Education Research 14*(3) and the *Canadian Journal of Environmental Education 15*, and in international seminars (Meyers et al. 2007; Russell et al. 2010). These discussions can be contextualized within broad educational discussions that emphasize the role of cultural studies in the understanding of science and education (see Biesta 2006).

With renewed focus on post-critical curriculum and pedagogical issues in both science education and environmental education, attention has been directed to those elements/dimensions of theory, as well as methodological and school experiences, which raise creative and imaginative questions. For example, when learning and teaching are not occluded by traditional categories, questions of unsustainable and unethical dimensions of human material culture that affect the environment become possible. Conceptual spaces become available for less individualist and more relational approaches to human subjectivity. However, what is not needed is another curriculum package—the product of superficial attempts at reforming science education practice. The cumulative evidence of several decades of dedicated work in retheorizing and repracticing has generated too many questions at fundamental levels concerning what has been accepted as natural or good enough science education and environmental education. Biesta's (1999) question about whether there is a way to think more reflexively about intersubjectivity is too important to ignore for environmental educators who, like Stables and Scott (2001), view post-humanism as a pragmatic corrective toward curricular reform. It is also important for those who wish to move toward deconstruction of dominant cultural narratives, that is, toward places where the (post)human subject can only be understood in relation to ecological systems. This chapter examines substantive arguments that provide counternarratives to "common sense" attitudes of education that work to maintain the status quo rather than engage in post-critical questioning of the biodynamics of the education–culture–environment complex.

3 Recognizing Science Education and Environmental Education as Knowledge Frames

In many ways, Australian educators such as Ian Robottom (1987), John Fien (1993), and Bob Stevenson (1987) laid the groundwork for these debates in the 1980s. Each raised questions about the legitimacy of certain frames of knowledge for education, as groundings for either science education or environmental education. Each took positions on knowledge construction in relation to pedagogy. Robottom, for example, proposed that if knowledge is viewed as historically located and socially constructed, then the tasks of school science can only be understood in relation to the meanings people use to make their actions intelligible within critical theory. It followed that human actions should be understood only in terms of the assumptions, beliefs, and purposes (i.e., the subjective meanings of people within the social/cultural context that make those meanings possible [see Carr and Kemmis 1983; Codd 1983; Popkewitz 1984]). So, from a critical perspective, it seems reasonable to question whether, in fact, school science knowledge has served particular interests. It is a position that must accommodate a level of uncertainty (i.e., an onto-epistemic insecurity) across disciplines that works toward interdisciplinary dimensions. The idea, reiterated by St. Pierre (2000) and McKenzie (2004), that choice is always relative to human interests implies a responsibility to articulate and justify contested positionings across boundaries or intersections that may decenter traditional subjects. While science educators such as Lemke (2000), Hughes (2000), and Hodson (1994, 1998a) have articulated socioscientific or sociocultural counternarratives, these have not penetrated the discursive structures of school science. Environmental educators with a background or interest in science education wonder why and whether they can extend the possibilities for what can be thought and taught in science education.

Calling for a critically engaged account of differences between traditional approaches to science education and environmental education, post-critical educators have questioned the way power works to position certain discourses as dominant, that is, how "official" knowledge as policy and practice prescribe what to teach, who and how, economically and efficiently, it should be done. This idea was taken up by Stevenson (1987, 2007) in terms of contradictions in the purposes and practices of schooling from the perspective of environmental education. Contrasting the socially critical and political action goals of environmental education, he questioned the uncritical role of schooling in reproducing rather than troubling existing social conditions. Like Fien (1993), he raised ideological conflicts within the environmental movement to illustrate how technical, political, and socially critical approaches either aligned with or contested historically dominant educational discourses. On the pretext that environmental education has always maintained the critical purpose of transforming values in support of extending personal and social ethics to include an environmental ethic, he pointed to contradictions between traditional purposes of schooling, including school science, and those critical purposes of environmental education that work toward social reconstruction through active student engagement and question how current models of schooling can be sustained socially as meaning-making processes in the face of global learning and technochange.

The value of Stevenson's (1987, 2007) contribution is that it refocuses school purposes on knowledge frames that recognize the onto-epistemological subtexts of these differences in purpose. Beyond objectivist conceptions of schooling lie subjective, socially constructed ways of knowing, less discrete and thus less easily measured or assessed. The imperfections of assessing human learning through participation/group learning in multiple contexts means changing teachers. And because teacher ideology is fundamental to pedagogical practice, teachers' understanding of their own epistemological positions is integral to changing teaching and learning. This means opening up the discourses of school science education for deeper scrutiny. These arguments involve breaking objectivist–subjectivist binaries. Fien's (1993, 2003) work positions environmental education as a form of critical curriculum theorizing that uncovers the values and ethics informing worldviews (i.e., as onto-epistemic in nature). As he says, the idea of a critical pedagogy is to engage students and teachers in forms of praxis, that is, in free and open discussions involving ideology critique and analysis of social interests.

Critical ecological pedagogy involves teachers and students in construction of social and environmental consciousness, involving critical and creative thinking and problem-solving skills, the consideration of values and ethics, and political literacy in democratic decision-making. This consciousness, actualized as critical praxis, involves a wide range of teaching–learning strategies—inquiry-based, action-based, community-oriented, values clarifying, ideology, critique, and critical reflection. Change is recognized, beginning in internal subjective thought and extending as social interactive processes capable of critical discourse analysis and ideology critique. Both teachers and students are active agents in debates about socially critical thought and actions. "Becoming critical" seems a crucial step for science educators whose site of study is set to move beyond existing conditions of, politics of, and interpretations of meaning that disciplinary subjects seem to convey for students who increasingly recognize themselves in an interdisciplinary world. The question for this chapter is whether an argument can be constructed for something beyond critical pedagogy where both discourse and the subject become crucial to rethinking school science.

4 Can Environmental Education Offer a Post-Critical Theory/ Pedagogy for Science Education?

Beyond conditions of difference that characterize an educational structure of contingent curriculum and knowledge formations, some crucial questions remain. In an overrationalized world of input–output measures contrasted with diminishing resources, threatening climate change and social injustices, how can different genres of meaning incubate and grow within institutional practices? The science educator, no less than the environmental educator, is situated at the edge of pedagogical difference. What is at issue is an onto-epistemological distinction between the dominant technical–rational and socially critical knowledge interests (Habermas 1971). To break away from the existing dominant model represents a psychological, hence subjective, struggle as well as a philosophical one. Acknowledging poststructural notions of multiple ways of knowing implicates educators' professional identities in more general educational debates about legitimate ways of constructing knowledge. For example, post-critical debates around issues of race, class, gender, and place have taken poststructural turns that have begun to test preconceptions of schooling in constructive ways. Somewhat parallel critiques of the objectivist epistemology of science education, as distinct from environmental education, have raised ethical concerns about the role of science education in society (e.g., Lock and Ratcliffe 1998).

Increasingly, it seems, science educators argue for a type of school science education that can increase public understanding of science as implicated in social and environmental issues (see Dillon and Gill 2001; Donnelly 2002; Jenkins 2003). Hodson (2003) characterizes a set of arguments that have led directly to an enhanced role for critical and social dimensions of learning (see also Corrigan et al. 2007; Désautels et al. 2002; Roth and Désautels 2002). These debates have raised issues concerning, for example, the educational value of fieldwork, informal and community-based learning, and engagement in sociocultural, political, and ethical issues-based activity. As Hodson (2003) says, science education has lost much of the innocence and purity afforded it by purveyors of the major American and British curriculum programs of the 1960s. Yet, ironically, according to (Aikenhead, G. 2010, Personal Communication), nothing has really changed in actual school practices. That contradictions between theory and practice continue to escalate suggests that more of the same kinds of change strategies is not good enough. This kind of reasoning begs questions of appropriation, in this case, from environmental education.

Environmental education and science education seem to me to meet across a paradigmatic divide, a gap involving different philosophies. We seem to have a "failure to communicate" across world(views) of difference—modernist and postmodern worldviews, ways of knowing, and genres of discourse. Whereas in the past, differences were mixed at the level of school practices alone, the argument here is for engagement of difference at levels of knowledge and learning where epistemological commitments can be articulated. There are no quick fixes where environment-related activities are simply incorporated within the master discourse of science education. Arguments must address the pragmatics of language in ways that acknowledge language not as a neutral medium but as one infused with intentionality. What matters most, given past experience, is to address philosophical as well as political difference in terms of who decides what counts as a legitimate voice in charting the future of science education.

Engagement with the philosophical–conceptual roots of issues and ideas, within socially critical environmental education, construed from a post-informed lens, challenges the privilege of objectivism through the privileging of its representation in the social field of education. Placed within such a scenario, science education is perceived as a formal process within a formal education system, both of which depend on some form of foundationalism. Taken to the extreme, this is a form of scientism that dismisses every alternative as relative and by implication, inferior. One is forced to choose sides by those in power who are unwilling to accept the costs of exploring the uncertainties inherent in schooling practices that involve exploration of complex social and environmental issues. The education system continues to favor a kind of school science education unwilling to accept the costs of skepticism of the norms and truth of science and the industrial "banking model" of education (Rogoff and Lave 1984). We see this, for example, in the debate between Zembylas (2008) and Schultz (2007) concerning the character and prospects of (post)modern science (education) that attempts to move beyond an either/or dichotomy of foundations and relativism.

It is beyond the scope of this chapter to engage purely philosophical arguments. My purpose here is to explore questions of legitimation from post-informed extensions of critical environmental education as challenges to school science education. In so doing, I focus on notions of discourse and subjectivity. My interest is how science education works as a cultural narrative nature of education to produce young people in certain ways. In other words, how can we look at what school science does to children's constructions of themselves within their social worlds? And, how can environmental education interrupt this taken-for-granted process? It seems to me that environmental education, in its post-critical form, introduces a different onto-epistemological frame to science education—a new discourse or worldview contemplated by only a few science educators (see Blades 1997, 2001; Roth and Désautels 2002; Weaver et al. 2001; Woolgar 1986, p. 312; Zembylas 2007, 2008), from constructionist (i.e., poststructural) rather than constructivist epistemological frames (Crotty 1998), that bring into sharper relief contradictions within the realist frame that characterizes traditional school science.[2]

[2] School science is used here because the onto-epistemological frames have widened within science education proper.

5 Exploring Multiple Epistemological Frames for Science Education

Gough (1994) credits poststructuralism for destabilizing privileged discourse by insisting that we read our own stories and those of others intertextually[3] in the production of meaning. He draws on narrative theory to ask questions about ways in which discourses of environmental education and science education (configured as stories) may be used to query the adequacy of the narrative strategies deployed in these fields. For example, in exploring stories of science education, he suggests that those who defend the practice and possibility of a politically disinterested science education recognize their silence as a political act that contributes to the reproduction of particular forms of power and authority in societies. He also suggests that the dominant storytelling practices of environmental education reflect what Sandra Harding calls the longing for the one true story that has been the psychic motor for Western science (Harding 1986). The point is to think differently about science education so that the stories which assimilate language to the complexities of local cultures, as contextualized transactions, bridge subject and object worlds by signifying values that make our storied understandings possible (see also Corrigan et al. 2007).

A science education devoid of such storied forms of knowing lacks the ability to cause young people to think about their position/subjectivity in the world. I see here the basis of an argument for science education inclusive of the narrative form advocated by a socially informed environmental education (see, e.g., *Canadian Journal of Environmental Education, 7*(1, 2), *13, 14*). This is a science education more inclusive of subjective stories, as in Aboriginal construals of science education (Aikenhead 2006; Aikenhead and Michell 2011), so that we can see through to the moral/values/ethical imperatives needed beyond necessarily objective scientific knowledge. These conceptions of self and subjectivity acknowledge the legitimacy of multiple ways of knowing that accompany narrative construction of things. This work involves both cultural critique and reconstruction so that dominant viewpoints can be exposed as cultural constructions of particular kinds. Thus, we need to remain alert to the range of culturally constructed sites within which teachers' and learners' subjectivities reside (Gough 1994).

From such grounding in narrative thought, it can be argued that a fundamental problem in school science is onto-epistemic and that its traditional grounding within a realist perspective works to create boundaries around concepts and to separate epistemological, ontological, and sociopolitical issues of theory and practice. Such reasoning also works to construct arbitrary lines as binaries between learning as individualist (as in learning *about* the nature of science) and learning as social/relational (as in *looking at* the nature of learning science). Traditional framings of

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[3] Employing the term "text" (as in intertextually) acknowledges that the field of curriculum is composed of various discourses and suggests issues involved in understanding science education curriculum and pedagogy that have been ignored prior to post-critical or poststructural mappings of the field. Thus, textualist mappings of science education have links to poststructuralism.

school science make it difficult for science teachers and educators to "hear" arguments about the intimate relationship between cultural narrative and action (see Zembylas 2008). A multiple-storied view does not prohibit such distinctions but attempts to create conditions that enable teachers and students to gain better insight into how and why we may choose to do certain things and not others in school science. As St. Pierre (2000) says, such a nonfoundationalist view does not lead to "anything goes." Rather, science-based knowledge is addressed historically and contextually as something known, but we are also aware of the ways or schemes through which we have come to know, as well as what can be known, within the discursive framings of a subject area such as school science education.

School science is quite simply not much aware of research and theory in science education or active debates about major issues of position, direction, and practice. University-based science educators have initiated or interacted with curriculum-based initiatives since the major disruptions involved in the STS(E) curriculum. Reports such as *Beyond 2000* (Millar and Osborne 1998), *Benchmarks* (AAAS 1993), Pan-Canadian (CMEC 1997), and many other national and international initiatives from outside and inside science education on a variety of issues ranging from New Literacy Studies (e.g., Fendler and Tuckey 2006; Rivard and Straw 2000) to cultural psychology (e.g., Bruner 1991) have generated thoughtful, constructively critical propositions that within the last decade have been taken up in the science education research literature. For example, science education theorists such as Shamos (1995), Jenkins (2002), Aikenhead (2006), Fensham (this volume) along with Millar and Osborne (1998), and Bybee (this volume) have provided thoughtful bases for change in school science. Challenges to most school subjects such as social studies, language arts, and early childhood education have also been influenced by counternarratives from critical and post-critical, feminist, and cultural studies. Yet the theory–practice gap persists.

Environmental education, like "wellness" in health education, as a counternarrative to school science, in particular, has been subsumed by dominant institutional discourses. While many science educators within the academy have tended to regard environmental education as something of a curiosity or "little added frill" (see Hart 2010), post-critical thinkers such as Roth and Désautels (2004) have argued for more fundamental change toward a worldview or onto-epistemic position familiar to many environmental educators. Rhetorical similarities between many new proposals for science education—a scientific literacy more broadly conceived as politicizing the science curriculum—and environmental education notwithstanding, the fact remains, according to Hodson (2003), that teachers are not educated to understand how dominant social values are already embedded within a supposedly neutral curriculum of "objectivist" science. Avoidance of sociopolitical issue investigation with the science class already involves taking a value position. Adopting such a position mistakes the very purpose of the science component of public education as education for sustaining existing inequalities within society rather than equipping young people to view society in ways that can lead to critical change toward a more socially just democracy and more ecologically sustainable lifestyles. Naming and grounding these rhetorical similarities, in terms of post-critical influences for educational research across many subject areas as well as new learning theory and cultural and discursive psychology, seem a worthy next step in the evolution of science education.

David Blades (2008) characterizes the various positionings of recent science education writings across a spectrum that considers the restructuring of school science education in terms of an incommensurability of aims. This is not surprising given the diversity of philosophies that constitute the academic field of education. What may be surprising is the consistent challenge to rational–objectivist foundations of school science education that have their origins in the critical theory that spawned environmental education. According to Fendler and Tuckey (2006), new literacy studies applied to science education, such as the discursive production of knowledge (whether science-based or sociopolitical), have already influenced both science education as well as environmental education (also evolving as a field). Applications of action-based inquiry from environmental education (see Barrett et al. 2005; Posch et al. 2006) or dialogic inquiry from science education (see Roth and Duit 2003; Wells 2000) exemplify sociocultural learning practices in action. Such applications have implications for reconsidering not only curriculum but the pedagogy of school science. However, such reconsideration is now also cognizant of teachers' subjective construction of their craft. In other words, problems that appear intractable at the level of school science (i.e., barriers to change) are more likely to originate subjectively "in here," that is, inside our heads, as intertextual (i.e., failure to acknowledge multiple ways of knowing), than out there (as curriculum, institutional issues) (see Hart 2010).

It is often seen as enough for teachers to stand and deliver prescribed science curriculum without ever understanding how it works constitutively and discursively along with pedagogy to produce subjects (i.e., the construction of a particular view of reality). If one asks, as feminist poststructuralist scholars do, how any given mode of education, applied pedagogically in particular ways, acts to create learning, responses are often instrumental, assuming that tests can measure what was really learned. If the same question is posed differently (i.e., from a social–relational rather than rational–objectivist frame), its primary interest may be how students have come to construct themselves in relation to the subject matter or more broadly in relation to society or environment. Both the method of "assessment," given the different "interest," and the expected result change. What have they learned becomes what have they "really learned"—in relation, beyond the measurable content. So the evaluation of learning must change in complex ways that implicate qualitative methods of inquiry as well as teacher (re)education.

6 School Science and Teacher Education

If it seems reasonable to think of learning science in terms of internal constructions of ideas, that is, the ability to think about social problems involving "scientific" concepts, then the curriculum and pedagogy advocated by post-critical environmental educators and reconceptualist scholars warrant serious debate in the preparation of teachers. What science teachers decide to count as pedagogically appropriate depends on their particular view of educational discourse, including science education, and of science. Thus, reconstruing science teacher education to focus, for example, on the discursive production of scientific knowledge affects the meaning of school science in at least three ways. First, discursive constructions of science knowledge can have epistemological consequences where science facts and concepts cannot be abstracted from their socioscientific base in the real world. Second, a discursive approach to science implicates a discovery–inquiry base. Third, such approaches alter what can count as pedagogy. Considering the importance of written discourse in the field of science as well as new learning theory, one can see how changing the frame within science education can balance the focus of relational and literacy work in school science. Of course, many other examples of revisioning school science aimed at new dimensions of scientific literacy may be found in the literature. The point of critically examining how exactly science teacher education is framed seems crucial to extending possibilities of what can be thought, studied, or imagined in the name of science education (Fendler and Tuckey 2006).

Continues to argue, from the onto-epistemic position of relational and narrative ways of knowing, that the focus in education must change. Rather than being passive consumers of knowledge, teachers as learners must become more aware of how they are actively co-constructing not only a sense of self in young people but also the culture in which they live (p. 324). Not only must we learn as teachers how not to be completely taken over by an existing cultural field such as school science education, we must learn how to become critically aware of the objective and subjective structures that are at work to orient our thought in certain directions. For example, if science is the frame, then how is it being used within particular educational settings to position subjects? How are prospective science teachers being socialized as scientists and as science teachers? One way to explore these questions is to incorporate critically reflexive processes within science teacher education in ways that can help us make sense of the taken-for-granted ways that discursive fields subtly condition us. This line of thinking leads to questions about how learners learn to construct their critical sense of self-awareness and how they can more consciously construct themselves within discourses such as science or science education.

Environmental educators have long asked how education systems have evolved into spaces that obviate the necessity to engage with questions of how intersections of curriculum and science are actively lived by the students (and teachers). The post-critical interest here is in understanding ways in which young people are produced by the cultural narratives and discourses that position them within social worlds of school science. For example, within the current institution of school, science operates as particular discourses/practices, such as those concerning what counts as science literacy. For example, how do students come to construct themselves as scientifically or environmentally literate? How can we, as science teachers, learn how to work back from this to critically examine how school science discourses actually function in the construction of students' ideas and about science but also about themselves in relation to science or to the environment (i.e., as a process of subjectification)? And how important do we think that it is to do this? Using ideas related to young children's construction of their gendered identities, Bronwyn Davies (2003, 2006) illustrates how this process requires an understanding of both discursive constitution and those ways in which relations between possible positionings may be worked through in complex and contradictory constructions of agency. This pedagogical focus may then serve as an intersection where differently trained teachers/researchers can begin to uncover (using qualitative narrative inquiry methods) at least some of the cultural narratives/discourses operating within educational systems such as "the science class."

This post-critical line of thought underpins pragmatic questions such as "What am I to do?" Gough's (1994) response involved "exploring stories" of a range of people, including those defending a politically disinterested science education. It seems a useful part of teacher education for teachers to consider their philosophies/perspectives/discourses as configured as stories that signify values that in turn make understandings meaningful as subject positions, even as partial and contradictory (Hart 2003). As Gough (1994, p. 201) says, "I am confident that comparative readings of our own and others' stories is a sound pedagogical strategy for seeking such wisdom closer to home." Finding ways for prospective teachers to articulate their stories may be as onto-epistemologically potent as any other "official" language in rendering meanings from their university-based immersion in science and science education. And because stories may be our only way of getting to conceptions of self and subjectivity, they can provide useful autobiographical about "what to do" that makes subjectification work useful as a means of transforming thinking about what counts within science education. Cheney's (1989) early work in postmodernist reconceptualization of identity as a relational construct involved developing pedagogical strategies for learning that incorporated ideas of subjectification. This idea of coming to know oneself within the "landscapes" or discourses, deconstructively, as cultural constructions engaged a range of culturally constructed sites where subjectivities/identities could arise. The idea of including landscapes as well as networks of messages and signs that constitute our environment as a universe of communication recognizes those young people who live inside technology (i.e., a world of simulacra) as those who know the most about postmodernism. Perhaps these ideas will change the focus of teacher education.

7 The Relevance of Subjectification as a Change Strategy

In the remaining section of this chapter, I explore the potential of "identity work" (i.e., subjectification) in challenging a kind of alchemy (see Popkewitz 2002) which occurs when science subject matter "takes on" the discursive and material hegemony of schooling, that is, where modernist discourse frames thinking and practice. I focus on extending discussions of the discursive production of knowledge to question what is really happening to young people as they are produced by the education system. Following Probyn (2003), I use the term subjectivity, and rarely identity, in relating to the relationship between subject and discourse in the performance of selves. Notions of processes of subjectification disrupt traditional psychological views of identity as unitary, as well as assumptions of the autonomous individual who has varying degrees of freedom to choose what to do and what kind of person to be. In fact, Wetherell's (1998) premise is that identities are in part conferred through positioning and in part actively constructed, contested, and negotiated. My particular interest is in how subjectification works in teachers' and students' construction of science identity and ecological agency that may provide direction for thinking and pedagogy in science education and environmental education. It seems to me that narrative can work as a discursive resource in this process through which the accomplishment of science education teaching makes both literacy and agency possible.

Recognition that subjectivities of young people are in part created within discourses of education seems a first step in acknowledging that the way we experience subjectivities is an important critical pedagogical consideration. Understanding how subjectification occurs within the context of immediate social/interactional processes and how it derives from meanings which prevail in wider social, cultural, and historical contexts, as discursive resources for positioning subjects, is part of this thinking. If subject positions can be understood as temporary-formative identity, then how subjectivity/identity is conferred in school science education is fundamental to learning. Such identity work, as taken up by students of science and environment, becomes part of who these young people want to be, and to be seen to be by others, and creates perspectives from which they view the world (i.e., part of an onto-epistemic position [Davies and Harré 1990; Taylor 2006]).

Exactly how this happens or could happen has not been a focus within education or teaching. Given the power of this hidden critical pedagogical dimension as a site for the production of knowledge, feelings, and emotions, it seems important to learn to sense how we are subjected to the practices of different discourses (or ideologies, see Probyn 2003). Within the education experiences provided for us, critical environmental educators argue that to see them operating can provide a basis for learning how to work in willful contradiction of them (see Britzman 2000; McKenzie 2004).

In Judith Butler's conceptual work, undertaken to extend Foucauldian notions of subjectification, she focused our thinking on understandings of students as they experienced their school provision (Davies 2006). As Davies (2006) says, Butler's subjects have agency, although conditioned, within "which they can reflexively and critically examine their conditions of possibility and both subvert and eclipse the powers that act on them" (p. 426). This work aligns with forms of environmental education that, since the 1980s, have articulated a critical pedagogy with emancipatory potential. Science educators generally seem to have come more recently to the realization that the constituted character of the subject is the very precondition of its agency, rather than to claim it as determined. As Butler (1995) says, "… what is it that enables a purposive and significant reconfiguration of cultural and political relations if not a relation that can be turned against itself …?" (p. 46). The point is that science education can and should provide experiences (i.e., active practices) through which these (un)determined subjects might be said to construct themselves. In recognizing the context of these narratives within culture generally, translated within the discourses of school subjects such as science, attention is refocused from psychologies of the students themselves to the operating discursive structures of school science that are in need of reconstruction. This shift in focus, long recognized in environmental education, is now articulated as a transition from critical to post-critical thought. Rather than changing students, we work to change the discourses. It is this shift that I think has been largely absent from science education discourse in search of ways to change school science.

There have been many recent attempts to understand what is happening to us as we are shaped by certain kinds of discourses–practices. Probyn (2003) found examples in the performance of particular roles of gender, class, and race (e.g., in the historical weight of ideology surrounding heterosexuality), where getting beyond gender distinctions in geography and cultural history was a long, slow process. Pile and Thrift's (1995) work with actor network theory focused in the relational nature of communities of practice as part of a "forest" of literature emphasizing poststructural issues of structure–agency involving questions of just how free people were to choose their own paths. Their focus on power relations as we move away from notions of a coherent stable self toward ideas of emplaced, embodied multiple, mobile subjectivities speaks to why people may either embrace or resist student involvement in public/community activism (i.e., the politics of sociocultural issues). Roth (2007), among others in science education, has extended these ideas as cultural–historical activity theory (CHAT) which was developed to incorporate emotional, motivational, and identity-related aspects of everyday human praxis into dimensions of activity systems such as school science education.

The idea, in each of these cases, was to conceptualize identity within the discursive processes of subjectification. Science education experiences served as nodes or meeting points where students' relation to discourses happened. Such refocusing permits questions about how the school classroom enables, resists, or denies access to certain roles and performances and how students and teachers construe themselves in relation to their learning experiences (Barrett et al. 2005). We can ask paradoxically why young people are learning to hate school science conveyed by caring, responsible teachers who see themselves as positive role models delivering prescribed curricula. We can begin to explore how each of us is "hailed" by different discursive structures and how we establish our boundaries as positions with respect to various discourses. As Walkerdine (1995) puts it, subjects are created as multiple positionings within material and discursive practices. So, we need to know more about our relative positioning, to be more conscious of how we may actively learn how we can choose to (re)position, and to learn to deconstruct the boundaries, say, between culture and nature (e.g., Haraway 1991; Whatmore 1999) or between nonhuman and human culture (Fendler and Tuckey 2006; Russell 2005).

8 A "Missing-in-Action" Dimension in School Science Education: "Social" Knowing and Learning

In a special issue of the *International Journal of Educational Research* focused on the role of discourse in the construction of identity, Wells (2007) questions how and why people differentially construct their identities and the values that mediate their participation in society. Those working in the areas of cultural psychology (e.g., Rogoff 2003), social constructionism (e.g., Gergen 1985), discourse analysis (e.g., Wetherell and Potter 1992), discursive psychology (Edley 2001; Edwards and Potter 1992), and narrative analysis (Bruner 1990, 1991) who view understandings of ourselves and others as an artifact of communal exchange are finding ways to respond to such questions. Having put aside conventional assumptions of mainstream research that observable aspects of a person are transparently obvious of something "inside," these approaches are more interested in how people come to position themselves in terms of meanings they derive from society and culture—those discursive styles or routines taken up as a consequence of the young person's various discursive apprenticeships (Taylor 2006).

Gutiérrez et al. (2009) provide a framework for learning through "learning ecologies" of sociocritical literacies. The educational process is one of redesigning contexts for learning through remediation activity that includes contexts of criticism, discovery and application of given context across both vertical and horizontal forms of learning (see also Gutiérrez and Rogoff 2003). Rogoff (2003) sees this process as a complex of interpersonal, social, cultural, and discursive relations where teachers' intentions (as well as actions) must be accounted for in terms of their influences in students' trajectories of subjectification. In other words, how do the activities of school come to take the forms they do as both institutional/curriculum discourses and as teachers' pedagogical compliances or resistances? If learning can be (re) conceptualized as a process of subjectification, then understanding more about how we approach learning experiences is crucial to whom we want students to become. How young people come to "know" can then be viewed as relations among communities of praxis, participation in practice generative of identities (Lave 1996).

The notion of knowing and learning as "social" relational processes further directs attention to the social crafting of identities/subjectivities as an epistemological position that grounds both narrative discursive inquiry and constructivist pedagogy. For example, Roth (2007) examines the close relationship between identity and participation/action as a process that mediates the nature of who a person is. He describes a school science education, more broadly conceived to accommodate identity work, in direct relation to students' sense of ethico-moral decisions. Science education, he says, ought to create conditions and provide students with the resources to work in community (and the world) as responsible and responsive citizens (see also Roth and Désautels 2004). These activities/experiences are different from typical science class experiences, given their social motive and participation in the collective needs of communities. Roth (2007) focuses on environment-related school activities (e.g., creek revitalization) as concrete examples of students' making sense of their actions within ongoing social/environmental activity. This sensemaking is part of their identity building as community members who have agency and who learn how to look at their work and themselves more (self)consciously. It is in the relational connections between one's self and others that constitute agentive, subjective, and cultural beings within communities of practice that, in the post-critical sense of pedagogy, help to override the cultural–historical hegemony of standard educational practice and generate imagination and possibility.

Fendler and Tuckey (2006) exemplify post-critical thinking in relation to the argument that science education is inextricably related to language and emphasizes the contingencies of social interactions in knowledge production. We now know, from structuralist and sociolinguistic analyses, how much our ability to learn to use (science) language (i.e., concepts) hinges on engagements in complex social interactions. Thus, teachers would do well to both rethink one of the dominant myths in science education—that objective science is the most appropriate approach for school science—and refocus their activities on the interactive relational production of scientific knowledge. This view of complex reengagement in school science, supported by other research (O'Neill and Polman 2004; Roth and Duit 2003; Yore et al. 2004), shows, for example, how the learning of physics resembles the learning of language. And this kind of research on the value of "social" learning continues to expand our understandings about how students are learning to use communication strategies as "learning to learn."

It is interesting for environmental educators to read lately about how participatory and conversation-based approaches are implicated in teaching and learning science ideas central to thought in environment and education since the 1960s. For example, recent arguments from within the traditional paradigm of science education, such as Fendler and Tuckey's (2006), challenge the dominant science education discourse. They represent evidence, within science education research, that "contextualization" of knowledge makes science concepts accessible to more people. The idea that certain arguments suddenly have legitimacy coming from research in science education is both ironic and even paradoxical, given their history in outdoor and environmental education research. As Fendler and Tuckey (2006) say, current debates within science education about what constitutes scientific literacy have not only shaken conventional beliefs about learning and pedagogy, they have been long argued in other fields such as troubling long-standing notions of ways it is possible to think about and to perform science in schools. It would seem that serious epistemological as well as pedagogical issues have purchased for further inquiry.

9 A Final Caution About Becoming Critically Aware

For several decades, critically minded environmental educators have argued that education should go beyond exploration of realities constructed by particular individuals and groups to look at questions of how and why reality comes to be constructed in particular ways. Many science educators have also come to support approaches that are critical and participatory in seeking out how self-interests have shaped our social/environmental predicaments as well as the educational processes that foster complacency and do not challenge the status quo. Just as Greenwood (2008), McKenzie (2008), and Kahn and Lewis (2010) have challenged environmental education provision that has not engaged elements of critical pedagogy, so Roth, Désautels, Blades, and an increasing number of science educators challenge science education. These challenges are a natural part of becoming critical. Winch (2004) argues that because late modern societies depend on a critically minded population for democratic processing of competing interests, the demand on the education system is to create conditions for young people to develop some facility for critique. The problem, he recognizes, is familiar within both science education and environmental education as it is within general education systems that advocate education for sustainable development (ESD) approaches as more broadly focused than environmental education. This is the tension and uncertainty that arise from the requirement of critique. As Winch (2004) says, attempts to delimit critique to considerations of only what is worthwhile are bound to be futile, and yet this is precisely what neoliberal versions of ESD and environmental education want education to do. So there remains, within environmental education, and, I would argue, future research and pedagogical debates within science education, this problem of reconciling preparation for social participation, and perhaps forms of activism, within traditional education.

Post-critical pedagogies now openly question the ideological/discursive role of cultural institutions in the formation of the subject (i.e., the subjectification process), how one has been constituted, how one's worldview has been constructed, and thus how one can become critical and retain the capability to break free. It is such pedagogy that has focused awareness on the cultural politics of educational discourse, that is, on what it is actually doing to young people—intellectually and emotionally. Environmental education, when construed as critically informed pedagogy, directs our gaze toward power within the science education discourse as a particular way of constructing identity/agency through use of discourse. This perspective goes beyond "becoming critical" in the sense that we learn how to raise questions about the means (i.e., pedagogical processes) in terms of the ends. That is, we become more aware of how we learn to make sense of our experiences within particular institutions as representing social culture.

Once we learn to question how this power occurs, we can begin to look at how particular means and ends of subjects (as forms of representation) legitimize and privilege certain forms of knowledge (e.g., propositional over practical/experiential/relational/social). This is another way of reconceptualizing what critical forms of environmental education have been suggesting, according to Stevenson (1987, 2007) for half a century. The difference now is that we have the conceptual language from poststructural and Foucauldian forms of critical discursive analysis as resources for critique. This difference is translated as qualitative forms in research methodology and post-critical awareness of the meaning of our school practice. The argument may sound the same, but the methodological basis in onto-epistemology is different.

This is where various pedagogical strategies, some derived from qualitative methodologies and methods, such as autobiography, autoethnography, and hermeneutic phenomenology as narrative discursive work, become useful. Such forms can help us look back in critical awareness of, say, our experience in school physics, using the physics text as representation (see Nolan 2007), through ironic inversion or parody, to bring us to critical confrontation with the discourse of physical science as represented in those texts and experiences. Such parodic or ironic discursive work can help us learn how to question the nature and formation of those traditional ways of doing physics (i.e., critical discourse analysis) as well as what they have done for/to us (i.e., our subjectivities). If science curriculum is broadened to incorporate practical experiential (as well as propositional) ways of knowing, then pedagogy and research into pedagogy are poised to engage more complex and critical forms of inquiry. Such inquiry can incorporate new views of learning that ground the reconceptualization of science experiences, more inclusive of diverse perspectives and more imaginative of difference in subjectivities of the self, within multiple narratives of science and environment (or ESD).

10 Conclusion: What Counts as School Science Education?

In school science venues, the performing and engagement of critically informed thought and pedagogy is crucial if post-critical ideas from environmental education are to be properly inscribed within the politics of science education. It could be argued that every educational experience frames the "outcome" for the young person in terms of values, understandings, and identity/agency. Applying certain criteria or rules of engagement can legitimate or delegitimate any knowledge form; thus, judgments of worth must be appropriate to the knowledge form, whether propositional, interpretive/hermeneutic, practical/experiential, or relational.

Questions of quality reside within genres of discursive meaning. How do we assess meaning in learning across genres of discourse? What kinds of conditions come into play in determining how science education is able to create meaning in particular ways? These questions cannot be assumed in school science that affects the meaningfulness of experience in young people's subjective minds. "Creating conditions" must be recognized as a political process where discourses of education become discourses of identity and subjectivity (as a process of subjectification). So, it is as important to attend to such discursive processes of production as it is to curriculum and learning processes.

Environmental education may provide a useful starting point because the field has always questioned the legitimating processes of science education as a privileged idea of propositional knowledge structures embedded within the industrialized discourses of education. Critical pedagogues have questioned this privileging but have failed to penetrate the dominant social paradigm (Fien 1993). There are, however, signs, as this chapter indicates, that a different kind of change may yet be possible. Overlying this image of change are questions from the environment where assumptions of Western individualism and capitalism with inalienable rights may replay themselves outside the dominant social and educational paradigms. Taken-for-granted notions about the constitution of human identities have, until recent decades, evaded critical capture. Today, post-critical and poststructural disruptions work to fold these images back on themselves as figurations of representation that heighten political awareness of how certain myths, sacred stories, and "rules" have been construed and legitimated. It can now be seen that science, through school science education, creates subjectivities as much as it does objectivities.

Unmasking the privileging of certainty within science education raises questions of onto-epistemological positioning fundamental to the work of school science within the education system. Working through critical and poststructural perspectives that are skeptical of privileging of any kind has generated increasing awareness of the philosophical politics of educational theory, translated in methodological ways of analyzing policy and practice. Perhaps foreshadowed by the critical politics of environmental education, such awareness creates openings for political structures, more methodologically capable of examining discursive practices, that have resonance with multiple ways of knowing. Resistances to this kind of activity notwithstanding, critical conversations in the study of science education have become available in forums such as the conference that has generated this book. If we can accept that sites of contestation over theory, research accountability, curriculum, and pedagogy remain as a part of a robust, critical, intersubjective relationship, then we may be able to comprehend possibilities less restricted by tradition and more concerned about asking better questions at all of the levels of school science discourse.

We are learning how to understand educational activity from individual, societal, and cultural perspectives using methods and methodologies more attuned to complexity theory than causal–comparative analyses of discrete factors. The subjective, intersubjective, intertextual, and narrative–discursive aspects of educational activity within global technology-driven contexts demand a kind of science education (and environmental education) capable of offering meaningful accounts of subjective learning in traditional school contexts. Simplistic tweaking of the science curricula no longer satisfies critically minded researcher–practitioners who actively interrogate the spaces of current conceptualizations of teacher and student and school (science). Working from a range of post-critical perspectives, many science educators are broadening the focus of inquiry at both ends of the cultural–personal, examining culture, power, and ideology as processes of subjectification. They are tracing beyond earlier inquiries into significant life experience by interrogating discursive spaces/places where identities are being continuously reconstituted in ongoing processes of "becoming" (Deleuze and Guattari 1987).

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General and Environmental Health as the Context for Science Education

Alla Keselman, Savreen Hundal, and Catherine Arnott Smith

1 Background and Assumptions

The conviction that science education can benefit all learners, regardless of their future occupations, dates to the late nineteenth century. While many things have changed over the past 100+ years, including the beliefs about the specific benefits of science education, the idea of "science for all" has persisted, under different names. Scientists who advocated for the inclusion of science education in the school curriculum in the late 1800s believed that science trained students in rigorous intellectual thinking. In the twentieth century, the emphasis of the discourse shifted from abstract habits of mind to the more concrete benefits of teaching science to nonscientists, which can be divided into three broad categories (for extensive treatment of the subject, see DeBoer 2000). The first category includes views that emerged in the USA in the 1950s, fostered by rapidly accelerating technological progress and Cold War era concerns about national security. The Rockefeller Brothers Fund report on the state of education in the USA, issued in 1958, noted an urgent national need not only for highly trained scientists but also for the general public that was literate in science. From this perspective, the public was cast in a supporting role, understanding science and its importance well enough to be supportive of the scientists' pursuits. The 1950s gave rise to the term "scientific literacy" (Hurd 1958; Rockefeller Brothers Fund, 1958), which initially emerged simply as a phrase denoting the public's need to better understand science. The cornerstone of the scientific agenda of the 1950s and 1960s was space exploration, and science curricula of the era focused on the grandeur of the abstract models, without many obvious links to students' daily lives.

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Educational leaders of the 1970s and 1980s brought forward a new view of the relationship between science education and citizenship. Like their predecessors, they viewed science education as key to informed citizenship, but the nature of that citizenship became much more clearly defined. The role of the public was no longer limited to generalized support. Instead, scientific knowledge was expected to culminate in social action, with the public uniting in groups, analyzing issues, making decisions, and influencing policies (Ramsey 1989). The discourse was framed in terms of the science–technology–society connection, and the curricula focused on linking scientific knowledge to societal concerns. In the 1990s, the belief that scientific literacy is essential for informed citizenship remained strong. It also acquired a new sense of urgency, related to the global problems faced by the human race moving into the twenty-first century (Fensham 1988).

The third category of arguments for teaching science to all students has to do with science knowledge as it is applied to daily lives of individuals. The US *National Science Education Standards* (National Research Council in 1996) make five assumptions justifying the need for scientific literacy for all. One of these assumptions is that "everyone needs to use scientific information to make choices that arise every day" (p. 1). This belief about the relevance of science knowledge to daily tasks and activities is not new and can be traced to the beginning of the twentieth century (Committee for the Reorganization of Secondary Education 1920). Shen (1975) calls scientific literacy that is exercised in such daily tasks "practical science literacy."

The "daily life applicability" argument for teaching science to future nonscientists has been criticized as a prescriptive assumption, not validated by empirical research. Feinstein (2010) points out that "the triumphal progress of science literacy has for the most part taken place in an empirical vacuum" (page 2). According to Feinstein, most research pointing to deficits in the public's scientific knowledge starts out with the *assumption* that the scientific knowledge that people do not have—for example, why seasons change—is useful outside school. He proposes that in order to decide what the science curriculum for all students should look like, we need to focus on how science literacy manifests itself in daily life. Research on the uses of scientific knowledge in daily life comes from a range of fields, so its implications for science education are difficult to summarize in a brief statement. Research on health literacy, which is reviewed at greater length further in this chapter, suggests that better understanding of health and disease is associated with better health outcomes for patients (Schillinger et al. 2002). In contrast with this, studies of "everyday science" suggest that individuals rarely find science a useful framework for their everyday concerns (Layton et al. 1993). This is true even when those concerns involve issues with a scientific component, such as caring for children with Down syndrome or planning heating budgets.

This chapter is written with the assumption that science education for all students should reveal how science manifests itself in daily life and provide knowledge and skills for making that daily life better. Our assumption has two components, one philosophical and one empirical. Philosophically, we believe that while there are multiple benefits to learning science, many of these benefits are not obvious to children. Fensham (2009) describes students' waning interest in science as a great contemporary problem, common to many countries, including those that perform near the top of comparative international science tests. To succeed in learning science, students need motivation, and few things motivate as well as personal relevance. Empirically, we have been engaged in a research agenda, successfully linking scientific knowledge and science education to better reasoning about nonclassroom situation (reviewed below). We also believe that in an era when global warming and related environmental policies are becoming top international concerns, it is essential that science education produces citizens who are capable of intelligent engagement with these concerns.

To move beyond these general assumptions to educational implications, we need to resolve three things. (a) The first is identifying scientific domains that allow an easy connection to real-life issues and find a place for them in the current curriculum. (b) The second is showing that scientific knowledge in those domains indeed affects real-world behavior. If we are after curriculum change, the burden of proof is on us. (c) The third is identifying instructional methods that are likely to foster real-life application.

We propose that when it comes to the content domains for teaching science, health, including environmental health, has many possibilities for connecting the scientific, the personal, and the social. Regardless of their professional occupation, all people have to deal with health information, either as patients or as consumers. We make decisions about vaccinating our children, try to protect ourselves against colds and heart disease, and choose diet and exercise regimens, and our understanding of the underlying biology may support or hinder the making of those decisions. While environmental health decision-making may be less prevalent, human influence on the environment and the resulting negative impact on human health is a rapidly growing global concern. Understanding the relationship between environmental issues, such as water and air pollution, climate change, and chemicals in household products and food on the one hand and health and disease on the other is essential for responsible social action.

The rest of the chapter will do the following:

1. Review some existing US science education curricula for the presence of general and environmental health connections, as well as available room for introducing them.
2. Present evidence that lack of scientific knowledge is related to problems with health behaviors outside schools.
3. Review concepts that are related to the ability to apply scientific knowledge in informal settings and give examples of educational interventions where this has been accomplished.

2 General and Environmental Health in the US Curriculum

In the United States, science curriculum is determined on the regional level, with the specific content and order of presentation varying among states and counties. However, regional standards are usually based on state standards, which, in turn, are grounded in the 1996 US *National Science Education Standards.* Health is taught as a separate school subject, independent of science. Health curricula are also determined locally, and there is no national health curriculum. The emphasis of health education is on basic factual knowledge about health issues that are relevant to children and adolescents (e.g., healthy nutrition, dangers of smoking and alcohol), risks and prevention, decision-making, self-efficacy, and communication skills. Biology, on the other hand, focuses on complex mechanisms, such as cell division and molecular transport across membranes, and often not in the context of human organisms. Ensuring deep understanding of the underlying biological concepts is beyond the scope of health classes, and health classes are not coordinated with biology. Individual schools may emphasize interdisciplinary efforts among teachers of different subjects and thus encourage each grade-level team to work together on finding connections. This, however, is not common.

In Montgomery County in the State of Maryland, location of the National Institutes of Health, which we will use as an example, health concepts currently taught in grades 6–8 are divided into seven broad categories: (1) mental and emotional health; (2) alcohol, tobacco, and other drugs; (3) personal and consumer health; (4) family life and human sexuality; (5) safety and injury prevention; (6) nutrition and fitness; and (7) disease prevention and control (Montgomery County Public Schools, n.d.). Objectives of specific lessons span the social (e.g., social and legal consequences of drug abuse), the procedural (e.g., basic first aid), and the conceptual (e.g., "explaining how nutrients affect the risk factors for four common chronic diseases"). While the conceptual objectives have the potential for the science connection, health teachers are rarely able to explore this connection because of the large amount of total content that needs to be covered and a lack of science background.

The county science program for the same grade levels spans biology, ecosystems, forces and motion, astronomy, and earth science. Biology topics are currently taught in the 7th grade and include biochemistry, genetics, structure and function of living organisms, and biotechnology (Montgomery County Public Schools, n.d.). The curriculum is problem-based and connects to issues of daily living. For example, students study biochemistry in the context of developing a menu for a chosen group (e.g., a middle school or clients of a food bank). As students learn about the transformation of matter and energy during metabolism, they make a connection to the role and sources of essential nutrients. Similarly, as students learn about genetics, they assume a role of a genetic counselor and develop a report about a genetic disorder. The county middle school science program, however, does not include coverage of any other (nongenetic) disorders and health issues.

Unlike general health, environmental health is virtually absent from the US curriculum, both in the health and in the science classroom. Focus group discussions with middle school science and health teachers in four states, conducted by the US National Library of Medicine, suggest that many teachers view environmental health as an important and worthy topic, which easily sparks students' enthusiasm

(Specialized Information Services, NLM 2009). Science teachers also see many potential connections between the existing topics in earth science, ecology, climate/weather, and chemistry and environmental health. Yet several barriers need to be overcome to make these connections in the classroom. These include limited classroom time, pressure to teach to standards and tests, and lack of appropriate background knowledge among the teachers.

3 Knowledge-Related Terminology Throughout This Chapter

The previous section made a distinction between basic factual knowledge about health issues and a deep understanding of the underlying biological mechanisms involved. Throughout this chapter, we refer to understanding biological mechanisms as "conceptual knowledge." The term "conceptual knowledge" comes from cognitive studies in education. It is related to the basic cognitive psychology's "declarative knowledge" or the knowledge of objects, events, and relationships between them (Anderson 1976). "Declarative" and "conceptual" knowledge refer to similar notions of knowledge organized into networks of related concepts. However, "declarative knowledge" is usually used in the context of contrasting it with procedural knowledge or knowledge on how to do something (e.g., measure blood pressure with a cuff monitor). While procedural health-related knowledge is important in daily life, discussing its place in the science classroom is beyond the scope of this chapter (but see McCormick 1997). "Conceptual knowledge" is used in research that focuses on the depth and organization of knowledge structures and their impact on problem solving. Knowledge networks can be rich, with a multitude of concepts connected by causal, conditional, and other relationships, or superficial and fragmented. Studies in areas ranging from physics to astronomy suggest that rich, complex networks provide stronger basis for solving complex novel problems (Vosniadou 1992). Much of this chapter deals with the role of knowledge in reasoning about health, attempting to distinguish between the effect of deep and shallow knowledge. Technically speaking, all declarative knowledge we discuss is conceptual because it involves biological or health-related concepts. For simplicity, rather than referring to "rich, connected conceptual knowledge" and "superficial and fragmented conceptual knowledge," we refer to the former as "conceptual" and the latter as "factual." For example, when an individual explains that cholesterol is a fatty substance, which could form plaque in the arteries and thus contribute to heart disease, we call her knowledge "conceptual," stressing the causal connectedness of this knowledge network. Alternatively, when an individual knows that fatty foods raise cholesterol level and that high cholesterol is unhealthy but does not understand how cholesterol affects health, we call this knowledge "factual." We do so for convenience, while acknowledging that the demarcation between factual and conceptual levels of understanding is not a clear-cut line.

4 Research on the Relationship Between Health Knowledge, Reasoning, Information Seeking, and Health Behaviors and Outcomes

In the first section of this chapter, we made a claim that scientific knowledge had relevance to reasoning about everyday situations of health and disease. In the second section, we demonstrated that teaching about the biological bases of health is not common in the USA. It is now time to describe specific situations where the lack of scientific knowledge causes some hardship, while gaining scientific knowledge provides benefit.

The relationship between education and health is well documented in the field of public health: more education correlates with healthier behaviors, greater utilization of preventative care, and longer life span (Cutler and Lleras-Muney 2006). The controversy arises in trying to explain the correlation. Greater education leads to higher income, which improves access to health care. It is also possible that higher educational attainment leads to jobs with safer, healthier work environments. However, controlling for these factors is not sufficient to explain differences in health. Cutler and Lleras-Muney suggest that education may equip people with critical thinking skills, which contribute to the ability to comprehend and use health information.

4.1 The Impact of Health Literacy on Health Behaviors and Outcomes

Over the past decade, much research was conducted on the relationship between health literacy and health behavior and outcome. Health literacy is "the degree to which individuals have the capacity to obtain, process, and understand basic information and services needed to make appropriate decisions regarding their health" (Nielsen-Bohlman et al. 2004; for in-depth treatment of the subject, see Schulz and Nakamoto, this volume). These studies involve multiple definitions and measures of health literacy, many associated with general literacy. Although none of these include pure measures of conceptual understanding, studies suggest that individuals' health literacy is independently related to their knowledge of health and disease (Gazmararian et al. 2003). Multiple studies link inadequate health literacy with suboptimal health behaviors and poor outcomes. For example, Kalichman et al. (2000) reported that HIV patients with lower levels of health literacy "had lower CD4 cell counts, higher viral loads, were less likely to be taking antiretroviral medications, reported a greater number of hospitalizations, and reported poorer health than those with higher health literacy." Baker and colleagues (2002) found that inadequate health literacy increased the risk of hospitalization among the elderly. Schillinger et al. (2002) found that diabetes patients with inadequate health literacy were less likely to achieve good glycemic control and more likely to suffer from retinopathy. These effects remained significant even after adjustment for various social (e.g., social support), demographic (e.g., age), and health status characteristics (e.g., years with diabetes). After similarly controlling for a number of sociodemographic and health variables, Wolf et al. 2005) found that older adults with inadequate health literacy were more likely to have poor physical and mental health functioning.

4.2 *The Role of Health Knowledge in Online Information Seeking and Comprehending Medical Documents*

While health literacy studies clearly point to the relationship between literacy and health status, they do not propose the mechanism that accounts for this effect and do not characterize the nature and level of health knowledge needed for adequate functioning. To address these questions in our own work, we focused on the relationship between individuals' health knowledge and their performance on realistic tasks that involved interacting with health information. For example, in a study of online health information seeking, we presented twenty participants with a scenario about an elderly relative (e.g., a parent) who carries several bags with groceries up the stairs and experiences an episode of squeezing chest pain, nausea, and shortness of breath (Keselman et al. 2008). The symptoms subside after 2–3 minutes of rest. The symptoms in the scenario describe a condition called *stable angina*, usually caused by narrowing or partial blockage of coronary arteries, due to the buildup of cholesterol. Stable angina is not a heart attack. The main difference between a stable angina attack and a heart attack is that stable angina does not cause permanent heart damage, while heart attack does. However, if the cholesterol buildup causing stable angina is not treated, it may eventually lead to a heart attack. Unlike stable angina, heart attack pain is usually prolonged and does not go away with rest. The scenario used in the study did not mention "stable angina" by name and did not explain the physiology of the process. Participants were interviewed about their in-depth understanding of the health problems experienced by the character in the scenario and then asked to search MedlinePlus, a health information portal developed by the US National Library of Medicine, for a site describing the condition in the scenario (http://www.nlm.nih.gov/medlineplus/).

Participants in the study were selected to represent different levels of education: half had only completed high school, while the other half had college degrees. When it came to explaining the symptoms in the scenario, none of the participants mentioned stable angina. Instead, they proposed a broad list of hypotheses, ranging from heart attack to noncardiac problems, such as arthritis, stroke, asthma, and diabetes. Strikingly, only one participant was able to navigate to a website about stable angina when searching MedlinePlus. The rest either ended up on websites about other diseases, which, they felt, corresponded to the symptoms in the scenario (e.g., heart attack), or abandoned their searches. This difficulty in information seeking occurred regardless of the general education level, despite the fact that the more educated participants had greater Web experience and general searching skills.

Our goal of the study was to conduct an in-depth qualitative investigation of participants' understanding of heart disease and describe how background-knowledge-based hypotheses influenced information seeking strategies. To study participants' understanding of heart disease, we applied *semantic analysis* methodology, in which graphical representations of participants' knowledge models were compared against a gold standard model, derived from consumer health texts about stable angina. The benefit of this analytic method is that it goes beyond pointing out to the deficit in participants' knowledge, providing detailed characterization of the key concepts, the relationships among them, and their coherence. Describing the details of the methodology is beyond the scope of this chapter. The analysis suggested that participants' knowledge differed from the gold standard model in three aspects: the **key concepts** employed, **symptoms' grouping**, and **symptoms' characteristics**. The gold standard model was based on relating three **key concepts**: the *process* of atherosclerosis, the coronary artery disease (CAD) *caused* by the process, and the stable angina chest pain, a *manifestation* of the disease. Participants' understanding did not involve the concepts of stable angina and the coronary artery disease and did not make coherent connections between the pathophysiological process and the symptoms. The second distinction involved **symptoms' grouping** or the tendency to connect the symptoms in the scenario to either one (stable angina) or multiple conditions. The gold standard involved understanding that chest pain, nausea, and shortness of breath were related to a single disorder. Participants, on the other hand, frequently hypothesized that the different symptoms in the scenario could signify different health problems (e.g., chest pain may be indicative of a potential heart attack, while shortness of breath may be indicative of asthma). Finally, the third distinction involved level of importance, ascribed to **symptoms' characteristics**. In the gold standard, the pain's duration and its response to rest were essential to the differential diagnosis (of stable angina vs. heart attack). Participants did not see these specific symptoms' characteristics as important.

Cognitive psychology suggests that problem comprehension is essential to its solution. Indeed, people respond not to the problem as it is represented in a text but to the problem as they see it through the prism of their background knowledge. It is, therefore, reasonable to hypothesize that participants' understanding of the scenario influenced their information seeking. For example, someone believing that the scenario described a heart attack could start the search with a heart attack query. Similarly, someone connecting shortness of breath with asthma could choose to look at a website about asthma. Indeed, the study suggested that participants' information seeking strategies were related to their hypotheses and the overall knowledge structure. Participants who started out with one specific hypothesis typically proceeded by trying to verify this hypothesis. Most frequently, the single hypothesis involved heart attack, which led participants to explore some websites that described symptoms of heart attack and then (incorrectly) conclude that the description matched the symptoms in the scenario. Lack of importance that participants ascribed to specific symptom characteristics may explain this verification of the incorrect hypothesis. In participants' minds, the description of the heart attack was similar enough to what they saw happening in the scenario. Participants who started out with an unspecified "area" hypothesis (e.g., "this is something related to the heart") often proceeded by trying to narrow their hypothesis. This narrowing also led to either an incorrect conclusion or to confusion, which, once again, could perhaps be related to the organization of the background knowledge. Finally, some participants chose to "suspend" their hypotheses and conduct bottom-up searches that involved symptom queries. However, these queries involved terms that were rather broad (perhaps, reflecting the lack of specificity in participants' knowledge) and also led to incorrect conclusions or to confusion. Our information seeking study involved a small sample size and focused on one artificially constructed problem scenario, so further research is needed. However, it suggests that the lack of knowledge about health and disease is likely to create a barrier in dealing with health information.

If we believe that the way people access, comprehend, and use information affects their health, we have many reasons to be concerned. Lay people generally have difficulties dealing with a variety of medical documents, such as their electronic medical records (e.g., Keselman, Slaughter et al. 2007) and consent forms for participating in clinical trials (Joffe et al. 2001). Studies by Keselman, Dalrymple, and Smith (in preparation) examined errors that people made retelling two types of medical documents: doctor's notes and a description of a clinical trial (see Smith et al. 2011; Keselman and Smith, in press). In line with other research into individuals' understanding of medical documents, participants generally had trouble with comprehension. The errors often had to do with various aspects of scientific literacy, such as conceptual knowledge (e.g., understanding that insulin is a hormone rather than a nutrient) or knowledge of research conventions (e.g., understanding the difference between interventional and observational clinical trials).

4.3 Depth of Conceptual Understanding and Reasoning About Health Myths

The studies described so far do not show how the knowledge is actually used in reasoning about health and do not distinguish between different levels of biological knowledge. In a 2004 work, Keselman, Kaufman, and Patel studied the relationship between adolescents' understanding of HIV biology and their reasoning about scenarios containing myths about HIV. Twenty-one middle school students (grades 6–8) and high school students (grades 9–12) were interviewed about their conceptual understanding (knowledge) of HIV. Following the knowledge interview, they also had to evaluate two myth scenarios. The first scenario suggested that HIV could be expelled from the body via urine and sweat; the second scenario suggested that contracting other sexually transmitted diseases reduced one's risk of contracting HIV. The students were asked to explain why they believed these scenarios to be true or false. Based on the knowledge interviews, administered before the scenarios, students' understanding of HIV biology was classified into one of three conceptual models: naïve, intermediate, and advanced. Assignment to the models was done on the basis of students' understanding of three factors: (1) core concept of HIV, (2) biological mechanism of infection, and (3) disease progression. A naïve level of understanding involved knowing that HIV is a disease, which gets inside the human body and "makes one sick." Students classified at the naïve level did not have deeper understanding of HIV biology but could be, and often were, well-versed in basic HIV facts (e.g., HIV is incurable, HIV is sexually transmitted). At the intermediate level, students knew that HIV is a biological entity which enters the body via bodily fluids and destroys the immune system. Finally, at the advanced level, students knew that HIV is a virus with specific cellular-level components, that it enters the body with bodily fluids and penetrates T-cells of the immune system, and that it destroys T-cells while using them for replication. Of the 21 participants in the study, 11 were classified at the naïve level, 7 at the intermediate level, and 3 at the advanced level of understanding.

Depth of HIV understanding, as expressed by the model assignment, correlated with students' ability to reject the myths. The three students at the advanced level of understanding consistently rejected both myths. In contrast, of the 11 participants with the naïve level of HIV understanding, only two rejected the first myth and four rejected the second myth. Of the seven students at the intermediate level of understanding, three rejected the first myth and two rejected the second myth. Naïve and intermediate level students who allowed the possibility of expelling HIV with urine and sweat often did so despite having explicitly stated during the knowledge interview that HIV was incurable.

Analysis of the transcripts of students' reasoning about the scenarios suggested that the depth of biological understanding mediated reasoning and affected the judgment about the plausibility of the myths. In thinking about the scenarios, students used both biological and nonbiological reasoning. Biological reasoning involved inferences about biological plausibility of the myths (e.g., "There is no way sweating has something to do with your blood system"). Nonbiological reasoning involved references to authority, experience, or common sense. ("A lot of people have HIV and if it was that easy they would just do it [expel it and be cured] in a second.") Reasoning grounded primarily in nonbiological knowledge could lead to rejection of the myths but did not consistently do so, depending on the student's specific experiential beliefs. For example, one student concluded that it was not possible to expel HIV by sweating because it seemed too easy to be true. Another student, however, remembered hearing a story about an against-the-odds cancer survivor who kept her spirit up by exercising and concluded that it was similarly possible to "exercise [one's] way out of HIV."

In contrast, the outcome of biological reasoning depended on the depth of biological knowledge in which the reasoning was grounded. Students with naïve and intermediate models of HIV understanding made nonspecific or system-level biological statements while reasoning about the scenarios. Nonspecific reasoning statements referred to structures and processes that were biological only in the most generic sense (e.g., body, disease), while system-level reasoning statements mentioned specific organs, bodily fluids, and some biological mechanisms (e.g., skin, blood, absorption). Such reasoning could lead to both denial and acceptance of the myths, as the underlying knowledge did not seem to provide enough of a foundation for understanding why the myths could not be true. The following quote illustrates the reasoning of a student with an intermediate level of HIV understanding, accepting the first myth: "It's possible. You see, if it [HIV virus] just got in, it's not really in your system that much yet. . . . At the beginning, it did not get to infect your T-cells really yet, it just approaches them." The situation was different for the students with advanced models of HIV understanding, all of whom made biological statements referring to structures and processes at or below the cellular level. At this level, they were able to use their biological knowledge to construct an explanation for why the situations described in the scenarios were not plausible, as exemplified by the following, "It does not really make sense, because AIDS virus, it's found in sweat, but not. . . it's only in minor quantities, so you can't just expel it, if you do it, there is going to be virus still in your blood that just keeps replicating." This cellular-level biological explanation could be provided alone or as support for the experiential notion that "things don't work that way."

The findings of Keselman et al. (2004) point to the importance of reasonably deep biological knowledge in the critical reasoning and information evaluation, related to "real world" health decision-making. This is consistent with the findings of the effect of the depth and coherence of biological knowledge on lay health reasoning in non-Western cultures. These studies focus on the relationship between two very different knowledge systems: the system of school-taught normative biological concepts and the system of traditional, indigenous health beliefs, transmitted through generations. When the normative biological knowledge is shallow and consists of disconnected facts, biological explanations of disease causality may be discounted in favor of more coherent, story-like traditional explanations (e.g., diseases are caused by an "evil eye") (Sivaramakrishnan and Patel 1993; Mull 1991).

5 Improving Conceptual Understanding and Reasoning About Health in the Science Classroom

The previous section argues for practical usefulness of understanding the biological foundation of health facts, thus making a case for bringing health biology into the science classroom and explicitly linking it with the behavioral, social, and communication aspects of health, taught in the health classroom. None of the studies cited so far, however, address the question of how health should be taught in the science classroom. We started out with the assumption that science should be taught to all students and demonstrated that science-based health knowledge is related to more effective health information behaviors outside the classroom. However, the studies described in the previous section do not tell us about the science education that the participants received. It is possible that those with greater knowledge did not learn it in the science classroom, or if they did, that this learning happened because of students' superior motivation, related to some personal reason. The reverse situation is also possible: that some of the participants who lacked the needed knowledge had previously attended classes where the relevant concepts were addressed in some way. Studies of informal reasoning suggest that people often have difficulty applying school knowledge outside the classroom. For example, Voss and colleagues (Voss et al. 1986) found that formal instruction in economics increases the knowledge of economics but "does not necessarily lead to superior performance on everyday economics tasks" (p. 269). The difficulty of applying classroom knowledge to real life is a special case of the general challenge of knowledge transfer to a novel domain (e.g., Vosniadou 2007). Studies suggesting lack of transfer do not suggest that knowledge is irrelevant but rather point to the great challenge facing educators wishing to teach it in a way that is relevant. How, then, should we teach science to all?

Drawing on the large body of research on conceptual change in science education, Keselman et al. (2004) pointed out five competencies they viewed as critical for applying HIV knowledge to real-world situations. These include (1) conceptual knowledge, (2) reasoning and argumentation skills (the ability to build and defend a coherent viewpoint on the basis of the evidence), (3) metacognitive competency (the ability to differentiate between theories and evidence in order to engage in evidence seeking and evidence evaluation), (4) epistemological commitment (viewing investigation and reasoning as a worthwhile pursuit, capable of answering real-life questions), and (5) discourse practices (familiarity with the vocabulary and structure of scientific discourse). Science education research presents an overwhelming body of evidence for the importance of these competencies to scientific literacy. We further maintain that fostering these competencies is important in helping students apply biological knowledge to real-life problems. The remaining part of this section provides some examples of successful interventions, improving the application of biological knowledge. However, as extensive review of what works in biology education is a formidable task well beyond the scope of this chapter, we focus on interventions that support reasoning and argumentation about health-related issues and measure success as an improvement in these skills.

When it comes to skill building, science instruction has traditionally focused on the skills, involved in the first-hand inquiry process, or experimentation, such as prediction, observation, measurement, and classification. Much attention has been dedicated to students' understanding and mastery of the control of variables strategy. However, lay adults' engagement with science rarely if ever involves experimentation and generation of the empirical evidence. Instead, we read and evaluate accounts of the evidence generated by others, formulate opinions, and share and defend our views. In science education literature, generating and evaluating positions about complex issues is referred to as "informal reasoning" (Perkins 1985). Informal reasoning may be viewed as a form of internalized argument. In the recent years, argumentation came to be conceptualized as a core scientific practice, mastery of which should be an important goal of science education (Kuhn 2010). Specific argumentation skills involve justifying a position by finding evidence, explaining its implications, and anticipating and countering the opponents' response. These skills emerge via sustained practice, in goal-directed activities, which make connection to students' personal experiences and promote meta-level reflection about the reasoning process (Kuhn 2010). Currently, there is some controversy as to whether argumentation skills taught via explicit, direct instruction result in transfer to novel situations and domains (Kuhn 2010; Larson et al. 2009; Schworm and Renkl 2007). There are also debates about the richness of the content knowledge needed to exercise the reasoning skills (Metz 2004; Kuhn 2010). While we do not yet have enough intervention research to resolve the controversy, we have evidence of successful projects teaching health-related knowledge and reasoning and argumentation skills to adolescents. We review examples from two subject areas, HIV and genetics.

5.1 Fostering Critical Reasoning About HIV

In a follow-up to our earlier study of adolescents' conceptual understanding of HIV (Keselman, Kaufman et al. 2007), we built a 12-session curriculum, in which seventh grade students developed conceptual understanding of HIV biology and applied this knowledge to reasoning about real-world problems. The content of the intervention was chosen in collaboration with the students' science teacher. The first challenge that had to be resolved was a practical issue, one that is likely to face any research effort to bring health education into the science classroom. The study was conducted in New York City, where, like in most places in the USA, the middle school curriculum did not include HIV biology and the room for introducing new topics was limited. The seventh grade science consisted of two units, covering a wide range of science fields. Two of these pertained to life sciences: the second, "Beginning of Life," and the sixth, "Human Body and its Environment." The standard curriculum of "Beginning of Life" covered unicellular organisms, so we decided to introduce a lesson on the nature of viruses into this unit. The standard "Human Body" unit included coverage of the circulatory system. We added a review of the virus theme and introduced the immune system in that unit. Introduction of the new content involved teacher-led lectures and student-led small group presentations.

The study involved two seventh grade classes, which participated in different versions of the intervention, and an eighth grade class, which served as a nonintervention posttest-only control group. In addition to the content-focused lessons, students in the intervention conditions participated in critical reasoning activities. These activities involved interpreting and discussing social implications of media coverage of situations involving infectious diseases and immune response. For example, during one of the lessons, students read "Rare Cancer Seen in 41 Homosexuals," a New York Times article from 1981, and discussed how the incomplete scientific understanding of the time could give rise to common HIV/AIDS misconceptions of the 1980s. The goal of the critical reasoning activities was to foster knowledge elaboration and application to real-world problem solving. In addition, students in one of the seventh grades participated in writing intervention activities that were designed to promote argument building and knowledge integration (Bereiter and Scardamalia 1987; Keys 1999). During two lessons, students in the writing-focused seventh grade class worked in small groups, assuming the role of HIV counselors responding to an advice-seeking letter from a (fictional) young woman. The young woman wrote about having recently contracted a sexually transmitted disease, chlamydia, from her boyfriend. She wondered whether she should get tested for HIV and also expressed hope that contracting chlamydia meant she could not have contracted HIV at the same time because "HIV and Chlamydia would fight with each other as to which of them goes in, and HIV would win, because it is stronger." Students from the other, nonwriting-focused seventh grade class participated in the alternative activity, reading and discussing a newspaper article about HIV testing in Kenya.

Pre- and posttest in the study consisted of three measures: (1)a multiple choice questionnaire about basic HIV facts (e.g., "Can a person get AIDS/HIV infection from being bitten by mosquitoes or other insects?"); (2) essay-question HIV/AIDS conceptual understanding test; and (3) an HIV/AIDS critical reasoning task. The critical reasoning task was similar to the writing intervention activity, asking the students to assume the role of an HIV counselor and write a response letter to a young woman whose friend was diagnosed with HIV. The young woman wanted to remain friends but expressed specific fears of contracting HIV. These fears represented three common misconceptions about HIV infection: the possibility of contagion via saliva (sharing utensils), sweat (sharing towels), and surface contact (sharing nail clippers).

Results of the study demonstrated significant pre- to posttest improvements on measures of students' HIV knowledge, HIV understanding, and critical reasoning for both groups. Students started out with some misconceptions about ways in which HIV could be transmitted (e.g., by mosquitoes) and improved this knowledge of basic facts in the course of the study. This improvement was paralleled by an improvement in understanding of HIV biology. The coding scheme for understanding was adapted from Keselman et al. (2004), again classifying conceptual knowledge into the naïve, intermediate, and advanced models. At the time of the pretest, 43 students across both groups were classified at the naive level and three students were classified at the intermediate level of HIV understanding. At the time of the posttest, 11 students were classified as naive, 29 as intermediate, and 6 as advanced. Finally, the study measured two aspects of the students' critical reasoning. The first involved judgment accuracy or the ability to tell the fictional character that she was not at risk of contracting HIV via superficial contact. The second involved the number of biological explanations supporting the judgment. Students from both groups increased their reliance on biological reasoning (with the improvement being greater in the writing group), but this led to the improvement in judgment accuracy only for students in the writing group. Across both seventh grade conditions, posttest performance on the measures of conceptual understanding and reasoning was higher than the performance of eighth graders who did not receive the intervention.

The study suggests that school biology instruction can be made relevant to reasoning about real-world health issues. Providing students with sufficient opportunities to apply their knowledge to reasoning and writing about realistic problems leads to more accurate judgment, grounded in better conceptual understanding.

5.2 Improving Argumentation About Genetic Dilemmas

Advances in genetics and gene technology push the field to the forefront of socioscientific discourse. Genetic research has bearing on thorny health issues that are heavily intertwined with ethics, economics, and politics (e.g., genetic engineering, cloning). Reasonable policies and sound personal decisions are likely to depend on the public's ability to understand the issues and participate in the discourse, which makes genetics a prime candidate for science-for-all instruction with an emphasis on reasoning and argumentation skills.

Zohar and Nemet (2002) conducted a study in which they incorporated explicit instruction in argumentation strategies and argumentation practice into teaching human genetics. Israeli students in grades 9 and 10 participated in a 12-hour long experimental genetic revolution unit. They learned about advanced topics in human genetics, participated in a lesson devoted to explicit argumentation instruction and practiced argumentation strategies in group discussion about various dilemmas in human genetics. Dilemmas involved decisions about genetic testing and their implications. For example, students had to decide whether an expectant couple in which both the husband and the wife have siblings with cystic fibrosis should abort the pregnancy. Students in the control group participated in the same-length conventional genetics curriculum, with no special emphasis on reasoning and argumentation.

Pre- and posttest assessment focused on (1) understanding of the advanced genetics concepts and (2) quality of argumentation. The results suggest that students in the experimental group, but not in the control group, improved the quality of their argumentation, as measured by the increase in the number and complexity of justifications for their position. In addition, while students in both groups improved their understanding of human genetics, improvement was greater in the experimental group. Zohar and Nemet's (2002) study suggests that improving argumentation skills in the classroom context is possible. It also points to the potentially mutually beneficial relationship between depth of content knowledge and argumentation. This conclusion is consistent with the findings of Venville and Dawson (2010). Similar to Zohar and Nemet (2002), Venville and Dawson (2010) found that following a classroom argumentation intervention in the context of human genetics, the experimental group outperformed the control group not only on the measures of argumentation quality and complexity but also on measures of genetic understanding. Remarkably, Venville and Dawson (2010) were able to achieve this effect in only three lessons, one involving direct instruction in argumentation and two engaging students in whole-class discussions.

6 Socioscientific Issues as the Context for Teaching Health Biology

The two main reasons for teaching science to all students, put forward by the proponents of this approach, are that science knowledge is necessary for informed citizenship and that it improves daily lives. These two uses of scientific knowledge by lay people are usually viewed as disparate. Daily lives examples usually come from the domain of personal health, as exemplified by the work of Keselman et al. and the health literacy studies described in this chapter. Informed citizenship examples, on the other hand, usually pertain to controversial issues at the heart of contemporary political discourse. These controversies can be divided into two large categories: the ones related to environmental issues (human-affected climate change, alternative energy sources, waste management, and recycling) and those related to advances in modern genetics (genetically modified foods, cloning, genetic engineering and genetic medicine, and stem cells).

In the recent science education literature, scientific challenges at the center of social and political controversies became termed "socioscientific issues" (Sadler 2004). Sadler defines socioscientific issues as "complex, open-ended, often contentious dilemmas, with no definitive answers" (p. 514), which are deeply embedded in both social and scientific factors. As such, these issues are prime candidates for teaching science to all students and creating a link between content knowledge and informal reasoning and argumentation skills (Driver et al. 2000; Sadler et al. 2007). Research evidence suggests that engagement with socioscientific issues promotes both content learning and students' understanding of the nature of science (NOS) (Sadler et al. 2007). Students also learn to integrate the rational, the emotional, and the moral and ethical considerations in their reasoning (Sadler and Zeidler 2005).

One of the key challenges of teaching science to all is developing curricula that would stress both benefits of the public's scientific literacy: science for participating in political discourse and science for practical use in daily lives. Since science in daily life has much to do with health and socioscientific controversies often involve environmental and gene technology issues, we see two domains where the personal and the socioscientific intersect: environmental health and genetics as applied to human health. Situating genetics instruction in the context of social and moral dilemmas is already a subject of much attention in research in socioscientific issues, as exemplified by the Zohar and Nemet (2002) and Venville and Dawson (2010) studies, described in the previous section. So far, environmental health has received little attention. This stands in sharp contrast to general environmental science and ecology issues, which play significant roles both in standard school curricula and in research in socioscientific inquiry. Environmental health is a complex field, which draws upon physical, chemical, and biological sciences, so bringing it to the school classroom may be an intimidating affair. However, it also holds the promise of "personalizing" environmental concerns by connecting them to students' daily lives. Findings from our science discussion groups' project suggest that teachers see environmental health as an important-to-teach domain, of high interest to students, and related to many issues currently in the curriculum. As a proof of concept, we are currently collaborating with a group of science and nonscience teachers on developing an environmental science afterschool club curriculum that engages middle school students in argumentation.

7 Conclusions

We opened this chapter by identifying with the science-for-all position: viewing scientific literacy as having the potential to improve daily lives of citizens, as well as for promoting informed citizenship and better policy-making. We also proposed that of the many things that can be taught in the science classroom, aspects of general and environmental health are perhaps the most relevant to those goals. Finally, we provided evidence that a certain depth of conceptual understanding and reasoning skills is necessary for the knowledge to be applicable outside the classroom, suggesting that health education alone, unsupported by science education, is not likely to provide a solid basis for real-life reasoning and decision-making.

What this chapter does not provide is the picture of what an effective science-for-all education looks like. While the studies described here may answer some questions, others remain unanswered and new ones arise. Most research on the relationship between health knowledge and reasoning/behavior/outcomes is conducted outside science education, in fields such as social sciences and public health. These studies, therefore, do not tell us how much knowledge is necessary and sufficient for making good decisions in daily life. Science education research focusing on socioscientific issues is also a relatively young field. It points to the likelihood of a mutually beneficial relationship between content knowledge and informal reasoning and argumentation skills but does not describe how one influences the other. As a consequence, more research is needed before we can answer the question about the ideal content–skills balance in such instruction. The issue is likely to remain controversial (see Kuhn 2010; Metz 2004), which is good for lively scientific engagement but problematic for educators working on the ground. Currently available research also does not provide time estimates and assessment metrics for the topics in question.

Another question that needs to be addressed has to do with the relative strengths and benefits of problem-based vs. subject-based curricula. Socioscientific issues and issues of health and disease are complex and multidisciplinary. Brief research interventions that address these issues are problem-based, touching upon biology, chemistry, and physical and social sciences. The history of science education over the past century has seen a movement from problem-based to basic science education and back again (DeBoer 2000). Basic science education, organized around a set of scientifically, rather than socially, related concepts certainly has its advantages. It may be less engaging to students but can provide more systematic knowledge, with fewer gaps and better organization. We do not advocate replacing basic science instruction entirely. Depending on the context, problem-based units can be introduced within existing programs, as supplemental unifying courses, or through extracurricular activities, such as afterschool clubs.

When introducing socioscientific dilemmas to the science classroom, we need to be aware that their open-ended nature and the absence of the right answer may be a pedagogical double-edged sword. On the one hand, they allow us to stress the interconnectedness of the scientific and the social, thus making science more relevant. On the other hand, we have to be careful not to misrepresent the nature of science as tentative and perpetually inconclusive, stressing how science contributes to the knowledge base for the decision-making, even if it does not provide all the answers. Last but not least, there is also the matter of the first-hand vs. secondary engagement with the natural world in science education. "Real science," as practiced by scientists, is about first-hand engagement in the laboratory. For young students, much of the joy of science comes from participating in hands-on activities in the science classroom. However, science issues pertaining to human health and disease processes are difficult to represent in school labs. A partial solution to this comes from the world of computer simulations (e.g., see description of Bransford's Preparation for Future Learning assessment (Rubenstein 2008).

In summary, providing curricular specifications is beyond not only the scope of this chapter but our expertise and abilities. However, at a more general level, we believe that science education emphasizing informal reasoning and argumentation about general and environmental health, situated in the context of realistic situations and socioscientific dilemmas, is likely to promote scientific literacy, which can then contribute to informed citizenship and healthy personal choices.

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A Win-Win Situation for Health and Science Education: Seeing Through the Lens of a New Framework Model of Health Literacy

Albert Zeyer

Health is a "megatrend" (Kickbusch 2006). It has become a crucial driving force in the economic, political, and social development of the world. Nevertheless, the role of health and health education in science education is unclear, as the teacher educator Jennifer Harrison concludes in a review (2005). It has been less important than the role of environmental education, which enjoys a long – though not unambiguous – history of inclusion in science education. This may be in part because environmental educators have been interested in science education for decades (cf., e.g., the Science Technology Society Environment (STSE) curricula introduced in the 1980s), while health educators have traditionally focused on other school subjects including home economics, life skills, and physical education.

The difference between health and environmental educators' attitudes toward science is a reflection of a cultural-historical constellation in health and health promotion as will be discussed in the following section. The emergence of the concept of health literacy offers a promising approach for newly addressing the relationship between health and science education. To this aim, a framework model for health literacy will be presented in this chapter.

The framework model for health literacy will be used for two reasons. Firstly, it will show explicitly that health literacy is inherently knowledge-based and that this reveals a strong link between scientific literacy and health literacy. A win-win situation exists between these two fields that is yet to be fully exploited. The second reason for adopting this model is to facilitate a systematic approach to the research, development, and teaching of health issues in the context of science education. Several concrete examples will demonstrate how the systematic analysis of health issues through this framework model may reveal the potential benefits of including health issues in science education. It will also be underlined that health literacy

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refers not only to the field of good health in its narrowest sense but also to the field of diseases and to medicine, which opens up a whole range of topics that are fascinating and relevant to students.

With reference to a review of recent literature in science education research (Zeyer and Odermatt 2009), the potential win-win situation between health and science education will be sketched out. Finally, a concrete example of a teaching unit will be presented along with a discussion of the need for institutional efforts to develop and spread such examples of best practice. To this end, two vignettes created by other authors have been included in this chapter.

1 Salutogenesis and Pathogenesis

"Health is covert," as Hans-Georg Gadamer writes in his famous essay "The enigma of health: the art of healing in a scientific age" (1993). Health is not a positively definable construct, but rather, illness is the condition that can be defined and systematically objectified. This problem has led to the construction of an antinomy between health and illness, which has dominated the health promotion scene for decades. It has found its salient expression in the pathogenesis-salutogenesis concept developed by the medical sociologist Aaron Antonovsky in the 1980s (cf. Antonovsky 1997). He distinguishes a pathogenetic from a salutogenetic approach. In the pathogenetic approach, the causes of illness are sought. It is based on (biomedical) knowledge of risk factors and predispositions to illness. This is used to develop and implement individual prevention and therapy. In contrast, in the salutogenetic approach, aspects that foster good health are sought. In doing so, the focus lies on psychosocial resources and resilience and the societal organization of health promotion is of primary interest.

With the course of time, the salutogenetic approach has become gradually detached from the pathogenetic approach, and concurrently the latter has come under more and more criticism. As a result, this process of separation has led to a critical view of biomedical health knowledge within health promotion settings. For example, in the standard reference book *Foundations for Health Promotion*, the authors Naidoo and Wills characterize the pathogenetic (biomedical) approach with three unambiguously critical terms: reductionist, mechanistic, and allopathic (i.e., repair-oriented) (2003: 10). Such statements have opened a gap between the culture of medicine and the culture of health promotion. In German speaking countries, this has frequently resulted in a certain neglect of the role of biomedical knowledge in health education (Hafen 2007).

2 Health Literacy: A New Concept

The concept of health literacy promises to address this problem in a new way. Indeed, recently, this concept has gained an increasingly larger space in discourse on health and illness (Baker 2006). In this volume, an entire chapter by

Peter J. Schulz and Kent Nakamoto is dedicated to the issue. Here, only some important features will be recalled to help in the understanding of the significance of health literacy for science education and the reason why it could be instrumental in encouraging greater inclusion of health education within science education.

The health literacy movement finds its origins in a straightforward understanding of "literacy" in terms of the ability to read and comprehend prescription bottles, appointment slips, and other essential health-related materials. However, over the course of time, this term has seen a sophisticated elaboration that brings it close to the modern concepts of scientific literacy (cf. chapter by Rodger Bybee in this volume). The most simple but quite substantial definition describes health literacy as a knowledge-based ability to make health-related decisions. The comprehensiveness of this approach can be identified in the following, more detailed description:

> A person with an appropriate health literacy level has the knowledge, skills, experience and attitudes to deal with their health in a demanding space every day. Health literacy includes, among other things, knowledge about when contact with the healthcare system is necessary and how to navigate oneself around the healthcare system to achieve the greatest benefit. This also includes understanding one's doctor and taking responsibility for oneself, making health-promoting decisions and leading a health-promoting lifestyle. (HCC-Lab 2005: 5, own translation)

Thus, the term "health literacy" refers not only to institutions of health promotion and prevention but also to medical institutions. In fact, health literacy plays a role in all areas of health and illness, i.e., in health promotion and prevention, as well as in acute or chronic illness and in therapeutic and palliative care settings. Within the health care system as a whole, the health literate person is able to navigate themselves self-confidently and in an informed manner.

Clearly, health literacy is an overarching concept that includes medicine, prevention, and health promotion, and indeed, it is close to Antonovsky's original approach that locates every human's position of well-being on a continuum between the two poles of perfect health and absolute illness. In the following section, a framework model of health literacy will be presented in which, by nature of its very structure, the role of (scientific) knowledge in health literacy is emphasized. As a result, this will help to bridge the historically determined gap between the pathogenetic-biomedical and the salutogenetic-psychosocial cultures and accordingly to promote the role of science education within a health promotional context.

3 Health Literacy: Gräsel's Framework Model

Quite a substantial body of literature exists in which the conceptual framework of health literacy is discussed (cf. chapter by Peter J. Schulz and Kent Nakamoto in this volume). However, a framework model of health literacy that is rooted in the educational sciences does not appear to have been developed thus far. In Fig. 1, such a model is presented (Zeyer and Odermatt 2009). It is adapted and slightly expanded from an existing framework model of environmental literacy proposed by Cornelia Gräsel (2000), a German educational researcher.

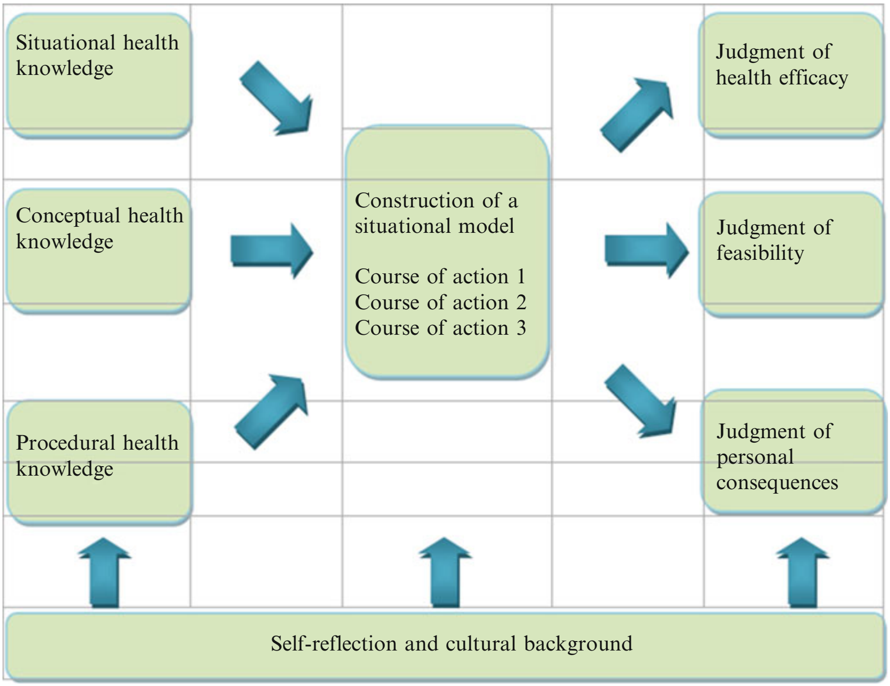

Fig. 1 Framework model for health literacy (Zeyer and Odermatt 2009) (Adapted and expanded from Gräsel (2000))

This approach has two main advantages. Firstly, the conceptual kinship of environmental and health literacy is underlined, which suggests and motivates a comparable role of these two fields in science education. This corroborates the basic assumption underlying this volume. Secondly, since the model has been developed from inside the educational field, fundamental educational concepts, such as the theory of knowledge, moderate constructivism, and the role of (self-) reflection in learning processes, are taken into account.

This framework model is designed to operationalize the conscious planning processes involved in everyday health activities. Routines that are not deliberately used in the planning process are not taken into account. The model consists of three main parts. The *input side* (i.e., the left-hand side in Fig. 1) of the model is knowledge-oriented. The *construction of the situation* is displayed in the center of Fig. 1, which includes different possible courses of action. The *output side* of the model (i.e., the right-hand side of Fig. 1) is judgment-oriented. Furthermore, every part of the model is influenced by a basic level of *self-reflection* and of the subject's *cultural background*. The following is a more detailed analysis of the model's significant aspects.

3.1 Knowledge

Based on pedagogical knowledge theories, Gräsel proposes that three types of knowledge are involved in the planning process: situational, conceptual, and procedural knowledge (2000: 89):

- Situational knowledge refers to knowledge about concrete situations and their typical features in a particular domain (in this chapter, health and illness are the general domains). Situational knowledge is necessary in order to construct a mental model and allows the involvement of other types of knowledge (conceptual knowledge and action-related knowledge) in the construction process. For example, situational knowledge about healthy nutrition includes knowledge about food, shops, food labels, prices, cooking, etc. Situational knowledge about vaccinations includes knowledge about diseases and their symptoms, available vaccinations, side effects, etc.
- Conceptual knowledge is knowledge about facts, terms and principles, and particularly about their mutual relationship. It is more than knowledge about isolated (declarative) facts, but rather facts that are connected in a network of relations and linked to other facts and concepts. Conceptual knowledge is thoroughly processed, structured, and stored in memory. It is active, in contrast to inert forms of knowledge, and it often applies to not only one context but many. For example, in knowledge about HIV and AIDS, conceptual knowledge includes knowledge about the immune system and its functioning, about the reverse transcriptase and its role in infection, or about the sexual transmission of diseases. Another example, knowledge about the correct treatment of an infection, includes conceptual knowledge of the differences between viruses and bacteria, the mechanisms of antibiotics, or about how antibiotic resistance may develop.
- Lastly, procedural health knowledge involves knowledge about suitable courses of action in concrete situations and practical knowledge about concrete health-related activities. Gräsel differentiates declarative action knowledge from procedural action knowledge. The first typically applies to health situations that lie outside of personal experience, while procedural action knowledge accumulates through experiential situations and normally is automatic and efficient. A good example of health-related action knowledge is knowledge about various kinds of physical activity or knowledge about how to use the Internet to search for health-related topics.

3.2 Situational Construction

The three types of knowledge described above inform the construction of a so-called situational model that lies in the center of the diagram. Hereby, moderate constructivism is taken into account. In this concept, which is widely accepted as a theoretical basis for research in science education (cf. Duit and Treagust 1998), substantial learning is assumed to be able to emerge only when the learner is actively engaged in mentally processing incoming knowledge. Moreover, Gräsel refers to cognitive research results which show that planning meaningful action is only possible when the situation is perceived to be relevant to the corresponding problem. Then, and only then, potential different courses of action can be identified. Therefore, in this construction process, a so-called anchor is important (a cognitive anchoring of the situation in a health-related base), which activates a situation in view of a question relevant to health and illness. Therefore, planning a course of action is conceptualized as the construction of a situational model.

The construction process is informed not only by knowledge elements but also by other incoming stimuli. In the original model, these influences are subsumed under "self-reflection," which Gräsel describes as a means to "break up everyday routines and consider and analyze one's own actions" (Gräsel 2000: p. 105).

In this adapted model, other aspects of (meta-) reflection are included. In Fig. 1, these influences are labeled by the general heading of *cultural background*. This label essentially refers to Aikenhead (2000), which pointed out the educational consequences of a cultural concept on science education. Adopting Geertz's (1973) definition, Aikenhead defines a culture as an ordered system of meaning and symbols, in terms of which social interaction takes place. This includes norms, beliefs, expectations, values, and the conventional actions of the group of people involved (Phelan et al. 1991). Students live simultaneously in different subcultures at school and in everyday life. Western science is only one of many subcultures.

Culturally connoted values in a health literacy context may concern, for example, genetic testing, abortion, or vaccination solidarity (i.e., people should be vaccinated not only for their own health but also for epidemiological reasons). Epistemological questions are also important cultural considerations in the context of health and illness. For example, a discussion about traditional medical knowledge in (alternative) medicine has, on the one hand, to refer to a common (standard) account of science (Cobern and Loving 2001) but, on the other, also has to avoid a cultural clash by promoting naïve positivism (Zeyer 2009). If such sociocultural aspects are included in science teaching, then the involved situational construction is usually called a socioscientific issue (Sadler 2004).

3.3 Judgment

The situational construction and its different avenues of action form the basis of and are followed by a judgment process (in German *Bewertung*), which is displayed on the right-hand side of the framework model. "On the basis of situational knowledge, conceptual knowledge and (health-promoting) procedural knowledge, an actor considers different activities in the situational model. These alternative courses of action are judged in three ways, in terms of: (1) the [*health efficacy*], which falls back on conceptual knowledge, (2) the *feasibility*, for which procedural and situational knowledge is vital, and (3) the *personal consequences* for an individual (drawing on experience-based procedural and situational knowledge)" (Gräsel 2000: 116f, own translation). In the following, we discuss these three areas of judgment in more detail:

- The first type of judgment is the judgment of health efficacy (in German *Wirksamkeit*), in which the subject evaluates the consequences of a certain course of action. In terms of Antonovsky's concept of the health-illness continuum, the actor considers whether the chosen course of action will shift the evaluated situation toward the pole of health or not. This move along the continuum toward good health may be realized on a systemic (social) level (health promotion) or on an individual level (prevention). For example, a teacher may ask whether or not offering healthy meals at lunchtime will help students to maintain their normal weight. Another person might consider whether washing one's hands regularly prevents them from catching the flue. Moreover, health efficacy is also at stake in therapeutic situations. A mother may ask if antibiotics will help her child who has a cold. A patient may ask if a hip operation will relieve the pain.
- The second judgment concerns feasibility. When a person evaluates a course of action, they will assess how difficult it will be to realize it. To this end, situational and action knowledge will be used in order to evaluate material and personal resources. For example, a teacher who intends to include regular gymnastic breaks in their lessons will determine whether or not the classroom is suitable for physical activity and if the students will be motivated to join in. A person who decides to be vaccinated against the seasonal flu will evaluate whether or not they are willing to be vaccinated and if they fulfill the conditions for a successful vaccination.
- Personal consequences are considered in the third judgment. In this type of judgment, an actor takes into account that everyday actions are often polytelic, i.e., they usually are simultaneously aimed toward several intentions and goals and are evaluated from various, sometimes complementary points of view. A course of action that might be beneficial for health promotion may be costly in some other way. Classical cost-benefit analyses mostly refer to financial costs. However, qualitative costs are also involved, for example, social costs, lifestyle costs, or disadvantages for the quality of life. Positive and negative consequences entailed by a certain course of action will be judged on the basis of situational and procedural knowledge. For example, a person who wants to stop smoking might take into account that giving up smoking cigarettes could result in weight gain. A politician who votes for a general smoking ban in restaurants might worry about the financial costs for the regional hotel and service industry.

4 Applying the Framework Model: A Concrete Example

The use of the framework model presented in this chapter is valuable for several reasons. First and foremost, it provides an instrument for a systematic description and analysis of health-related planning processes.

Consider the following example: a person suffers from chronic polyarthritis (CP), which is a typical example of a chronic illness. When confronted with this diagnosis, the person cannot intend to achieve or return to their former state of complete health. Instead, their challenge is to ensure that both their pain is kept at a minimum level and – at the same time –their mobility is maintained as far as possible. This person must learn to live with their illness. In order to succeed in this, they have to be familiar with or acquire certain knowledge. For example, the person must understand what CP is, they have to be aware of the possible symptoms of the illness and what it means for them to have the illness; this is an example of situational knowledge. Relevant conceptual knowledge could include basic knowledge about joints and movements as well as about inflammatory processes. Procedural health knowledge might include learning how to deal with CP in everyday life, for example, how to talk to medical practitioners and choose appropriate and therapeutic types of physical exercise.

Based on this knowledge, the person will start to construct the situation, which will be heavily influenced and informed by self-reflection and by their cultural background. For example, are they a strict adherent of conventional medicine? Or do they use alternative medicine? Then again, as many people do, do they blend the two and create their own health culture? Depending on a person's response to such questions, they will combine different health knowledge resources in order to construct their own idiosyncratic model of the situation.

As a result of this construction process, a person's judgment of the situation will considerably vary from someone else's. For example, a person will judge the progression of the illness and the importance of slowing down the inflammatory process. In considering the feasibility of a method, a person might judge the therapy the doctor proposes; do they want to administer the cortisol in the way the doctor has prescribed? And when evaluating the potential personal consequences of therapy, the side effects of medication might be assessed and the pros and cons of choosing to try acupuncture instead of taking medication might be weighed up.

In the framework model, applying health literacy means to go step by step through these judgments in order to reach wise decisions (which does not necessarily mean conventional medical decisions). Judging the various courses of action is self-evidently of vital importance for the arthritic patient described in the example. The same applies of course for somebody living with diabetes or with high blood pressure. In fact, the example of a person living with a chronic illness was intentionally chosen in order to underline that health literacy is not only relevant to health promotion but also in every other medical situation. It goes without saying that health literacy also helps a person to make reasonable healthy lifestyle choices and take preventive measures to avoid illness.

The application of the framework model may be helpful in other ways, too. For example, the framework model clearly reveals that a direct shortcut between knowledge and judgment does not exist, but rather, a situational construction process is always involved. At first glance, this might appear to be a trivial remark. However, in terms of biomedical issues, students find themselves all too often indoctrinated with naturalist fallacies, which means that facts are directly transformed into normative judgments. For example, teachers often expect students to immediately be in favor of limiting their alcohol consumption after having learned and understood the effects of alcohol on the human body. However, the framework model reveals another possible outcome. Instead, young people might well construct a situation in which they fear losing their colleagues if they were to reduce their alcohol consumption, and therefore, they might not reduce their alcohol intake. In other words, the social costs outweigh the benefits, and as a result, the planning process produces a different result from that which the teacher initially expected.

The same holds true for other "burning issues" in prevention. For example, although frequently suggested, no naturalist shortcuts exist between reducing the risk of lung cancer and giving up smoking, or reducing the risk of high blood pressure and increasing physical activity. Such claims inevitably must also involve situational constructions, though this is usually not made transparent. If people have diverging situational constructions, then the situation will be evaluated in a variety of different ways, which will entail different outcomes.

On the other hand, health promoters are often prone to making the opposite mistake. For example, one of the important messages found in health promotion is that a person should "watch their weight." Although most people may acknowledge this judgment, only few people know why this is more than just a question of esthetics (which is evidently subjective and also potentially controversial). In fact, to understand why a person should monitor their weight, one must understand the health problems frequently associated with obesity: insulin resistance, high blood pressure, lipometabolic disorder, and fibrinolytic disorders. While understanding these problems (often labeled as the metabolic syndrome) is not difficult, a person nevertheless does need to acquire specific knowledge. Without basic biomedical knowledge, healthy body weight may appear to be purely a social construct of psychosocial assessment, which would then be not grounded in biomedical facts.

5 Learning from Antonovsky's Sense of Coherence: An Alternative Framework Model

In the context of science education, Gräsel's framework model has two flaws. Firstly, it does not make explicit that science is generally not the only available source of knowledge that people draw on when they construct a situational model. If knowledge is defined as justified true belief (Boghossian 2006), then it is important to consider what acceptable justifications for belief and for truth exist. Based on an extensive review of philosophical knowledge concepts, the economist Stephen A. Marglin (2008) has proposed distinguishing between two knowledge systems: algorithmic knowledge and experiential knowledge. Human knowledge and action are based on a combination of at least these two knowledge systems. Every system has its own path of epistemology, transmission, innovation, and politics.

Algorithmic knowledge is analytical. It is acquired through inductive and deductive reasoning, transmitted through rational argumentation, and its knowledge is shared, at least in theory, by equals. Experiential knowledge is practical and intuitive, acquired by experience, transmitted through scaffolding and convention, and it involves authoritative relations between experts and students.

The aim of this chapter is not to embark on an extensive epistemological discussion. I therefore refer to Cobern and Loving (2000) who give an in-depth analysis of the relations between scientific knowledge and traditional (ecological/medical) knowledge, the first is perhaps the most important example of an algorithmic knowledge system and the second is the most important example of an experiential knowledge system. In their writings, these authors also make clear that the relationship between scientific knowledge and traditional knowledge is indeed an important issue in science education. It goes without saying that the relationship between the different types of knowledge is also an issue in health education and in medicine. The clash between traditional and alternative medicine is notorious, and dealing with it is an important aspect of health literacy.

Secondly, Gräsel's model neglects the inherently subjective character of health promotional judgments. In John Searle's philosophy of mind (Searle 2004), he introduces the distinction between first-person ontology and third-person ontology. Mental phenomena have a first-person ontology, in the sense that they exist only insofar as they are experienced by some human (or animal) subject, some "I" that has an experience. A third-person ontology is a mode of existence that is independent of any experiencing agent.

Scientific knowledge in its objective, interpersonal form is the prototype of perceiving the world from a third-person perspective. Health promotional judgments on the other hand essentially have a first-person ontology. These judgments include mental phenomena like values, emotions, and intentions, and therefore, they are not only the result of a fully conscious, deliberate, analytical calculation process as suggested by Gräsel's framework model.

Antonovsky's "sense of coherence" (SOC) concept (2007) explicitly takes into account the first-person perspective. He examined health-promoting factors in his salutogenetic model and developed the concept of sense of coherence (SOC) to explain why some people become ill when stressed while others remain healthy. SOC is defined as the global orientation that expresses the extent to which one has a pervasive, enduring though dynamic feeling of confidence. In the SOC concept, an individual view of the world is generally expressed and includes three components: comprehensibility (the extent to which stimuli from one external and internal environment are structured, explicable, and predictable), manageability (the extent to which resources are available to a person to meet the demands posed by these stimuli), and meaningfulness (the extent to which these demands are challenges worthy of investment and engagement) (Dragset et al. 2008).

In correspondence to the *general* SOC concept developed by Antonovsky, which describes a global orientation of an individual, here, we assume that individuals can also judge constructions of health-related situations from a coherent point of view. As a result, the *situational* sense of coherence does not describe an overall individual view of the world, but an individual evaluation of a particular health

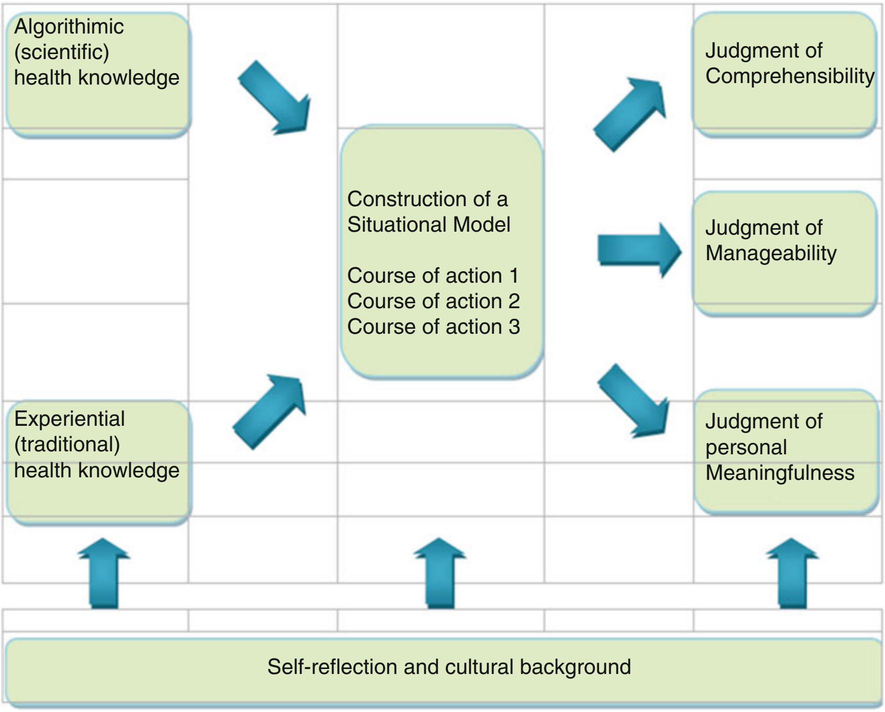

Fig. 2 An alternative framework model for health literacy

situation. The situational SOC includes, like its global counterpart, the judgment of comprehensibility, manageability, and meaningfulness of the different constructions of a concrete health situation.

Based on these two modifications – the distinction of two knowledge cultures by Marglin and the situational SOC in correspondence to Antonovsky's SOC concept – an alternative framework model of health literacy can be proposed (Fig. 2).

The two modifications emphasize the bridging function of health literacy between science education and health promotion. Thus, the model embodies the proposed win-win situation between the two fields.

6 Health Education and Science Education: A Win-Win Situation

A review of relevant science education research journals (Zeyer and Odermatt 2009) showed that the term "health literacy" has not yet been introduced into the field. Nevertheless, much research can be found on health-related themes in science education. Based on qualitative content analysis, research can be grouped into three categories. Health literacy is a clear theme in articles that belong to the first category, even if the authors do not explicitly work with this term. In the second category, publications are found in which themes are addressed that are of value to health literacy but in which the authors have undoubtedly focused on another area. All articles that touch on health issues but only as a "means to an end" belong to the third category.

In most studies found in all three categories, health is not the authors' main focus; it is rather part of a broader spectrum of different research concerns. Nevertheless, the impressive list of themes indicates a win-win situation for both science education and health education. Using the framework model, one can identify two perspectives on health literacy in the reviewed literature.

Within the first perspective, science education is an eminent source of knowledge. In the reviewed literature, building a strong (biomedical) knowledge basis has then been seen as a condition for equipping students with the ability to form sound situational constructions and to critically judge health situations (Keselman et al. 2007; Kolstø et al. 2006; Bögeholz et al. 2004, see also Keselman et al. in this volume). The lack of conceptual coherence so far observed in the many individual articles makes it difficult to draw clear conclusions about how health and health literacy can be integrated into science education. The framework model could help to improve this situation.

On the other hand, the second perspective drawn from the framework model reveals that health issues can be seen as providing interesting situational contexts for science education. In fact, not only girls are drawn to health issues used in science education (besides Jones et al. 2000; Baram-Tsabari et al. 2006; Miller et al. 2006; Christidou 2006 deserve mention). Topics involving health and illness generally capture the attention and improve the achievements of not only students but also student teachers and teachers (Vogt et al. 1999; Schwartz-Bloom and Halpin 2003; Berger 2002). Furthermore, health- and illness-related topics provide an excellent context for the application of scientific content (Bolte 2003a; 2003b; Todt and Götz 1998). From this point of view, the judgment process promotes the attractiveness of the context and the relevance of the context to students' personal lives.

In the reviewed literature, the first perspective is the most common. However, the second is attractive as well. Huge numbers of medical topics (Colicchia et al. 2001; Müller 1999; Zeyer 2006) offer contextual avenues for biological and also physical and chemical science topics, and sometimes in unexpected ways. For example, a chemistry teacher might discuss mechanical ventilation of premature babies in order to medically contextualize the topic of surface tension (Zeyer and Welzel 2005). Or, for example, a teacher might use the erythrocyte sedimentation rate (ESR), a common laboratory test used to monitor the progression of Chronic Polyarthritis (CP), for a lesson in a physics class. This test provides an excellent example of free fall in a viscose liquid, which may be calculated with an easy to solve first-order differential equation (Zeyer and Welzel 2006). Or, yet another example, physical dynamics might be taught in terms of growth percentiles, which provide a biomedical context for drawing space-time diagrams.

Such contexts are fascinating for many students, and they are relevant to their lives and personal experiences. Sometimes, this might not be apparent immediately but may only become evident later in life. A polyarthritis patient who had learned about the ESR in a physics class may understand more clearly the meaning of this test within the personal context of their illness. Or, if a student has calculated blood pressure and learned about its dependence on the position of the sphygmomanometer cuff on a person's arm, this may help them – perhaps many decades later in life – to avoid common errors in measuring blood pressure.

7 X-ray Photographs in the Classroom: A Concrete Example

In order to meet the growing demand for such contexts by teachers and teacher educators, many health-related science teaching units have been created. They have been developed mostly through collaboration between teachers and biomedical experts. Normally, they include attractive material for both teachers and students. One concrete example is presented in Vignette 1 of this chapter. In this teaching unit for 7th or 8th grade, students will become acquainted with the electromagnetic spectrum and in particular x-rays, and they will learn about the relatedness of x-rays and light waves. Through experiments that involve casting shadows of skeletal bones onto paper screens using a video beamer, the students will grasp the principle of x-ray beams. After this teaching unit, students are also able to give a basic anatomical interpretation of x-ray photographs.

This example of a teaching unit demonstrates the potential win-win situation between health and science education once again. The unit includes interdisciplinary (mostly physics-related) science content like the electromagnetic spectrum and the principle of photographic imaging. It also gives students the opportunity to discuss many health-related problems like the interpretation of x-ray photographs, the anatomy of inner organs, and bone fractures, and students are also given a platform to share stories about diseases and accidents.

In the development of this teaching unit, the international consensus of "Inquiry-Based Science Education" (Csermely et al. 2007; Osborne and Dillon 2008) was taken into account. Firstly, the teaching unit is clearly context-oriented. Personal experiences, shared stories, and x-ray photographs are anchors that immediately link the personal lifeworld of every student to the classroom. Secondly, the teaching unit offers educators at least two attractive hands-on components: working with prisms to study the fraction of light and using projectors in order to "create" x-ray photographs. Thirdly, rich and freely accessible literature on Internet about the topic is beneficial for students in the self-organized learning area.

In this teaching unit, "talking science," ethical-practical discourse of *socioscientific issues* together with peers (Sadler 2004), is best realized through repeated sequences of discussing and analyzing personal x-ray photographs. Students can apply their newly gained knowledge in order to understand and judge the reported experiences and related x-ray photographs. It goes without saying that a teacher who is an expert in "talking science" can steer discussions as they arise toward the technical aspects of the analysis and understanding of x-rays as well as toward health-related considerations, such as the following: How can a person avoid accidents on the ski slope? How dangerous is it to take an x-ray photograph, and what benefits and risks have to be taken into account before being x-rayed? Thus, the judgment side of the framework model actually finds its home in “talking science.”

Last but not least, the “fun factor” should not be forgotten. When the x-ray unit was tested in the classroom, the students loved to present their x-ray photographs and they eagerly scrutinized them in order to find the fractures. Both boys and girls were fully engaged in taking their own x-ray photographs (thereby drawing their own “fractures”). Embedded in this medical context, they intensively discussed the electromagnetic wave spectrum and its applications and most of the students also appreciated participating in the prism experiment. The evaluation of the unit revealed widespread acceptance and an urgent demand for more lessons of this kind.

In fact, teachers and teacher educators all over the world have developed many similar teaching units. Only a few of them have received wider recognition. In order to make use of these hidden gems, international projects have been launched to identify and promote these innovative approaches for teaching and learning science. KidsINNscience, presented in Vignette 2 included in this chapter, is such a project. Indeed, through this project, the teaching unit on x-ray photographs developed in Switzerland has enjoyed much attention from teachers in other countries, and as a result, it is likely to be used to promote health literacy in many classrooms in different parts of the world.

Vignette 1

Toni Müller, Albert Zeyer, Schulhaus Turmatt, and Stans, Switzerland

X-ray Photographs in the Classroom

Teaching Unit for 7th or 8th Grade, Lower Secondary Level (All Levels)

Copyright:

This teaching unit may be downloaded, copied, and reproduced free of charge for teaching purposes and without any restrictions. Adaptations are allowed. This is subject to reference of the original source of the teaching material (EducETH, PHZH, ETH Zürich, Universität Zürich) and the authors.

1 Preconditions and Teaching Material

1.1 Outline of the Content

This teaching unit focuses on the relation between x-ray beams and visible light. By the end of the unit, students will be able to apply their experiences and understanding of light waves to x-rays. The students will learn:

- About the findings of James Clark Maxwell (1831–1879): visible light is only a small part of the electromagnetic spectrum (please refer to the figure on the exercise sheet).
- That x-ray beams are short waves and "rich in energy." They are able pass through the human body except for the skeleton.
- That the shadows cast by the human body are depicted in x-ray photographs. Areas where x-ray beams are absorbed strongly by the human body are light on the x-ray picture. Areas where the x-ray beams can pass through the human body unabsorbed are dark on the x-ray picture as they react with the film negative. This is just like a photo negative. This principle will be familiar to students, which means that this teaching unit is suitable for low-achieving classes in science and technology.

1.2 Materials Needed

- X-ray photographs, for example, students bring their personal x-rays to school; see below
- Overhead projector, slide projector, or beamer
- Material to demonstrate/conduct experiments for the topic "optics," for example, a light/ray box, prism
- Skeleton, thorax model
- Transparent plastic sheets to be cut, for example, folders to file documents
- Optional: a camera (analog) to produce film negatives

1.3 Class Preparation Before the Teaching Unit

Personal experiences of the students: students should write a brief text about their personal experiences with x-raying and bring in x-ray photographs to class if applicable/available, for example, from their family doctor or dentist (this worked very well when this teaching unit was tested).

[A group of students can share one x-ray photograph. In this case, the respective students have to make an informed decision about how to share this sensitive data with their class mates. As a backup, the teacher can provide x-ray photographs of anonymous people taken, for example, from the internet. However, this lessens the direct relevance of the content for the students, which has been found to be a key ingredient in motivating students for the subject in this teaching unit.]

2 The Teaching Unit on X-rays

2.1 Lesson 1 Introduction to the Topic X-rays (50 min)

Duration (mins)	Activities	Material
20	Place on the overhead projector the x-ray photographs from students who volunteer. Give the students the opportunity to explain what is going on in the photograph. Examine the x-ray photographs as a class: which bones can the students identify? Can they be located on the skeleton?	X-ray photographs Overhead projector
5	Ask students to formulate their own question about x-rays. Collect the questions on a flip chart or on the blackboard. Remind the students that there are no "stupid" questions: How does x-raying work? How harmful are x-rays? Why are these waves called x-rays? What do we need x-rays for? Include questions that arise later also in the collection on the flip chart: How were fractures diagnosed before the invention of the x-ray machine? If you do not see anything on the x-ray photograph, what other possible diagnoses are there? What are laser beams? Can light be harmful, too? How is the x-ray photograph projected on the screen?	
25	**Experiment carried out by students**: Refracted light produces a colored spectrum. [Figure refraction of light by a prism]	Experimental material "optics" Exercise sheet 1

Comments on the different phases of the lesson:

Reports from the Students

[…] The challenge is to spend no more than 15 min on the introductory part.

Electromagnetic Spectrum

[…] Students have become familiar with features of x-ray beams, and they are prepared (for the next lesson as they know) that certain features can be observed for visible light, too.

2.2 Lesson 2 Visible and Invisible Light (45 min)

Duration (mins)	Activities	Material
5	Use exercise sheet 1 from the last lesson and repeat the results of the students' experiments (maybe as a demonstration experiment).	Exercise sheet 1
10	Discuss the electromagnetic spectrum: visible light, infrared, UV light, radio waves, x-rays.	Exercise sheet 1 (3rd exercise)
	[Figure spectrum of electromagnetic waves]	
30	Option 1: Student exercise: look for information on the internet and compile a profile of William Conrad Röntgen. The profile should include important dates, aspects of his life, his work as a researcher, and his discoveries.	
	Side note: Instead, students could carry out the research in groups and present their results in the end. Topics could include Röntgen's curriculum vitae, discovery of x-ray beams, and properties of x-ray beams.	
30	Option 2: Alternatively show a video about x-rays and discuss the questions on the exercise sheet "film."	

2.3 Lesson 3 Building a Model of an X-ray Machine (45 min)

Duration (mins)	Activities	Material
5	Repetition: Visible and invisible light	
40	Group work: Build an x-ray machine.	Slide projector
	The groups build a model of an x-ray machine with tables, flip chart sheets, and slide projector. Give a part of the demonstration skeleton (e.g., an arm, a leg, the skull, the thorax) to each group and ask students to draw an x-ray photograph. In addition, students should draw an injury/defect in their picture.	Flip chart Pens

Comments on the Different Phases of the Lesson:

Shadows when Projecting

Fig. 1 X-ray machine

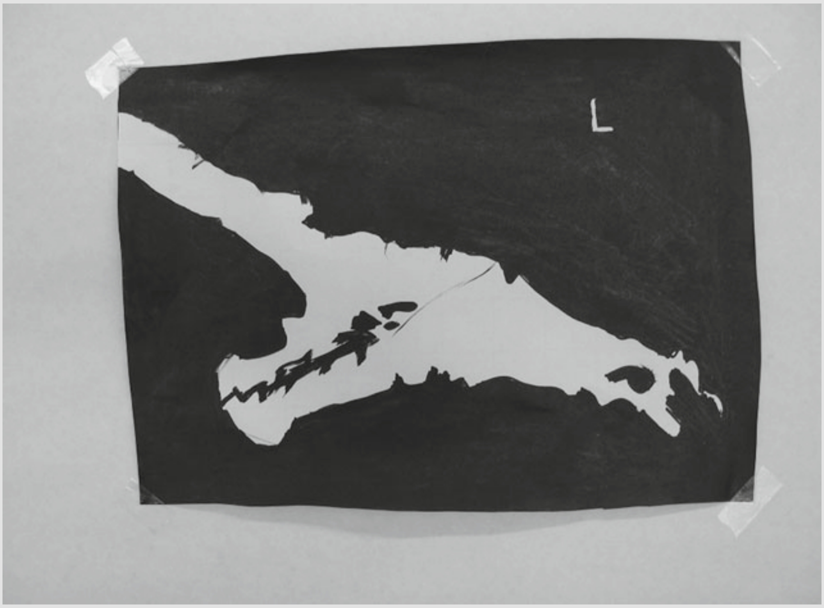

Fig. 2 X-ray photograph

One way to create images with the model x-ray machine is to use bones in front of a strong light source to cast a shadow on a sheet of flip chart paper (Fig. 1). From behind this screen, the bone structure can be outlined with a pen or pencil. Students are free to arrange their pictures as they like. Usually, students reflect spontaneously on film positives and negatives. Some students added fractures to their picture (Fig. 2). The teacher could encourage groups to do so.

To discuss film positives and negatives, teachers can hand out film negatives from an analog camera. Alternatively, digital photos can be transformed into a negative with the help of computer software.

2.4 Lesson 4 Shadow Images/X-ray Patterns (45 min)

Duration (mins)	Activities	Material
5 (10)	Discuss exercise sheet 2 (shadows and film negative) or instruct students to work on the sheet alone.	Exercise sheet 2
20	Discuss exercise sheet 3 (photographs from inner organs) or instruct students to work on the sheet alone.	Exercise sheet 3 Overhead projector
10	Look at the x-ray photographs (probably on the exercise sheets) and discuss them with students using the newly acquired knowledge.	Overhead projector
	Again, use selected x-ray photographs from the students, which were used in Lesson 1.	Beamer
10 (5)	As a class, look at the students' questions on x-rays formulated in the first lesson and later. Discuss: Which questions have been answered? Which questions need to be added?	

Comments on the phases of the lesson:

Drawing an X-ray Photograph of a Thorax

Refer to exercise sheet 3. In contrast to bones, inner organs do not absorb all x-rays and therefore cast lighter shadows. Some organs appear to lie on top of each other so that the x-rays they absorb accumulate. Illustration: cut out organ shapes from different color transparent plastic pockets and project them on a screen using the overhead projector. The students should copy the projection as black and white drawing.

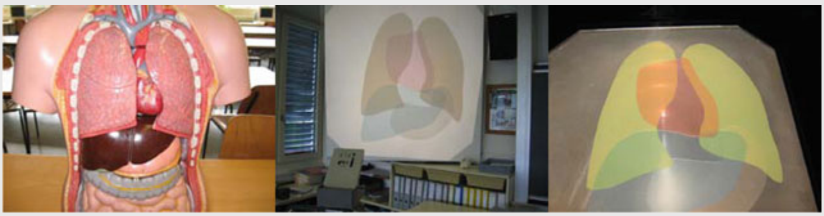

Fig. 3 Inner organs as shadows of organs cut out from transparent plastic pockets

Looking at the Students' X-ray Photographs Again

To close this teaching unit, it is advisable to show the students an unknown x-ray photograph of a thorax. The students can interpret it with their newly acquired knowledge. X-ray photographs from the Internet can be used for a PowerPoint slide show; chose photographs from websites which include explanations of the photographs.

Vignette 2

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kidsINNscience. Innovation in Science Education – Turning Kids on to Science

kidsINNscience. Innovation in Science Education – Turning Kids on to Science[1] is a research project involving ten partners in Europe and Latin America that aims to identify and promote innovative approaches for teaching and learning science. The goals are to facilitate educationalists at different positions in the educational system to operate more creatively within the system and to help generate changes toward active learning systems. It also aims to improve performance and interest in science and technology (S&T) amongst young people.

The basic assumption is that innovations in S&T education work efficiently if they meet agreed quality criteria and are adapted to the local circumstance and conditions. Therefore, kidsINNscience proposes to adopt adaptive strategies to enable participating countries to learn from each other and to develop feasible innovation plans and carry out effective pilots that fit the specific needs and conditions of a given country.

Main questions that the project addresses are:

1. What strategies for teaching and learning in S&T motivate teachers and learners in the participating countries?
2. What similarities and differences are there in innovating S&T teaching and learning in the participating countries?
3. What strategies to innovate S&T teaching and learning would work in the participating countries, considering their characteristics of S&T teaching and learning?

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[1] kidsINNscience is a collaborative SICA project funded under the 7th Framework Programme of the European Union. Participating countries are Austria, Brazil, Germany, Italy, Mexico, the Netherlands, Slovenia, Spain, Switzerland and the United Kingdom. Duration: November 2009 to July 2013. For more information, see www.kidsinnscience.eu. Disclaimer: The views expressed are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Union.

Steps Taken

Up to date (June 2011), following steps have been realized within kidsINN-science to find solutions to the challenges in S&T teaching and learning in the participating countries:

First, an initial set of quality criteria to describe and compare S&T practices and methodologies was agreed upon. Addressing environmental and health issues in science education was considered a quality criterion because these topics connecting to the everyday experience of pupils and students and to socially relevant decisions can be a starting point for scientific literacy.

Second, in each participating country, innovative practices meeting the quality criteria were collected and described. From the resulting compilation of 81 innovative practices in science education, a fourth (22) address environmental and health issues or Education for Sustainable Development (Mayer and Torracca 2010, p. ix).

Third, each country selected five innovative practices originating from other partner countries for adaption to the national educational conditions. In the first phase of the selection process, each partner country reduced the compilation of innovative practices to about 20 examples for potential adaptation, a manageable number of teaching units to be shared with the teachers. In the second phase of the selection process, each country identified – in close collaboration with the teachers implementing the innovative practices in field trials – five teaching units to be adapted. Features of innovative practices that have been selected by several countries are addressing socio-scientific issues, being set in a science-technology-society perspective, being the product of science education research and having been tested in schools (Jiménez-Aleixandre and Eirexas-Santamaría, 2010).

The adaptation process was framed by the following guidelines: coherence with the concept of Inquiry-Based Science Education (IBSE), preservation of the key features of the innovation and identification of the features or dimensions in need of change (Jiménez-Aleixandre and Eirexas-Santamaría 2010 p. 41/42).

Currently, the adapted innovative practices are implemented in a number of schools (school years 2010/2011 and 2011/2012). The field trials will be evaluated with respect to feasibility and effectiveness of activities. In addition, the clusters of partner countries adapting and implementing the same innovative practice of origin will allow for an interesting analysis of the changes applied against the backdrop of the individual national and local context.

Finally, based on the results of the field trials, the set of quality criteria for innovation in teaching and learning of science will be revised and country-specific strategies for innovating S&T education will be formulated.

During all steps, cultural diversity, gender aspects and activity-based and learner-centered approaches such as IBSE are explicitly addressed.

In the following, we will illustrate the adaptive approach applied in kidsINNscience with a teaching unit that combines physics with human biology and medicine.

An Example: X-rays: A Combination of Physics and Human Biology/ Medicine

Scan for Innovative Practices

When scanning Swiss teaching units for innovative practices in S&T education, we encountered "How x-ray photographs are produced" (short "X-rays"), a teaching unit for 13–15-year-olds by Toni Müller and Albert Zeyer (available from www.educ.ethz.ch/unt/um/ta/roe). There, students get acquainted with the spectrum of electromagnetic waves, in particular x-rays, and learn about their relatedness to light waves. Through experiments with casting shadows, the students grasp the principle of x-ray beams and students are able to come up with basic anatomical interpretations of x-ray photographs.

This example addresses several challenges in science education relevant to Switzerland, but not only there (Mayer and Torracca, p. 134):

(a) Low interest of pupils/students in science classes, particularly in physics. Approaching physical phenomena in the context of their application in health issues increases young peoples' interest, especially girls'.
(b) When school science is taught as separated subjects (biology, chemistry, physics), this does not reflect the interdisciplinary character which research questions and applications in S&T often have.
(c) In certain areas of Switzerland, school science is taught as "integrated sciences" at lower secondary level. Appropriate teaching and learning material is scarce.

Amongst others, the teaching unit "X-rays" features the following quality criteria from the initial set agreed upon in the project kidsINNscience: it addresses national problems in science education by taking gender issues into account and stimulating motivation and interest in science. Furthermore, it allows for diversity in learning materials and teaching methods, uses resources and teaching contexts from outside the school, includes practical work (hands-on activities, experiments, etc.), stimulates collaborative work and uses ICT skills.

Reception of the Innovative Practice Abroad

For the preselection, five out of eight[2] countries chose "X-rays," rating its flexibility and potential for adaptation in their country as being relatively high (3 and 3.2 on average, on a scale from 4 (high) to 1 (low)) (Jiménez-Aleixandre and Eirexas-Santamaría 2010, p. 23).

Later, three countries included the teaching unit in their final selection of five innovative practices (Austria, Brazil, Spain). One more country integrated it in a selection of four innovative practices from which the teachers eventually chose another one for adaptation (Italy).

Besides the quality criteria identified during the scan, reasons named for the choice of "X-rays" range from the countries' interest in interdisciplinary approaches in science education (Austria, Brazil, Italy, Mexico) – here, desirable links between two cross-curricular topics, health and physics – the teaching unit's flexibility to be adapted and implemented across a wide range of school types, curricula and student ages (Austria, Brazil, Mexico, Slovenia, Spain) to practical considerations such as use of low cost and authentic daily life material (Austria, Brazil, Spain) and the possibility to incorporate it into regular teaching hours (Slovenia).

Adaptation to a Different Context

In Brazil, the innovative practice was adapted to the school year when radioactivity is taught (student age 12–14 years) and extended from 4–5 lessons to 7 lessons. Links between health education and science education and between physics education and environmental education were emphasized, as was the history of science for the teaching about the nature of science. New activities added are, e.g. the subject of irradiation, analyses of characteristics of sunscreens based upon information available in labels, a discussion about atomic structure, the understanding of how x-rays affect living organisms, a lecture of a health professional or medical physicist (specialist in radioprotection), environmental issues such as student research on methods to extract and recycle silver from used x-ray plates and residue of chemicals used in the development from x-ray plates and the optional construction of a solar collector to expand the knowledge about electromagnetic radiation (Jiménez-Aleixandre and Eirexas-Santamaría 2010, p. 59 and Annex 80–82). Field trials will take place in August 2011.

In Spain, the innovative practice was adapted to low-achieving students of age 12–16 years. Emphasis was given to student activities and the harmonization

[2]The selection had to be made amongst innovative practices originating from the other partner countries, i.e. Switzerland could not choose this innovative practice; one partner country made no preselection.

with the curriculum, with the option of increasing the number of lessons used. New activities added are the following: "How can we observe and measure invisible things by using light?," the digital camera as starting point to illustrate the idea of "invisible light" emitting from a distance, different illuminants representing different types of light (e.g. fluorescent tubes, light bulbs, light-emitting diodes (LED)), demonstrating the partial transmission of electromagnetic waves through body parts by having a strong light source shine through the ears, discussing the importance of x-rays in the context of public health such as mammography, dental x-rays but also extensive sunbathing and a critical look at the authenticity of popular series playing at a hospital such as "ER," "Grey's Anatomy" or "House" (Jiménez-Aleixandre and Eirexas-Santamaría 2010, Annex 88/89). A field trial is currently running with the intention to increase the students' interest and confidence in learning science, to bring modern and contemporary physics to the classroom and to improve the coordination between biology and physics.

The selection and adaptation of the teaching unit "X-rays" exemplary shows that health issues in science education are considered to have the potential of addressing challenges in science education. The field trials will show whether this is true and whether the adaptive approach across countries can contribute to the solution of challenges in science education. The evaluation results will be published in fall 2012. Certainly, it can help make solutions known outside the scope of their country of origin and language.

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8 The Framework Model in Science Education

The efforts to realize the mutual benefit of health and science education have been somewhat accidental and contingent, as discussed earlier in this chapter. Often, health issues have not been the focus of interest, and as a consequence, their potential use for science education has not been fully exploited. The framework model can be used to help to improve this situation. Through the lens of this model, a teacher or a teacher educator who is to develop a science lesson in a health context will be able to clarify their aims and to see all the avenues open to them through the selected health issue. A systematic application of this model provides an encompassing view on different aspects of a health issue and the role that science education may play in its context. Conversely, given a certain topic of science education, the framework model may be used to help to find an appropriate health context for a science lesson and to reveal further aspects that should be taken into account when working in the chosen context. Teaching units that are created against the backdrop of the framework model will share a common structure regardless of the difference in content, and the rationale will reflect the model's structure; argumentative fallacies and shortcuts will be avoided. While teaching, a teacher may find it convenient to refer to the framework model as a guideline and as a red thread that organizes and structures the lesson. It may also have a methodological impact on the way a teacher or teacher educator teaches.

Many of these aspects also point to research questions that require investigation in science education. Thus, the model may also be used as a theoretical framework for research in the field. The model itself should become the subject of empirical research in order for it to be confirmed or else modified and improved. Since, in socioscientific contexts, the discourse of students can often be considered as a mirror of society (Zeyer and Roth 2009), further analysis of students' talk on health issues in the light of the framework model could also be interesting in a broader societal context.

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Revising Science Teaching: Responding to Challenges of Health and Environmental Education

Albert Zeyer and Regula Kyburz-Graber

This final chapter is intended to bring together and discuss the contents of this book, which contain a variety of perspectives, styles, attitudes, and intentions of the authors. All the contributions are strongly framed by conceptual standards, which reflect the state-of-the-art in the field. As a result, the authors, who sometimes offer quite controversial standpoints, are able to introduce several key lines of reasoning and add profound new perspectives to each topic. In this concluding chapter, we do not intend to harmonize different positions but to gather together the various arguments and concepts and to use them to form an overall picture for the reader. We have decided to structure this chapter by reflecting the motifs and themes that can be found in one or another way in all contributions to the book. This list is by no means exhaustive, and neither is this overview, which, of course, cannot and does not want to oust the authors' rich and multifaceted original contributions.

In the first section of this final chapter, arguments underlining why health and the environment *matter to science education* are the focus. This is followed by a section in which health and environment are considered as resources for *socio-scientific issues*. A third section elaborates on *knowledge issues* since health and environmental literacy both are inherently knowledge-based. The fourth section points out that science pedagogy inspired by health and environment would encourage the inclusion of a *first-person perspective*, while in current school science curricula, "objective" scientific knowledge has traditionally counted as the only legitimated knowledge.

In a fifth section, the authors look to the future of science education; some of the main aspects that are common to the variety of approaches suggested by the contributors to this work are drawn together in a *science education revisited.* The sixth and final section of the chapter highlights the key role of teachers and teacher education for getting underway a revised science pedagogy.

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1 The Importance of Health and Environment in Science Education

A basic consensus in this book is reached as each author argues for a more intentional and prominent inclusion of health and environmental issues in science education than at present. The title of this volume, which adopts a suggestion made by Dillon in his chapter, refers to the potential mutually beneficial relationship between these three fields in a revised pedagogy of science education. While all authors agree on this basic idea, they reach this conclusion in a variety of ways.

1. The first argument for the concept of science|environment|health can be summated under the heading *informed citizenship*. This argument finds great support among the chapters written by Fensham, Bybee, and Dillon, and it is also visible, although not preeminent, in the texts crafted by Keselman, Hundal, and Smith;, Schulz and Nakomoto,; and Zeyer. The argument finds its common ground in what Fensham has named the Grand Challenges and Opportunities of the twenty-first century (Table 1). These challenges consistently incorporate issues directly or indirectly related to health and environment.

   As a result, Fensham and Bybee diagnose an ultimate urgency for education to address these challenges. A public climate should be fostered in which difficult political decisions to be made in the future will be supported. Dillon points out that the cost to society of a range of conditions from environmental pollution to alcohol abuse and obesity will rise in a way that will increase the pressure to reflect health and environment in the core of future curricula. Schulz and Nakamoto argue that issues of health and healthcare will dominate social, political, and economic discourse around the world because of their impact on humans and their

Table 1 Grand challenges and opportunities of the twenty-first century (chapter Fensham)

Professional organization	Year	Grand challenges and opportunities
National Research Council, USA	2001	Bio-geochemical cycles, climate change, biological diversity, hydrologic forecasting, infectious diseases
The Gates Foundation	2003	Improve childhood vaccines, control insect transmission of disease, improve nutrition minimize drug resistant organisms
National Research Council, USA (Chemical Industry)	2005	Carbon management, renewable fuels, green chemistry and engineering, life cycle analyses
American Association for the Advancement of Science	2006	Global warming (sea levels, etc.), burning coal cleanly
National Academy of Engineering, USA	2008	Solar electricity, manage nitrogen cycle, advance health informatics, access to clean water, carbon sequestration, secure cyberspace, prevent nuclear terrorism. Fusion energy

enormous costs for society at large. Zeyer refers to Kickbusch who calls health a megatrend of society.

All these authors see overwhelming evidence for a growing societal pressure for health and environment to have a more prominent role in (science) curricula. Informed citizenship, based on scientific literacy, and in particular health and environmental literacy, will enable people to successfully participate in the political discourse and thus drive society toward solving the great challenges and seizing the historical opportunities of this century. Bybee condenses this educational approach of informed citizenry into what he calls the *Sisyphean question*: given a life situation that involves health or environmental issues, what should citizens know, value, and do? This question also underlines the relevance of an affective dimension of scientific literacy in addition to its cognitive dimensions, a point again discussed below.

Some of the authors have complemented the *informed citizenship* argument with a dual aspect that Keselman, Hundal, and Smith call the *improving daily life* argument. It is particularly present in texts in which health literacy is a focus of the discussion. For example, Keselman, Hundal, and Smith investigate how people proceed to try to understand medical documents and use the Internet to search for information. They are also interested in how young people identify and reject HIV myths. Schulz and Nakamoto focus on how people may cope with the mass of health information available to them in the media and they report a case study in which the factors that enable people to correctly deal with antibiotic treatment are identified. Through a framework model of health literacy (Fig. 1), Zeyer tries to understand the decision-making processes of people who are reasoning whether or not to be vaccinated and people who are learning to cope with a chronic illness like chronic polyarthritis. These authors are not focused on the grand challenges, but rather on the less spectacular challenges people face each day.

Zeyer's framework model, based on an earlier model proposed by Gräsel, avoids including action into its schema by intention. Indeed, Kyburz-Graber points out that the relationship between knowledge and action, that is, the dilemma of whether or not informed students will act as informed adults throughout their lives, has been a focus area of environmental education research for decades. She argues that while research studies may have revealed a disappointingly low correlation between knowledge and action, research designs are often unable to take into account the complexity of what can be considered as knowledge and what happens in learning processes. She does not fundamentally question the argument that students may become informed citizens as a result of the inclusion of environment and health issues in science education, but she does claim that teachers and students in their classrooms must discuss in a discursive context the topics that matter to them (knowledge) and the areas they find difficult in terms of environmental intervention (action).

In his chapter, Hart goes further when he states that the traditional framing of school science makes it difficult for teachers (and students) to expand learning into spheres of subjectivist and social/relational learning. These spheres would in fact enable teachers to gain a better understanding of the ways in which, and the

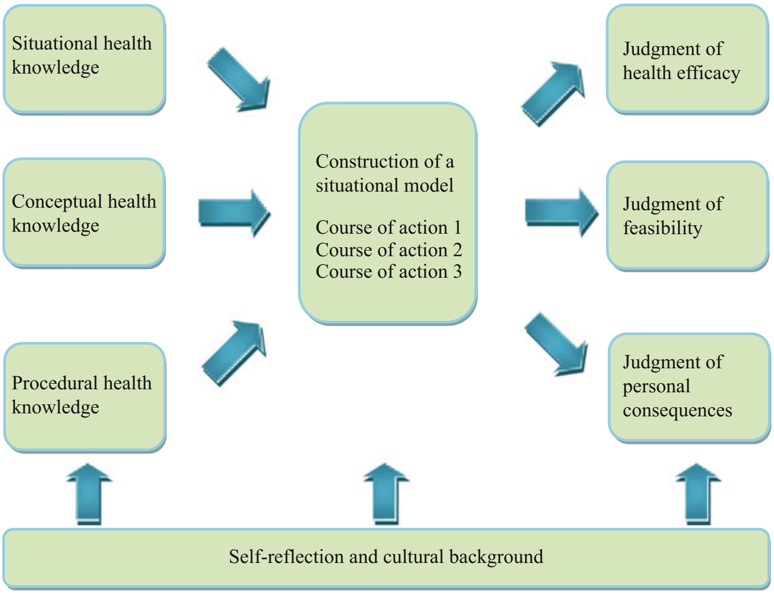

Fig. 1 A framework model of health literacy (Chapter Zeyer)

reasons why, students may choose to do certain activities and not others during school science. Teachers would also be able to more successfully determine the rationale for people's choices in a broader sense, outside the classroom, in places where people live and act.

2. The second argument for a science|environment| health pedagogy can be called the *awakening interest for science* argument. This argument finds impressive support in the findings of PISA 2006 on health and environment, as they are presented in Bybee's chapter, and in the results of the ROSE study, referred to by Dillon. Health topics in particular (including medicine) are attractive and interesting for most students. In PISA 2006, the ten topics students found the most interesting were all directly or indirectly concerned with health and medicine (Table 2). In the ROSE study, particularly girls' interests were predominately focused on health and medicine-related topics. Bybee and Dillon both conclude that including more health and environmental issues in science education can help to foster students' interest and motivation in science and science education.
3. The third argument reveals that incorporating health and environmental issues in science education can help in *promoting scientific literacy*. The authors in this book often refer to the distinction between *Vision I* and *Vision II* of scientific literacy as has been defined by Roberts. In *Vision I*, the emphasis is placed on learning subject matters, including major concepts and processes in science, while learning science in the context of life situations, which includes science and technology, are of the greatest importance in *Vision II*. Bybee argues that school science programs should incorporate *Vision II* clearly, consistently, and continually,

Table 2 The ten topics in which students showed the *most* interest (Chapter Bybee)

OECDrank	Non-OECD	Question label	Topic [*How much interest do you have in the following information]*
1	**1**	Fit for drinking QNc	Learning which diseases are transmitted in drinking water
2	**2**	Sun and Health QNa	Knowing how sunlight causes skin cancer
3	**5**	Physical Exercise QNa	Understanding better how exercise affects your muscles
4	**4**	Good Vibrations QNa	Knowing your own hearing sensitivity by having it checked
5	**3**	Physical Exercise QNb	Learning how your body controls your breathing rate during physical exercise
6	**18**	Airbags Q9Na	Knowing why airbags can be dangerous in some accidents
7	**7**	Good Vibrations QNb	Knowing how your hearing is damaged by loud noise
8	**9**	Alex's Band QNa	Understanding how loud music can damage your hearing
9	**6**	Mousepox QNc	Understanding better how the body defends itself against viruses
10	**11**	Tobacco Smoking QNc	Learning how the body recovers after stopping smoking

and that health and environment contexts are helpful for doing so. Fensham also advocates a general shift of the focus of school science to *Vision II*.

As an alternate route, Dillon suggests an interesting combination of the two visions. In this approach, the focus of *Vision I* would be on a range of issues and topics such as climate change, environmental causes of cancers, and growth and reproduction. Whereas the focus of *Vision II* would be on ethical issues including, for example, stem cell research, how climate change scientists work and the role of the pharmaceutical industry in drug research. For Dillon the consideration of value judgments in *Vision II* is of particular importance. This term can be understood as ethical in a narrow or broader sense, as discussed in the section below on first-person perspectives.

4. The fourth argument, especially put forward by Kyburz-Graber and Hart, is the *critical approaches to science* argument. These authors both conceive a wider perspective on environment and health in science education, which is grounded in critical discourses on the role of science in society and the role given to science in school contexts. Kyburz-Graber considers the possible contributions science has to offer for the future development of society as well as where the limitations of science should be accepted. Hart sees that critical perspectives are necessary not only for science itself but also for science education that includes the process of inquiry and critical reflection. Inspired by a critical ecological pedagogy, Hart writes that teachers and students should be involved in the construction of social and environmental consciousness, involving critical and creative thinking and

problem-solving skills, the consideration of values and ethics and political literacy in democratic decision making. In his chapter, Hart refers to Stevenson who questioned the uncritical role of schooling in reproducing rather than troubling existing social conditions. Hart is convinced that there is no way back: in his view, the poststructural debates on various aspects of human life and societies have already begun to test preconceptions of schooling in constructive ways. Hart argues that if teachers in their own education phase learn to scrutinize their ways of learning science, the dominant model of teaching science may break down.

2 Socio-scientific Issues

Central to all these approaches is to conceive health and environmental topics as important socio-scientific issues (SSIs) in science education. Keselman, Hundal, and Smith, drawing on Sadler, define SSIs as open-ended, often contentious dilemmas, with no definitive answers, which are deeply embedded in both social and scientific factors. SSIs embody four crucial characteristics, as described by Fensham, in reference to Wynne; these are risk, uncertainty, ignorance, and indeterminacy. Based on the so-called Cynefin Framework proposed by Kurtz and Snowden, Fensham categorizes SSIs (Table 3) according to their degree of uncertainty into simple SSIs, complicated SSIs, and complex SSIs. Simple and complicated cases, in principle, can be fully understood by applying natural laws of science. In complex cases, uncertainty cannot be fully mastered by the application of natural laws. It must be accepted as essential. The fourth category, chaos, is when an SSI has reached an uncontrollable state that is beyond the rationalities of science education.

Table 3 The location of school science and science education for socio-scientific contexts issues in the Cynefin Framework (Chapter Fensham)

Natural laws of science hold	Uncertainty holds
Simple cases **90+ % of school science (established mono-disciplinary knowledge)**	*Complex cases* ***Pilot teaching of S&T projects and SSIs (inter-disciplinary science and other knowledge disciplines)***
Contexts: idealized and contrived with directed laboratory exercises	**Contexts**: real world, in- and out-of-school projects including uncertain science and argumentation
Learning: one *correct answer (knowledge from established science)*	**Learning**: *possibilities and probabilities (balancing uncertainty in knowledge and its interactions)*
Complicated cases **≈10% of school science (interdisciplinary science knowledge)**	
Contexts: real world involving established science and open-ended laboratory exercises)	CHAOS
Learning: one *or more correct answers (knowledge from several sciences)*	

Fensham's point is that almost all of traditional school science is situated in the simple-cases quadrant and only up to 10% in the complicated-case quadrant of the Cynefin framework. Yet, as Fensham indicates, humanity is today locked in a complexity race, and science education must reflect this situation. Health and environmental contexts can help students to foster their ability to cope with the crucial aspects of complexity, while traditional school science cannot. Dillon also underlines the importance of learning to understand and deal with risk, and that this is poorly addressed in traditional science curriculum. He introduces the term "soft disasters," environmental and political crises that emerge slowly but are costly to society. These soft disasters are typical for health and environmental SSIs and should be recognized and taught about in science education.

Kyburz-Graber stresses the importance of remembering that interpretations of scientific observations and findings are never value-free but are dependent on the social context; this position is inherent to socio-scientific issues. Using the example of climate change, she illustrates how the so-called facts are interpreted and changed during communication and dissemination of information about climate change among scientists and in society. The point Kyburz-Graber is making about socio-scientific issues is illustrative of the shift that Hart talks about in increasing science teachers' awareness of that possibility that science as a way of knowing (realist-empiricist) can accommodate social constructivist as well as relational ways of knowing. Hart identifies a fundamental problem of school science, which, in its traditional grounding within a realist perspective, excludes epistemological, ontological, and socio-political issues of theory and practice. The inclusion of socio-scientific issues and theory can encourage teachers and students to engage in asking and exploring questions, which in turn break down boundaries that surround traditional scientific concepts.

In all these discussions, SSIs are understood in terms of large-scale contexts on the political and societal level. Again, the authors concerned with health literacy underline that the small-scale individual level is equally important. For example, almost any individual health situation, analyzed in terms of the health literacy scheme provided by Schulz and Nakamoto, or in terms of the framework model proposed by Zeyer, proves to be a SSI *in nuce* (that is, in a nutshell) that includes aspects of risk, uncertainty, ignorance, and indeterminacy. Based on the findings of PISA 2006, Bybee provides in his chapter an overview that combines the local and the global views (Table 4).

SSIs open the field for learning to cope with risk, uncertainty, ignorance, and indeterminacy. Yet, in this book, an interesting, somehow converse aspect is also frequently pointed out. Indeed, the aim of a literate approach to health issues can also be to actually reduce risk, uncertainty, ignorance, and indeterminacy for people. For example, in Schulz and Nakamoto's investigation of health literacy in the context of antibiotic treatment, the authors implicitly assume that a well-defined correct way of antibiotic treatment exists for promoting and maintaining good health. In their examination of how adolescents come to identify and reject HIV myths, Keselman, Hundal, and Smith's make an implicit assumption that both correct and incorrect ways to deal with HIV exist. The incorrect ways are grounded

Table 4 Contexts for health, environment, and resources (Chapter Bybee)

	Personal (self, family and peer groups)	Social (the community)	Global (life across the world)
Health	Maintenance of health, prevention of accidents, nutrition, diet	Control of disease, social transmissions, food choices, community health	Epidemics, spread of infectious diseases, influenza, bio terrorism, climate change
Environment	Environmentally friendly behavior, use and disposal of materials	Population distribution, disposal of waste, environmental impact, local weather	Biodiversity, ecological sustainability, control of pollution, production and loss of soil, climate change
Resources	Personal consumption of materials and energy	Maintenance of human populations, quality of life, security, production and distribution of food, energy supply	Renewable and non-renewable, natural systems, population growth, sustainable use of species, climate change

Adapted from PISA 2006 Science (OECD 2006)

in knowledge structures that the authors call "myths," which is clearly a label of disqualification in this context.

Therefore, when a teacher intends to use a health topic as an SSI, the direction to be taken in a lesson has to be decided. Should the health-related SSI be used as a means to discuss issues of complexity (Fensham), ways of knowing and knowledge limits (Hart and Kyburz-Graber), and risk and uncertainty (Dillon)? Or conversely, should the goal be to improve the cognitive and social skills which determine the motivation and ability of individuals to gain access to, understand, and use information in ways that promote and maintain good health, as Schulz and Nakamoto quote the WHO health literacy definition of 1998? Some authors consider both aspects to be essential. Fensham, for example, agrees that much of the science in an SSI is well established and already included in the science curriculum of most countries. With a similar perspective in tow, Keselman, Hundal, and Smith describe the open-ended nature of SSIs and the absence of the one perfect solution as a pedagogical "double-edged sword." On the one hand, they write, SSIs allow educators to stress the interconnectedness of the scientific and the social, thus making science more relevant. On the other hand, the nature of science should not be understated as tentative and irrelevant, but an emphasis on how science contributes to the knowledge base of decision making is important, even if it cannot provide all the answers.

Again, Hart offers an alternative perspective. According to him, educators must not be concerned with de-emphasizing or stressing certain topics, but rather try to understand what is subjectively meaningful for the learners and how certain aspects can be made relevant for them. Hart argues that the issue in school science is not so much that science cannot answer all questions but rather that, according to Hodson, teachers are not educated to understand how dominant social values are already embedded within a supposedly neutral curriculum of "objectivist" science. Teachers who avoid using socio-political issues in scientific investigation in the classroom *are* taking a value position, and teachers who avoid controversial and critical reflection on inequalities or uncertainties and risks *are* building barriers to change.

3 Knowledge

At its core, the tension between accentuating and reducing complexity in a socio-scientific issue (SSI) depends on the way in which a person understands (scientific) knowledge. In this book, authors who focus on health literacy, which is knowledge-based by its very definition, are prone to highlight the helpfulness and the reliability of health-related (and medical) knowledge rather than ontological-epistemological discussions. Others, as Kyburz-Graber and Hart, who are committed to (scientific) knowledge's limits and its constructional aspects, take an opposing position. Hart, for example, points out that if teachers envision "objectivist" scientific knowledge to be the primary goal of school science, they will miss the important goal of equipping young people to view society in ways that can lead to critical change. Zeyer warns against falling prey to the naturalist fallacy by taking a shortcut from bio-medical knowledge to normative health promotional judgments. Although frequently suggested, no naturalist shortcuts exist between reducing the risk of lung cancer and giving up smoking, or reducing the risk of high blood pressure and increasing physical activity. Such claims inevitably must also involve situational constructions, though this is usually not made transparent. If people have diverging situational constructions, then the situation will be evaluated in a variety of different ways, which will entail different outcomes.

Independent of these epistemological issues, a more technical question can be asked about what types of knowledge should play a role in health and environmental literacy. Keselman, Hundal, and Smith distinguish between factual knowledge and conceptual knowledge. In their text, factual knowledge has a negative connotation as superficial and fragmented, while conceptual knowledge is positively valued as rich, connected, and with a deep understanding of relationships and mechanisms. Declarative knowledge, which is the knowledge of objects, events, and relationships between them, is understood as a part of conceptual knowledge, and both declarative and conceptual knowledge are considered to be separate from procedural knowledge, which is the knowledge about how to do something. Schulz and Nakamoto, in their chapter, do not use the term conceptual knowledge and instead they differentiate between declarative and procedural knowledge. Zeyer, on the other hand, adopts Marglins distinction between algorithmic and experiential knowledge, which both include declarative and procedural elements.

The much debated question has been which type of knowledge is needed to foster health and environmental literacy. The authors in the book agree that if *talking science* is to be more than simply holding a nice talk on attractive topics, involving the correct conceptual knowledge is essential. Health education alone that is not supported by science education, write Keselman, Hundal, and Smith, is not likely to provide a solid basis for real-life reasoning and decision making. The greater the complexity of a case (analyzed in the Cynefin Framework), the more students require deep and connected conceptual knowledge in order to successfully deal with the case and to make literate judgments. Keselman, Hundal, and Smith show that reasonably substantial conceptual knowledge of infection paths and the immune system is needed to empower adolescents to approach HIV and AIDS in a literate manner. Zeyer provides a whole range of examples wherein health literacy calls for deep conceptual knowledge of biology as well as physics and chemistry. Schulz and Nakamoto point out that for students to adopt a literate approach to antibiotic treatment they need not only conceptual knowledge about the basic concepts of viral and bacterial infections, but also declarative knowledge about, for example, common infectious diseases that individuals are likely to encounter during their lifetime.

While Keselman, Hundal, and Smith acknowledge the importance of health-related procedural knowledge in daily life, their chapter does not discuss how or whether it should be taught in the science classroom. Zeyer, on the other hand, provides examples for teaching each of these knowledge types in science education. He argues that including aspects of situational and procedural health knowledge in science lessons is indeed one way to make science lessons attractive and relevant to all students.

According to Hart, school science will not be challenged by a push for knowledge acquisition, but rather by "storied forms of knowing," which are narrative approaches to knowing that cause young people to think about their position/subjectivity in the world. He sees learning as a process of constructing subjective meanings and building up conceptions of self. Knowledge in this respect cannot be merely a set of learned concepts or procedures, but is the ever-changing result of subjective and cultural narratives. Hart pleads for educators and researchers alike to look at what school science does to children especially in terms of how students construct themselves within their social world including the world of (school) science.

Finally, Schulz and Nakamoto point out the limits of knowledge acquisition. A health-literate person is not the same as an expert, they write. "Pale shadows" of experts, pseudo-experts, cannot be a desirable outcome of science education. Dillon, referring to Gayford, points out that even a teacher's understanding of complex cases will reach its limits. Not only because of a deficit in the required scientific knowledge but also because of a lack of experience in teaching value-based issues.

4 First-Person Perspective

Indeed, Dillon and other authors consider the integration of value issues into science teaching to be an important characteristic of socio-scientific issues-based science. Zeyer calls, with reference to Searle, (scientific) knowledge in its objective, interpersonal form a product of the third-person perspective. The previous section of this chapter has dealt entirely with this one type of world perception. Some of the authors of this book place great emphasis on a second, complementary type of world perception that is intrinsically subjective, but nonetheless essential to health and environmental issues; this is, in Searle's terminology, the first-person perspective.

This perspective is most prominently advocated by Dillon when he describes the possible form of students' experiences in his chapter. He writes about action-oriented educational activities such as scientific investigations of polluted water, of a commitment to a focus on helping learners to deal with the sheer complexity and splendor of the environment, and to engage students in hands-on contact with nature. Such clear formulations may give the reader an idea of the abundance of experiences that may be subsumed under the term first-person perspective. Dillon writes that a new science curriculum ought to provide opportunities for students to have individual responses and personal outcomes rather than to be pushed into the homogeneity (i.e., the third-person perspective) of contemporary (science) education.

Kyburz-Graber suggests that students should explore life situations including beliefs, values, interests, and meanings that are relevant for individuals and groups, including also inquiries into knowledge and beliefs about science. Their subjective perspective can provide the basis for such inquiries.

Schulz and Nakamoto state that we need to expand our vision of the ultimate subjective nature of a person's interaction with health information. Zeyer assumes that the turn to a first-person perspective happens in the situational construction of a health issue. While the involved (scientific) knowledge reflects an "objective" third-person perspective, the situational construction adds a subjective and a cultural perspective, which results in judgments on understandability, manageability, and personal meaningfulness.

Hart grounds his chapter in the argument that new perspectives on school science, such as socio-ecological, political, and cultural issues, will encourage students to engage in developing meaning and understanding through a profound process of subjectivity construction. He places particular emphasis on "identity work" and the need to explore what is really happening to young people as they are produced by the education system.

Judgment skills are also included in what Schulz and Nakamoto call the skill attainment view of health literacy. These skills enable a person who is confronted with different or novel aspects that appear in daily life to cope by making judgments on the basis of declarative knowledge. The ability to identify patterns and to adapt to discontinuous change by learning new patterns denotes again a turning point between a third- and a first-person perspective. It culminates, as Schulz and Nakamoto describe, in an inherently subjective ability, a wider notion of health literacy that has no meaning apart from personal (internal) experience. This subjective ability is identified as a combination of judgment skills and procedural knowledge, which falls closely along the lines of the classic concept of practical wisdom (*phronesis*) inherited from Aristotle.

5 Science Education Revisited

At this point, the discussion can turn to the future design of science education, and how it is to benefit from the challenge of health and environmental education. First of all, as Dillon puts it, health and environmental education should not be “swallowed up” by science education. He proposes the use of the term science|environment|health in order to make clear that for health and environmental education, there is and remains a role beyond a reconstructed science education.

Conversely, Keselman, Hundal, and Smith do not advocate for the replacement of basic science instruction entirely. They discuss the relative strengths and benefits of problem-based versus subject-based curricula and draw the conclusion that while SSIs of health and disease are complex and multidisciplinary, basic science education, organized around a set of scientifically, rather than socially, related concepts may provide more conceptual knowledge with fewer gaps and better organization.

Bybee proposes an interesting approach that takes into account both aspects. Science teachers in discipline-based courses could keep life situations in the background of their instruction and, as appropriate, briefly bring them to the foreground as examples, interesting applications, and meaningful connections to the primary subject. This strategy should be thought of as shifting SSIs related to health and/or the environment from the background to the foreground and to the background of instruction again. Long periods of time dedicated to SSIs are not needed, as Bybee asserts, but the teacher can continuously integrate these issues in a low-level, consistent, and continuous manner, and the impact on learning would likely accumulate and be a significant factor during the course of a year.

All of the authors who have their roots in science education in their chapters elaborate on curricular and pedagogical changes in response to the challenge of health and environment to science education. These proposals are rich and detailed and the present overview cannot account for the wide variety of approaches. Nevertheless, the various approaches do have common features.

First of all, their focus is never solely on either the curriculum or the pedagogy. The aim is to move beyond changing curricular topics, as Kyburz-Graber writes. Methods of teaching and learning must be questioned as well. Kyburz-Graber tries to characterize such new approaches by identifying three aspects. Firstly, less emphasis is placed on detached concepts but more on inquiries into authentic life situations with multiple perspectives. Secondly, fully predefined learning arrangements are replaced by more openness to what students really want to find out. And, finally, quantity is deemed as less important than in-depth investigation and meta-reflection. A major shift is required, as Dillon writes, to think about teaching students how to learn as individuals and groups rather than focusing on what they should learn. With this request, he joins Hart in arguing for more inquiries into the subjectivation process through school science.

Most of the new approaches outlined throughout the book are not directly designed to respond to the particular challenges of health and literacy. They stem from already

Table 5 Characteristics of an effective science pedagogy (Chapter Dillon)

Eliciting students' ideas about concepts and topics rather than assuming that they know nothing
The provision of concrete experiences supported by appropriate vocabulary so that learners become familiar with the subject matter
Choice of activities, so that they feel in control of aspects of their learning
Cognitive challenge, so that learners are presented with something which is challenging without being overwhelming
Plenty of time to discuss ideas with their peers and with adults
Feedback on their performance so that they know how to improve their work
Opportunities to practice operations so that they become confident in their skills
Time to engage with activities, so that they have an opportunity to think about problems without feeling too pressured

developed and tested programs, which have been concerned with the general use of SSIs in teaching. It is not the case, as one might assume, that the challenge of health and environment would entice science education down a completely new path. Rather these challenges are to be seen as catalysts to speed the change toward a science pedagogy that has already been spurred on by the concept of SSIs.

From this perspective, health and environment are primarily conceived as inexhaustible resources of SSIs. In particular, since the term health (literacy) always includes medicine, a wide field of attractive and relevant topics is available to be introduced into science education. Particularly, SSIs are not only to be found in the realm of big societal challenges, but also to be sought in the small-sized daily life of every human who has to make informed decisions about health and environmental issues. A whole range of individual health situations can be interpreted as SSIs, such as whether or not to be vaccinated, how to cope with chronic disease, how to live a healthy life and many more. The same holds true for environmental situations, which, as Kyburz-Graber points out, include not only the spheres of society and of global environment. Individuals also make their personal environmental decisions in a socio-scientific context.

Many frameworks, checklists, and guidelines proposed in the book will be remarkably helpful for the purpose of preparing and teaching science lessons. The Cynefin Framework for example, presented by Fensham, can help teachers to assess the interdisciplinary nature of a topic, the uncertainty of the science involved, and the importance of including teaching about risk in a lesson. The framework model of health literacy proposed by Zeyer is not only intended as a theoretical background for the analysis of health decision processes, but can also be used to develop health themes in the light of science education, to analyze the pedagogical potential of health issues and to structure the teaching and learning process in science lessons. A vignette by Müller and Zeyer, included in his chapter, provides a detailed example of how to thematize x-rays as a SSI in science lessons.

Dillon points out that social constructivist theories of learning, based on the works of Piaget and Vygotsky in particular, suggest characteristics of an effective science pedagogy (Table 5).

6 Teachers and Teacher Education

Many questions still remain unresolved. Science education research that focuses on socio-scientific issues is a relatively new field which may profit from investigating health and environmental contexts. The introduction of concepts like the Cynefin framework or the framework model of health literacy in research of science education may stimulate new research questions. In his chapter, Hart mentions a variety of theoretical and methodological research perspectives in environmental education which can inspire future research work on school science.

An important key for renewing science education lies with the experiences and beliefs of teachers, who have opinions on the best ways to teach and learn science, as well as what kinds of scientific knowledge can be considered legitimate and assessable. Kyburz-Graber, drawing on Stevenson, argues for professional teacher communities where a new discourse of professional learning could develop. In these communities, a participatory curriculum revision might be envisioned where teachers among themselves and together with learners critically reflect on the aims of science education and ways these can be addressed. Another field of inquiry for teachers' professional communities may be the much discussed and written about critical approach to scientific knowledge. Through further inquiries teachers may be led to explore learning experiences of their students, their concepts and image of science, and how they come to critically reflect on the relationship between science and society. In fact, teachers could become researchers in science education and thus contribute as actors to the transformation of the science curriculum and science teaching and learning. Health and environmental issues should be a major driving force in this reforming process.

Wolfensberger, Canella, Piniel, and Kyburz-Graber's vignette presents a current research project that explores how such learning processes can be initiated and how students in the upper secondary level of school can be encouraged to engage. For this research study, an example was developed from science history which was then used to show how scientific research is embedded in a historical, cultural, and social context.

Gerloff and Büchel show another approach to foster teacher communities on an international level in their vignette. kidsINNscience, *Innovation in Science Education – Turning Kids onto Science*, is a research project, in which ten partners from Europe and Latin America have been involved. The aim of the project is to identify and promote innovative approaches for teaching and learning science. The goals include facilitating educationalists at different positions in the eductional system to operate more creatively within the system and to help generate changes toward active learning systems. Another goal is to improve the performance of students and young people's interest in science and technology.

These examples are not solely focused on health and environmental issues. However, they provide powerful and already tried and tested instruments ready for use in pre-service and in-service training, and are, also in Dillon's perspective, a key for renewing science pedagogy.

Last but not least, the aim of this book is to stimulate further discussion on health and environment in science education, and to motivate teachers, teacher educators, and science education researchers to re-think science education through the lens of a renewed science|environment|health pedagogy.

Erratum to: The Concept of Health Literacy

Peter J. Schulz

Erratum to:
Chapter 5 in: A. Zeyer and R. Kyburz-Graber (eds.), *Science | Environment | Health: Towards a Renewed Pedagogy for Science Education*, https://doi.org/10.1007/978-90-481-3949-1_5

Dr. Kent Nakamoto should not be named as author to this chapter, as he did not fulfill all authorship criteria.

The extract of Kaldjian on p. 76 starting with "practical wisdom, acquired over time..." should have been placed in quotation marks. An institutional investigation by the Università della Svizzera italiana, Lugano, Switzerland found that this extract was not cited appropriately, but that any other overlap in this chapter was not significant.

The updated online version of this chapter can be found at
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