Albert Zeyer
Regula Kyburz-Graber *Editors*

Science | Environment | Health

Towards a Renewed Pedagogy for Science Education

Springer

Editors
Albert Zeyer
Insitute of Education
University of Zurich
Zurich, Switzerland

Regula Kyburz-Graber
Insitute of Education
University of Zurich
Zurich, Switzerland

ISBN 978-90-481-3948-4 ISBN 978-90-481-3949-1 (eBook)
DOI 10.1007/978-90-481-3949-1
Springer Dordrecht Heidelberg New York London

Library of Congress Control Number: 2012939620

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Contents

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

A. Zeyer • R. Kyburz-Graber
Institute of Education, University of Zurich,
Beckenhofstrasse 31, CH 8006 Zurich, Switzerland
e-mail: albert.zeyer@ife.uzh.ch; kyburz@ife.uzh.ch

A. Zeyer and R. Kyburz-Graber (eds.), *Science | Environment | Health: Towards a Renewed Pedagogy for Science Education*, DOI 10.1007/978-90-481-3949-1_1,

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.

P.J. Fensham (✉)
Monash University and Queensland University of Technology, Victoria Park Road, Kelvin Grove, QLD 4059, Australia
e-mail: p.fensham@qut.edu.au

A. Zeyer and R. Kyburz-Graber (eds.), *Science | Environment | Health: Towards a Renewed Pedagogy for Science Education*, DOI 10.1007/978-90-481-3949-1_2,

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

Index

A. Zeyer and R. Kyburz-Graber (eds.), *Science | Environment | Health: Towards a Renewed Pedagogy for Science Education*, DOI 10.1007/978-90-481-3949-1,