Albert Zeyer
Regula Kyburz-Graber *Editors*

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Towards a Renewed Pedagogy for Science Education

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

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

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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

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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.

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

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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