Exploring the Landscape of Scientific Literacy

Edited by
Cedric Linder
Leif Östman
Douglas A. Roberts
Per-Olof Wickman
Gaalen Erickson
Allan MacKinnon

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Exploring the Landscape of Scientific Literacy

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Scientific literacy is part of national science education curricula worldwide. In this volume, an international group of distinguished scholars offer new ways to look at the key ideas and practices associated with promoting scientific literacy in schools and higher education. The goal is to open up the debate on scientific literacy, particularly around the tension between theoretical and practical issues related to teaching and learning science. Uniquely drawing together and examining a rich, diverse set of approaches and policy and practice exemplars, the book takes a pragmatic and inclusive perspective on curriculum reform and learning, and presents a future vision for science education research and practice by articulating a more expansive notion of scientific literacy.

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Contents

Preface

The landscape of *scientific literacy* is impressive. Worldwide, scientific literacy is probably the most popular phrase now used to express in a nutshell the desirable outcomes of school science education. Indeed, a search for "scientific literacy by country," on any Internet search engine, would quickly register in the millions of items. In addition to its global sweep, the landscape of scientific literacy is also deep and rich in the literature and discourse of professional science education, associated frequently with the expression "Science for All." However, is everyone on the same page about that?

The intended audience for this book is primarily the science education research and professional community, and the professional education community more widely. The authors collectively believe that the current state of research and practice regarding scientific literacy as an overarching goal for school science education provides our community with an opportunity to meet some serious challenges. However, the international output of research and analysis surrounding this popular concept cries out for exploration, analysis, framing, and presentation in an organized, useable fashion.

To that end, the four parts of this book are organized according to a conceptual framework that begins with analyzing scientific literacy as an educational outcome, and continues through the implications for change associated with the larger picture of systemic educational reform. Representing nearly a dozen countries, the authors have inquired into a variety of aspects of scientific literacy through research, analysis, and practice. The international flavor of the collection is complemented by the diversity of theoretical and methodological approaches used, including linguistics, discourse analysis, policy research, classroom studies of implementation, and various aspects of teachers' professional development.

Acknowledgments

Several institutions and individuals were instrumental in supporting the development of this work, by hosting and organizing two international meetings of many authors who have a common research interest.

The Uppsala symposium was made possible through Uppsala University's celebration of the 300th birthday of Carolus Linnaeus, one of their most famous professors. At this occasion, the university conferred two honorary doctoral degrees in the Faculty of Educational Sciences, to Gaalen Erickson and Douglas Roberts. The financial assistance for the symposium that followed came from the Swedish Research Council and the Faculty of Educational Sciences at Uppsala University. For all of the organizational details associated with hosting that symposium, the authors express appreciation to Cedric Linder, Leif Östman, Per-Olof Wickman, and Anne Linder.

The University of British Columbia hosted the Vancouver conference and provided financial support through the Rex Boughton Fund for Science Education. Additional financial assistance was provided by the Vice-President's Fund for Academic Conferences at Simon Fraser University. The authors are grateful to Gaalen Erickson and Allan MacKinnon for making the conference and the subsequent authors' meeting possible.

Anne Linder deserves special recognition for logistical and editorial assistance associated with both author meeting events and the two publications arising from them. She created and maintained an authors' website, she single-handedly edited and brought the Uppsala symposium *Proceedings* to both print and online publication, and she contributed substantially to the organization and editorial work associated with the Vancouver conference and with bringing this volume to completion. Thank you, Anne, from all of us.

We would like to acknowledge the peer reviewers whose feedback helped us to shape the final manuscript: Roger W. Bybee, Edgar Jenkins, and James Ryder.

1 Overview

Scientific Literacy and the State of the Art in School Science Education

The Editors

This book is the product of collaborative effort by 34 authors from 10 countries, over a period of nearly three years. Consistent with its international perspective, the scope of the collection is marked by a diversity of topics, theoretical approaches, and research methodologies. At the same time, the collection is unified as a coherent whole by its focus on *scientific literacy* and its parallel focus on the complexities of understanding and influencing the practices associated with school science education. The "landscape" of scientific literacy is the best term we can think of, to capture the many facets of the worldwide interest this term currently enjoys as a rallying cry for rethinking what school science education is all about. As explained below, we have characterized the research in this volume according to four pervasive themes that stitch together the landscape of scientific literacy in terms that are representative of the concerns and activities of systemic reform in science education—in brief, curriculum, language in teaching and learning, classrooms, and professional development of teachers.

Origins and Concerns

The book originated at a two-day research symposium held at Uppsala University, Sweden, on May 28–29, 2007. The occasion was part of a celebration throughout Sweden of the 300th birthday of Carolus Linnaeus, one of Uppsala's most famous professors. In addition to his well-known scientific achievements, Linnaeus was widely respected for his teaching, especially for making scientific knowledge accessible by demonstrating its relevance in such matters as nutrition, health, and economics. At this Linnaeus Tercentenary Celebration, Uppsala University conferred honorary doctoral degrees on 14 scholars selected by the various faculties of the university. From the Faculty of Educational Sciences, the recipients were two science educators, Gaalen Erickson and Douglas Roberts. The symposium that followed, entitled "Promoting Scientific Literacy: Science Education Research in Transaction," featured presentations and discussion by an international group of 20 invited scholars in science education.

Common Focus of the Participants

The symposium opened with keynote presentations by the two honorary doctorate recipients. Roberts' (2007) analysis of research and writing on scientific literacy formed part of the overall framing of the subsequent discussions by identifying two competing visions of scientific literacy that are rooted in the history of school science education. *Vision I* derives its authenticity by looking inward to the products and procedures of the scientific disciplines themselves. *Vision II* is broader, deriving its legitimacy from the demonstrable role of science in a whole array of human affairs in addition to scientific activity. Erickson (2007) expanded the framing by addressing two orienting preoccupations of the symposium: the search for conceptual clarity around competing notions of scientific literacy, and the development of fruitful models of educational inquiry that recognize and accommodate the variety of aspects of research into the complex world of practice. These he dubbed, respectively, the "what" and "how" questions of scientific literacy.

The presented papers and discussions during the symposium ranged across both theoretical and practical aspects of teaching and learning science within a broad, expansive vision of scientific literacy, at both individual and societal levels. Participants stressed, as Linnaeus did, that science education has the potential to develop and enrich students' understanding of a wide array of human affairs in addition to scientific activity itself, that is, Vision II of scientific literacy. Yet, concern was expressed that Vision I still predominates in school science, despite some serious challenges that are becoming increasingly apparent. The published symposium proceedings (Linder, Östman, & Wickman, 2007) therefore include a formal *Statement of Concern* (pp. 7–8), which is reproduced here in its entirety.

The Statement of Concern

We, the members of the 2007 Linné Scientific Literacy Symposium, wish to express our concern about the current state of science education in many countries on the following grounds.

Attitudinal data from many sources indicate that it is common for many school students to find little of interest in their studies of science and to quite often express an active dislike of it. In comparison with a number of other subjects, too many students experience science education as an experience dominated by the transmission of facts, as involving content of little relevance, and as more difficult than other school subjects. This experience leads to disinterest in science and technology as personal career possibilities, and only a mildly positive sense of their social importance.

Science education has often overemphasized the learning of a store of established scientific knowledge at the expense of giving students confidence in, or knowledge of, the scientific procedures whereby scientific knowledge is obtained. Science education researchers have thus given increased attention to how various aspects of nature of science can be taught, but school science curricula remain too loaded with content knowledge for these aspects to be sufficiently well-emphasized by teachers.

In the last decade there have been widespread moves across many countries to increase the formal assessment of learning in science. These efforts have typically given more value to the students' retention of bits of scientific knowledge than to their abilities with the procedures of science and the application of scientific knowledge to novel real world situations involving science and technology.

Science education, perhaps because of the sheer depth and volume of the knowledge base of modem science, has isolated that knowledge from its historical origins and hence students are not made aware of the dynamic and evolving character of scientific knowledge, or of science's current frontiers. There is little flavor in school science of the importance that creativity, ingenuity, intuition, and persistence have played in the scientific enterprise. Nor is there any real sense of any meaningful exploration of issues that relate ethical and personal accountability to modern scientific activity. Indeed, the existence of human enterprise that makes science possible is almost ignored in science education. Curricula and assessment need to support teachers' being able to share the excitement of the human dramas that lie behind the topics in school science with their students.

Recent policy statements about the changing nature of our work and the *Knowledge Society* have challenged education systems to give priority to the development in students of competencies that focus on generic skills. In doing so they undermine the importance of those other competencies that are intimately dependent on content knowledge such as those that are associated with subjects such as science.

Citizens' lives are increasingly influenced by science and technology at both the personal and societal levels. Yet the manner and nature of these influences are still largely unaddressed in school science. Few students complete a schooling in science that has addressed the many ways their lives are now influenced by science and technology. Such influences are deeply human in nature and include the production of the food we eat, its distribution, and its nutritional quality, our uses of transportation, how we communicate, the conditions and tools of our work environments, our health and how illness is treated, and the quality of our air and water.

Science education is not contributing as it could to understanding and addressing such global issues as *Feeding the World's Population*, *Ensuring Adequate Supplies of Water*, *Climate Change*, and *Eradication of Disease* in which we all have a responsibility to play a role. Students are not made aware of how the solution of any of these will require applications of science and technology, along with appropriate and committed social, economic, and political action. As long as their school science is not equipping them to be scientifically literate citizens about these issues and the role that science and technology must play, there is little hope that these great issues will be given the political priority and the public support or rejection that they may need.

Reforms of science education that continue to frame scientific literacy in terms of a narrow homogeneous body of knowledge, skills and dispositions, fail to acknowledge the different ethnic and cultural backgrounds of students. Such science education stands in strong contrast to the popular media. It omits a discussion of the reciprocal interactions between science and world views and between values and science that the media regularly recognizes as important to the public interest. Furthermore, it fails to contribute to a fundamental task of schooling, namely, redressing societal inequalities that arise from differences such as race, sex, and social status. Instead of equipping students to participate thoughtfully with fellow citizens building a democratic, open and just society, school science will be a key factor in the reproduction of an unequal and unjust society.

In the chapters that follow, these concerns are directly addressed and a number of new directions for school science that have strong research support will be presented.

A Blueprint for the Book Emerges

At the Uppsala symposium, participants also expressed concern that the scientific literacy literature is missing a more open exploratory approach that does justice to the variety of international research that the field holds. Thus they decided to meet again to start working on production of such a comprehensive publication in the form of a book.

The second meeting was held in the context of an invited symposium entitled "Beyond Borders of Scientific Literacy: International Perspectives on New Directions for Policy and Practice," at the annual conference of the Canadian Society for the Study of Education, University of British Columbia, Vancouver, May 31–June 3, 2008. As part of this symposium a two-day workshop was held to develop the blueprint for the book and begin to shape the overall structure and coherence of its components. To emphasize the diversity of our work and its open exploratory nature, the book was given its current title: "Exploring the Landscape of Scientific Literacy." The focus on "exploration" is to bring out (1) the richness and diversity of contemporary thinking on various aspects of scientific literacy as these relate to research and practice in school science education, and (2) systemic reform that can address current challenges and concerns as expressed formally in the *Statement of Concern* from the Uppsala symposium. As suggested earlier, both of these components of our work are incorporated in the notion of a "landscape" of scientific literacy.

Participants agreed that significant change will require a commitment to nothing less than co-ordinated systemic reform of many aspects of professional science education (cf. Bybee, 1997). In the four sections of the book, aspects of systemic reform are addressed according to four themes:

- an examination of the characteristics and pervasive influence of science curriculum policy,
- a fresh look at the role of language in the practice of teaching and learning science,
- multiple aspects and possibilities of what scientific literacy means in a classroom, and
- the profoundly significant role of learning communities in teachers' professional development.

All of these topics of research and practice have been scrutinized, investigated, and discussed individually in the science education literature, some of them for many years. This book relates and solidifies the diversity of such topics through a common, unifying conceptual framework laid out in Roberts' opening chapter. There, curriculum policy choices and other aspects of systemic reform in school science education are linked according to their inter-relationship and the (intended) flow of influence that binds them together.

Many of the authors, a majority in fact, assembled as a group one more time, at the conference of the European Science Education Research Association held in Istanbul, August 31–September 4, 2009. At a symposium attended by more than 100 conference delegates, authors presented papers about the research themes in each part of the book, and about several representative chapters. Other authors were in the audience, and all responded to questions and discussion following the presentations.

A Synopsis of the Book

There are 18 chapters in the book, including this introductory one. These are presented in four parts, each of which has its own detailed introduction. This overview is intended simply to highlight the focus of each part and give a brief indication of the contents. Doing so will also indicate how the parts overall constitute a coherent whole about the landscape of scientific literacy.

The three chapters of Part I concentrate on the characteristics and potential influence of scientific literacy—whether Vision I or Vision II—as a curriculum policy construct. The policy "image" embodied in one or the other vision (or any other curriculum policy statement) is related to a cascade of subsequent events and activities of school program development and student assessment. Illustrating this cascade of events is the presentation of a radically different view of scientific literacy for a Knowledge Society, showing in detail how systemic reform could address many aspects of the *Statement of Concern* developed at the Uppsala symposium. The third chapter of Part I introduces concepts from curriculum theory as a basis for analyzing a curriculum policy document (the US *National Science Education Standards* is the example) with a view to demonstrating how a curriculum policy image is presented and explicated in such documents.

Part II consists of four chapters about the significance of language in teaching and learning science, as related to scientific literacy. The following topics are the focus:

- the nature of "epistemic practices" in science teaching discourse,
- the significance of developing students' ability to comprehend and make use of scientific text,
- the dominant influence of "literacy" when seen as a metaphor appropriated for understanding scientific literacy, and
- impacts on the scientific literacy of university students when they are taught in two languages (English and mother tongue), including development of a new construct called *bilingual scientific literacy*.

Scientific literacy in the classroom is the focus of Part III. Topics in these five chapters range across a diversity of research and development areas, united by their common attention to significant themes associated primarily with adoption of curriculum policies that resemble Vision II scientific literacy more than Vision I:

- conceptual and research inter-relationships among the familiar but contested concepts of *scientific inquiry*, *nature of science*, and "traditional" science *subject matter*, as these play out in a balance required for implementing scientific literacy in the classroom,
- consequences for content progression when scientific literacy is conceptualized as "scientific literacy in action,"
- how values and norms associated with scientific literacy are communicated in the classroom,
- relating views of scientific literacy to an ongoing and long-standing research and development program about socioscientific issues in the classroom, and
- how identity formation among students, especially young women, is affected by teaching for scientific literacy.

Part IV has five chapters that present case studies of science teachers' professional development, set in six different countries (Canada, China, Vietnam, the Netherlands, France, and South Africa). Despite this international breadth, the authors have brought out the common, profoundly important role played by the concept and enactment of "learning communities" of science education practitioners, including university professors, researchers, and classroom teachers. Each of the narratives in these five chapters tells a fascinating story in its own right, laced with conceptual, theoretical, and practical insights. Taken together, they bring this volume to a satisfying close by illustrating in graphic detail what happens in reality, when the idealized presentation of a curriculum "cascade" of events (Part I) is set in motion.

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12 An Inclusive View of Scientific Literacy: Core Issues and Future Directions

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16 Making an Innovation Grow: On the Shared Learning Within and Between Communities

1. Ownership

Designing exemplary teaching

materials by the teachers as a key

activity within the learning

communities The teachers are the owners of the newly designed curriculum; they form the key actors in decision making.

2. Developing (group) identity

Developing shared vision The alignment of individual and collective motives; for the individual to participate, for the community to create and continue the “scaling up” of its practices.

3. A system of interconnected

learning communities

As an organization model

fostering growth in curriculum

innovation For the system of communities: the organization of materializing the outcomes of collective learning, for example. in the sense of an expertise center that combines those whose knowing serves in the process of brokering (principle 5) and those who are able to document the collective learning in the form of boundary objects (principle 4). In each of the communities: the organization that knowing in action is documented and reported in such a way that it can become “knowledge” and “knowing” again. In each of the communities to take up explicit roles and responsibilities.

4. Effective boundary objects

Developing and collectively

building on certain standardized

documents such as a general

course design framework/format The development of the types of document that efficiently serve as boundary object that can be used for scaling up as an instrument for interconnectivity; the course design format in both case studies functions as such.

5. Brokering

Organizing multimembership of

different neighbor communities

allowing communicative

participant to cross the

boundaries of learning

communities that need to be

connected The participation of heterogeneous members (multimembership) to allow efficient brokering when scaling up; however, the community should have a clear focus and common purposes. Appelhof, P., Bulte, A. M. W., & Seller, F. (2008). Innoveren met perspectief, vernieuwing van betatechnisch onderwijs [Innovation with perspective, renewal of science and technology education]. Utrecht, NL: Oberon, Onderzoek en Advies. Bennett, J., & Lubben, F. (2006). Context- based chemistry: The Salter's approach. International Journal of Science Education, 28(9), 999–1016. Brickhouse, N. W. (2007). Scientific literates: What do they do? Who are they? Paper presented at the Linnaeus symposium, Promoting scientific literacy, Uppsala, Sweden. Bulte, A. M. W. (2007). Symposium, May 28–29, 2007 and Working Seminar, May 30–31, 2007. How to connect concepts of science and technology when designing context-based science education. Paper presented at the Linnaeus Tercentenary 2007, Promoting Scientific Literacy: Science Education Research in Transaction; The LSL Meeting, in Uppsala, Sweden. Bulte, A. M. W., Carelsen, F., Davids, W., Morelis, H., Pilot, A., Velthorst, N. et al. (1999). Dilemma's in de schoolscheikunde [Dilemmas in school chemistry]. NVOX, 6, 289–291. Bulte, A. M. W., & De Kleijn, E. (2009, May 27th-29th). Voorbeeldleerlijnen Nieuwe Scheikunde [Exemplar learning lines New Chemistry]. Paper presented at the ORD conference "Onderwijs een kwestie van emancipatie en (on)gelijkheid" [Education, a matter of emancipation and (in)equality], Leuven, Belgium. Bulte, A. M. W., Klaassen, K., Westbroek, H. B., Stolk, M. J., Prins,

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17 Professional Development of Teachers and Researchers in Collaborative Development of Teaching Resources

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18 “Struggling Up Mount Improbable”: A Cautionary (Implementation) Tale of a Vision II Scientific Literacy Curriculum in South Africa

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