CULTURAL AND HISTORICAL PERSPECTIVES ON SCIENCE EDUCATION: HANDBOOKS

Volume 1

Series Editors
Kenneth Tobin
The Graduate Center, City University of New York, USA
Wolff-Michael Roth
University of Victoria, Canada

Each volume in the 7-volume series The World of Science Education reviews research in a key region of the world. These regions include North America, South and Latin America, Asia, Australia and New Zealand, Europe and Israel, North Africa and the Middle East, and Sub-Saharan Africa.

The focus of this Handbook is on North American (Canada, US) science education and the scholarship that most closely supports this program. The reviews of the research situate what has been accomplished within a given field in North American rather than an international context. The purpose therefore is to articulate and exhibit regional networks and trends that produced specific forms of science education. The thrust lies in identifying the roots of research programs and sketching trajectories—focusing the changing façade of problems and solutions within regional contexts. The approach allows readers to review what has been done and accomplished, what is missing, and what might be done next.
The World of Science Education

Handbook of Research in North America

Edited by

Wolff-Michael Roth
University of Victoria, Canada

and

Kenneth Tobin
City University of New York, USA

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SERIES PREFACE

Science education, as science more generally, is premised on the ideology that scientific knowledge (about nature, learning, cognition, method, methodology) is universal and that it can be taught equally well anywhere and in any context. Statistical methods in the social sciences generally and in science education more specifically are the epitome of this form of thought. However, for those who travel a lot to different countries around the world, especially when they speak several languages it is immediately evident that not all forms of thinking are the same. In fact, one can detect cultural differences between the US and Canada even though most people living outside the North American continent often conflate the two. (Many Canadians and Americans can detect the other by the ways in which they speak and pronounce the English language.) Because of our experiences with science educators around the world, the differences in thinking, doing, and speaking science education has become quite salient to us. We therefore negotiated with Sense Publishers a series of handbooks that would take a regional focus. Such a series then would allow us to bring the regional differences into the light of day. The purpose of the series is not to explicitly work out the differences but to allow the differences to become salient in the side-by-side that the different regional volumes—each of which is spearheaded by a regional editor—will take.

After conferring with several potential regional editors, we decided to have seven volumes focusing on (a) North America, (b) Central and South America, (c) Europe, (d) Asia, (e) Australasia, (f) North Africa and the Middle East, and (g) sub-Saharan Africa. We imagined that each volume would consist of reviews of the key research foci that have characterized research in this geographical region of the world in the past 50 years or so. We therefore did not ask the editors to follow one scheme, as we expected the foci to differ according to the region. For example, there appears to be a substantive focus especially in the US on urban science education, whereas elsewhere a similar focus does either not exist or exists to a much more limited extent. It therefore makes sense to have a number of chapters focusing on urban science education in the North American volume but not in some other regions.

We envisioned that the focus could be on individual research programs and those that have most closely influenced such a program. The reviews would then begin locally and situate what has been accomplished within a given field in a regional rather than international context. We envisioned that the purpose therefore would be to articulate and exhibit the regional networks and trends that led to specific forms of science education. For example, if a North American conceptual change researcher agreed to do a chapter on the topic, s/he would include the work of other scholars like Peter Hewson or John Clement, but would not include those who work primarily in a different region, for example, Reinders Duit (Germany) or
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David Treagust (Australia). We knew that there would not be an easy answer to how to cut up the research, as there are numerous science educators who conduct research with colleagues in other parts of the world and therefore, with researchers whose work would be reviewed in a different regional volume. Thus, for example, Reinders Duit and David Treagust have a long-standing working relationship and have co-authored many papers. Would they be included in the Australasian or in the European regional volumes? We thought that such decisions could be made in a case-by-case manner. For example, the research that one of us (WMR) did in 1995 with Cam McRobbie researching physics teaching and learning in a high school in Brisbane, Queensland, would be part of the Australasian volume; however, research WMR conducted with Reinders Duit during the same year on learning physics in a German high school would be featured and reviewed in the European volume.

In the sense of getting key works included, we thought that a review would be inclusive of the most cited works and those that have shaped the field. The thrust would be on identifying the roots of research programs and sketching trajectories—focusing the changing façade of problems and solutions within regional contexts. A reader would be left with a sense of what has been accomplished and what is to be done next. We also should get a sense of the blossoming scholars within the regions of the world.

Victoria and New York
November 2008
The focus of this Handbook is on the various research programs in North American (Canada and US) science education and those that have most closely developed this program. The reviews of the research situate what has been accomplished within a given field in North American rather than within an international context. The purpose therefore is to articulate and exhibit the regional networks and trends that led to specific forms of science education. The thrust lies in identifying the roots of research programs and sketching trajectories—focusing the changing façade of problems and solutions within regional contexts. The intent is to allow readers to leave their reading of the book with a sense of what has been accomplished and what is to be done next.

Books such as this one are impossible without the support scholars receive from the context, the people that surround them, and the foundations and councils that support the work. Wolff-Michael Roth is grateful to his partner Sylvie Boutonné, who provides for the temporal and emotional spaces that intense involvement in writing and thinking requires. He also thanks the Canadian Social Sciences and Humanities Research Council and the Natural Sciences and Humanities Research Council for supporting this work through the funds that allow the hiring of (former) graduate students and postdoctoral fellows who, as authors and editorial assistants, contributed to this book. Likewise, Kenneth Tobin extends his love and appreciation to his spouse Barbara and to support from the National Science Foundation (DUE-0427570). Any opinions, findings, and conclusions or recommendations expressed in this chapter are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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INTRODUCTION

Science education is a rapidly evolving and expanding field. The standard reason given for the rapid development of science education in the US is the shock that rippled through American society with the successful launch of Sputnik by the Soviet Union during the height of the cold war. Being heavily funded by the US National Science Foundation—more heavily than in any other country around the world—science education research has made tremendous strides even during our own membership in the field. Since then, science educators have worked through and developed theoretical frameworks, methods and methodologies, and fields of interest that did not and could not have existed some 50 years ago.

In recent years, we have been able to observe a reflective trend in the field. Over the last decade, several handbooks have been published beginning with and since the *International Handbook of Science Education* (Fraser & Tobin, 1998). A recently published edited volume entitled *The Culture of Science Education: Historical and Biographical Perspectives* (Tobin & Roth, 2007) provides a kaleidoscopic micro-/macro-level description of the evolution of science education around the world. And the journal *Cultural Studies of Science Education* has published a history of the National Association for Research in Science Teaching (Joslin et al., 2008), possibly the premier and largest science education research organization on the planet.

Once a field has become more mature, some of its constitutive members, often the more senior scholars in the field who know and understand the diversity first hand, begin to think about taking stock and to conceptualize the field and its sub-fields as a whole. There may even be break-ups where one field comes to a branching point leading to the creation of two or more subfields. However, at the moment the community of science education researchers is rather small and the journals in the field cover all or nearly all relevant topics that its members are interested in. There is much to be gained by looking at the major trends that appear to be guiding the research in a field; and sometimes, looking back on what has been done allows patterns of thinking and theorizing to become salient that have not been salient in this way before. Taking stock and looking back and over a field are therefore important ways of engaging with the research literature because they may suggest and open up new avenues for research. In fact, such reviews have led to or supported new research in areas such as the role of inscriptions in science learning and how to theorize this learning (Roth & McGinn, 1998) or the role of gestures in the developmental trajectory from early exposure to phenomena to competent discourses about them (Roth, 2002).

W.-M. Roth & K. Tobin (eds.), *The World of Science Education: Handbook of Research in North America*, 1–6. © 2009 Sense Publishers. All rights reserved.
Why a handbook at all and why, given the existence of other endeavors of this nature, another handbook of research in science education? First, handbooks are important venues for research reviews especially because of the lack of sufficient journal space. The few journals that exist for education generally (Review of Educational Research, Review of Research in Education, Educational Research Review) and science education specifically (Studies in Science Education) provide insufficient space, especially space for reviewing an entire field of research such as science education. Handbooks therefore are the means for looking back over an entire discipline to be able to look forward and ask about new research questions, areas that need attention, and even entirely new areas of interest. There is a second important reason for this handbook in particular: Few if any reviews exist that take a look at the regional differences, which, in the spirit of an objective science of science education often get to be obliterated or are never read by scholars in countries such as the United States and Canada.

Second, there are regional differences within science education that could be interesting but generally are obliterated in a hegemonic hogwash of the generality and context-independence of scientific knowledge. Regional differences concerning certain questions, such as the ongoing debate about religion and science—creationism and intelligent designs versus evolution—are non-starters in most if not all European countries. If these topics now are salient at all in Canada, then this is in isolated cases rather than constituting a national phenomenon in the way it does in the US. Some of the discourse also comes across the borders with the movement of scholars who take positions in Canada. How can we make sense and explain the rapid expansion of our field? In a recent reconceptualization of the concept of legitimate peripheral participation, initially proposed by Jean Lave and Etienne Wenger, Maria Iñes Mafra Goulart and Wolff-Michael Roth (2006) conceive of a margin | center dialectic as a concept for describing the source and emergence of new phenomena within a culture. This dis-location in the new term is an expression of the underlying dynamic that is to be theorized, a state of becoming rather than being. Accordingly, every form of participation always gives rise to new forms of participation and therefore to the emergence of new cultural forms. In this way, science education as a field emerged from the already existing endeavors including natural science, the emergent field of educational sciences, and existing endeavors in philosophy and psychology.

The emergence of new endeavors is not homogeneous around the world but heterogeneous, as shown, for example, in the research Jean Piaget conducted since the 1930s. Thus, Piaget’s work on knowing and learning of scientific and mathematical concepts was not taken up in a major way in North America (US) until the 1970s, decades after some of his groundbreaking studies on the development of formal reasoning and, for example, the development of proportional reasoning from childhood to the early teenage years. This shows that there are regional differences from one continent to another. But it also sets the stage for understanding changes, as more recently, many innovations in science education have come from North America and have been imported to “the old continent,” where critics of
innovation rapidly will use expressions such “Why do we have to try every American innovation even after it has already shown to be a failure in the US?”

Once we had decided that we would publish a series focusing on science education in different regions of the world, we decided also to edit the version that summarizes research and articulates new directions for further research in North America, where, being immigrants to Canada and the US, we have conducted much of our research. Beginning to think about what we wanted the volume to look like, we engaged in the process of creating categories and inviting authors.

We began planning this volume with a list of terms and concepts that we felt reflected the main areas of interest in science education and grouped them into categories. Thus, our first list included as major heading Science and Language, and then the subheadings of “Talking science,” “Reading,” “Writing,” “Gesture, Nonverbal,” and “Inscriptions.” The other main headings included Epistemology, Learning Science, Teaching Science, and Equity. For each of these headings we had between five to seven subheadings.

Following this first cut, we then approached potential authors for writing within a particular area of science education research but leaving it open to them to make the decisions about the extent and depth they would review the area and the different foci that it included. For example, as we communicated with authors in the area of science and language, it became clear to us that it would be useful to distinguish scientific literacy as a separate entity. For each of the areas identified, we then contacted individuals who we knew had done considerable empirical and conceptual work. Once they agreed, we asked the author or authors to provide us with a tentative title, author list, and synopsis of what their chapter would be about. Once we had all the précis, we then looked at our groupings again and reorganized them as necessary. For example, in one instance we asked a group of authors—G. Michael Bowen, Lawrence Bencze, and Steve Alsop—who had written together in various combinations whether they were interested in covering a topic, which they could cut up in the way they felt did most justice to the field of research:

We are writing to you in particular to see whether you would be willing to write one long chapter (22-30k words) or a collection of 2 or 3 chapters (7.5-9k) on nature and history of science and inquiry in science education not only in elementary and secondary school, but, if this exists, across the life span. The review would only cover North American research. Are you interested in getting involved? So that you can get an idea what the book in particular and the series more generally is about, see the information below. We are just starting the invitation process and wanted to begin with some featured authors—one of which is you. We would work with you on making decisions and the way you want to cut up the domain, and who co/authors with whom. If you were to cut up, the remaining space to 30k should be used to have an introduction to the section, which would contain 2 or 3 chapters as suited.

The three authors then interacted with one another, decided how to cut up the tasked area in the most sensible manner and who would co-author the different
chapters in accordance with our initial guideline that an author may appear on the byline only twice. The three then sent us a proposal for writing the three chapters that are included here in the author configurations that they had initially suggested.

The present volume emerged from such interactions with the authors in the field. It therefore reflects not just our intuition about what are salient pieces of research topics, fields, and interests, but also what our contributors felt about what needed to be included.

Once we had the chapters, we grouped the chapters of this volume into seven major categories entitled “Theory and Method in Science Education,” “Teaching and Learning Science,” “Science Communication, Language, and Literacy,” “Equity in Science Education,” “Context and Science Education,” “Science Teaching and Science Teacher Education,” and “Improving Science Education.” We provide introductions and overviews to each section in an introductory text that goes with each section. “Why these sections?,” a reader might ask. There is no unique answer to this question, as there are many different ways in which the research in a discipline can be cut up and taken account of. Some groupings and fields suggest themselves simply because they are often co-located within the relevant research articles. Thus, conceptions and conceptual change have been research objects/motives for many science educators to the point that it has become the dominant ideology of how students learn despite the apparent shortcomings of the theory to which leading scholars in the area admit. Authors who use a conceptions and conceptual change framework cite one another, though they might draw on outside research and theories as well. But they generally do not reference works with sociocultural and cultural-historical frames, as these are inconsistent with the presuppositions made within the conceptual change area. There are therefore practical divisions that offer themselves in a theoretical review.

Even with some historical divisions apparent, there are still many different ways in which reviews might be conducted, especially when there are different purposes at hand for which such a review might be conducted. There are also personal preferences for looking at and understanding a field of research such as science education. With the increasing predominance that language has taken in the studies of science educators with the publication of Talking Science (Lemke, 1990), it is not surprising that one of the areas would be language. But, as a review of the literature shows, language specifically and communication more generally appears in different guises and contexts. Thus, although students primarily talk in science classrooms, they are formally tested primarily in written genres (we acknowledge the existence of oral examinations in other countries, they are not part of the mainstay in North America). Although complementary, reading and writing are not equally practiced on the part of science students, who are required to read texts that require much more competence in science and writing than they could ever produce themselves—including textbooks, newspaper articles, novels, or science (popularizing) journals.

A close look at science education shows that (a) science talk is often abridged, highly situated, and incomprehensible without further support of contextual clues, (b) involves communicative forms other than language, though these other forms
do not have the same semantic and syntactic features that are characteristic of language, and (c) in a strong sense, no communication can be understood independent of the context in which it occurs and which it contributes to constituting (Roth & Pozzer-Ardenghi, 2006). This means that in addition to the speech situation not only one person has to be modeled in communication—i.e., the speaker—but also the recipient. Speakers address specific recipients to achieve intended effects and they monitor the listener to receive clues about the actually achieved effects, whereas listeners not only attend to what is being said but also that their own understanding is received as such by the speaker. Speakers and listeners co-imply one another, which leads us to a different way in which scientific literacy has to be modeled. These considerations show how, in thinking through an issue such as language, a structure evolves that suggests itself as a possibility for subdividing topics within a section specifically and a book more generally.

NOTES

1 There are some interesting differences and non-overlapping communities in science education., though they understand themselves and the research they conduct in different ways. In this book, the science education research largely refers to individuals who are members of organizations such as the National Association for Research in Science Teaching, Australasian Science Education Research Association, or European Science Education Research Association. Not present in these organizations are science teachers, a considerable number of whom hold MA, MEd, or MSc degrees yet are members of the National Science Teacher Association. In the natural sciences, there also are individuals who orient themselves to their science colleagues and who have their own journals less known to the science educators publishing in the Journal of Research in Science Teaching or Science Education. Such journals include the Journal of Biology Education, American Journal of Physics, or Journal of Chemical Education, which tend to be listed and ranked within the science section of the ISI Web of Knowledge rather than with the social sciences.

2 For example, Lev Vygotsky (1986) conceives of thinking and speaking as dynamic processes rather than as the results of fixed conceptual or cognitive frameworks that are externalized in and through speaking.

REFERENCE


SECTION I

THEORY AND METHOD IN SCIENCE EDUCATION
In and of itself, praxis and practical understanding do not require (explicit) theory and yet express understanding that exceeds that of any theorist. For example, there are soccer, baseball, or tennis players around the world that stun by the mere precision with which they can play the ball into a position that allows them to win; and they do so even under very different weather conditions. They do so often without any courses in physics or any education at all. Yet their play exhibits a form of understanding that exceeds any theoretical possibility of calculating the precise trajectory that the ball is taking, especially within the limits that being part of the game requires. Pierre Bourdieu (1990) was quite aware of this problem and therefore published a book the title of which in English is, somewhat deceptively, but appropriately for our present purposes, *The Logic of Practice*. The title is deceptive, as it appears there is a logic of the classical type, such as the one taught in introductory philosophy courses.

The practical sense (“tacit” understanding) develops even without self-awareness, even in situations where the practitioner engages in the apparently most routine and boring jobs (Lee & Roth, 2006). We know that other important dimensions of everyday life change, including culture as a whole and language in particular. Neither the culture around us nor the language we employ are constant, but are in constant evolution; rather than stasis, change and difference are the norm.

If implicit learning were the whole story of cultural evolution, we would not be offering this book to our readers. Rather, an important aspect of the increasingly rapid development of praxis in any field comes about when practitioners themselves or outsiders who are concerned with the praxis of theory come to reflect about practice. This split between theory and practice came about, for example in architecture, after a praxis develops to a certain point after which new projects that can be envisioned apparently cannot be realized or only with great difficulty. This was the case during the Gothic era, when the attempted construction of gigantic cathedrals provided challenges to the master masons that they had not faced with the smaller buildings that predominated during their times (Turnbull, 1993). At this point, a new kind of practitioner evolves—in the construction business this would be an architect—who reflects on the practice itself and on its objects (e.g., cathedrals and palaces). In the building industry, the new science of architecture was born. The reflection turned out to develop both the understanding of the object of activity and that of the ways in which practitioners engage with it (i.e., construction practices), i.e., the method. This is not to say that practitioners themselves can become conscious of what they do and theorize what they do. This, however, requires reflection in some form. Reflection has the purpose both to articulate and represent practice, which allows a mediated, reflective access to what otherwise