HANDBOOK OF
RESEARCH ON
SCIENCE EDUCATION

EDITED BY
SANDRA K. ABELL
NORMAN G. LEDERMAN
Contents

Preface  ............................................................ .ix
Sandra K. Abell and Norman G. Lederman

PART I:  SCIENCE LEARNING

1 Perspectives on Science Learning  ......................................... 3
   Charles W. Anderson

2 Student Conceptions and Conceptual Learning in Science  ................... 31
   Phil Scott, Hilary Asoko, and John Leach

3 Language and Science Learning  ........................................ .57
   William S. Carlsen

4 Attitudinal and Motivational Constructs in Science Learning  ................ 75
   Thomas R. Koballa, Jr. and Shawn M. Glynn

5 Classroom Learning Environments  ...................................... 103
   Barry J. Fraser

6 Learning Science Outside of School  ....................................... .125
   Léonie J. Rennie

PART II:  CULTURE, GENDER, SOCIETY, AND SCIENCE LEARNING

7 Science Education and Student Diversity: Race/Ethnicity, Language, Culture, and Socioeconomic Status  ................... 171
   Okhee Lee and Aurolyn Luykx

8 Postcolonialism, Indigenous Students, and Science Education  ................ 199
   Elizabeth McKinley

9 Issues in Science Learning: An International Perspective  ................... 227
   Chorng-Jee Guo

10 Gender Issues in Science Education Research: Remembering Where the Difference Lies  ................... 257
    Kathryn Scantlebury and Dale Baker
CONTENTS

11 Special Needs and Talents in Science Learning ........................................... 287
    J. Randy McGinnis and Gregory P. Stefanich

12 Science Learning in Urban Settings ......................................................... 319
    Angela Calabrese Barton

13 Rural Science Education ................................................................................. 345
    J. Steve Oliver

PART III: SCIENCE TEACHING

14 General Instructional Methods and Strategies ........................................... 373
    David Treagust

15 Learning and Teaching in the School Science Laboratory:
    An Analysis of Research, Theory, and Practice ......................................... 393
    Vincent N. Lunetta, Avi Hofstein, and Michael P. Clough

16 Discourse in Science Classrooms ................................................................. 443
    Gregory J. Kelly

17 Digital Resources Versus Cognitive Tools:
    A Discussion of Learning Science with Technology .................................. 471
    Nancy Butler Songer

18 Elementary Science Teaching ......................................................................... 493
    Ken Appleton

19 Interdisciplinary Science Teaching ............................................................... 537
    Charlene M. Czerniak

20 High School Biology Curricula Development: Implementation,
    Teaching, and Evaluation from the 20th to the 21st Century ..................... 561
    Reuven Lazarowitz

21 Teaching Physics .............................................................................................. 599
    Reinders Duit, Hans Niedderer, and Horst Schecker

22 Teaching and Learning the Many Faces of Chemistry .................................. 631
    Onno De Jong and Keith S. Taber

23 Learning Earth Sciences .................................................................................. 653
    Nir Orion and Charles R. Ault, Jr.

24 Environmental Education ................................................................................ 689
    Paul Hart

PART IV: CURRICULUM AND ASSESSMENT
    IN SCIENCE

25 Scientific Literacy/Science Literacy ............................................................... 729
    Douglas A. Roberts
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Authors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>History of Science Curriculum Reform in the United States</td>
<td>J Myron Atkin and Paul Black</td>
<td>781</td>
</tr>
<tr>
<td>27</td>
<td>Inquiry as an Organizing Theme for Science Curricula</td>
<td>Ronald D. Anderson</td>
<td>807</td>
</tr>
<tr>
<td>28</td>
<td>Nature of Science: Past, Present, and Future</td>
<td>Norman G. Lederman</td>
<td>831</td>
</tr>
<tr>
<td>29</td>
<td>Humanistic Perspectives in the Science Curriculum</td>
<td>Glen S. Aikenhead</td>
<td>881</td>
</tr>
<tr>
<td>30</td>
<td>Systemic Reform: Research, Vision, and Politics</td>
<td>Jane Butler Kahle</td>
<td>911</td>
</tr>
<tr>
<td>31</td>
<td>Review of Science Education Program Evaluation</td>
<td>Frances Lawrenz</td>
<td>943</td>
</tr>
<tr>
<td>32</td>
<td>Classroom Assessment of Science Learning</td>
<td>Beverley Bell</td>
<td>965</td>
</tr>
<tr>
<td>33</td>
<td>Large-Scale Assessments in Science Education</td>
<td>Edward D. Britton and Steve A. Schneider</td>
<td>1007</td>
</tr>
<tr>
<td></td>
<td><strong>PART V: SCIENCE TEACHER EDUCATION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Science Teacher as Learner</td>
<td>J. John Loughran</td>
<td>1043</td>
</tr>
<tr>
<td>35</td>
<td>Science Teacher Attitudes and Beliefs</td>
<td>M. Gail Jones and Glenda Carter</td>
<td>1067</td>
</tr>
<tr>
<td>36</td>
<td>Research on Science Teacher Knowledge</td>
<td>Sandra K. Abell</td>
<td>1105</td>
</tr>
<tr>
<td>37</td>
<td>Learning to Teach Science</td>
<td>Tom Russell and Andrea K. Martin</td>
<td>1151</td>
</tr>
<tr>
<td>38</td>
<td>Teacher Professional Development in Science</td>
<td>Peter W. Hewson</td>
<td>1177</td>
</tr>
<tr>
<td>39</td>
<td>Science Teachers as Researchers</td>
<td>Kathleen J. Roth</td>
<td>1203</td>
</tr>
<tr>
<td></td>
<td><strong>Author Index</strong></td>
<td></td>
<td>1261</td>
</tr>
<tr>
<td></td>
<td><strong>Subject Index</strong></td>
<td></td>
<td>1307</td>
</tr>
<tr>
<td></td>
<td><strong>About the Author</strong></td>
<td></td>
<td>1323</td>
</tr>
</tbody>
</table>
Although some have predicted the end of science (Horgan, 1996), the scientific enterprise thrives and scientists generate new knowledge at an incredible rate. (A recent report from the US National Science Foundation stated that over 92,000 scientific articles were published in 2001 in comparison with about 70,000 in 1991 (Hill, 2004).) Essential to the vibrancy of science, scientists continue to ask questions of the world. In the July 1, 2005 issue of the journal Science, the editor compiled responses from senior scientists and published the 125 questions that science “should have a good shot at answering” (Kennedy & Norman, 2005, p. 75) in the next 25 years, many from relatively young sciences such as neuroscience, genomics, biomedical science, geophysics, astrophysics, and bioengineering. According to Siegfried (2005), in that same journal issue:

When science runs out of questions, it would seem, science will come to an end. But there’s no real danger of that. The highway from ignorance to knowledge runs both ways: As knowledge accumulates, diminishing the ignorance of the past, new questions arise, expanding the areas of ignorance to explore. (p. 77).

For many years, science education researchers prided themselves on following research approaches and paradigms that approximated those of science. Thus, it is interesting to consider the similarities between science and science education. How does science education as a discipline compare? Our field has a much shorter history than that of the natural sciences. Our research has appeared in science education journals and books for fewer than 100 years. Yet we have generated a substantial body of knowledge during this time, knowledge from which new questions have emerged. Like the sciences, our questions are partly shaped by the society in which we live and partly by the research community in which we work. Research in science is guided by and builds upon prior research. However, in the science education community, researchers are often opportunistic, studying what is convenient to them rather than building on previous investigations. We believe that a handbook of research in a discipline such as science education provides a foundation upon which future research can be built.

The purpose of this volume is twofold. First, the authors look backward in time in an attempt to capture where science education has been and what we currently know. Secondly, the authors project into the future, positing research agendas for
various subfields in the discipline. When we invited authors to take part in the project, we asked that they tackle these two purposes:

We are asking authors to write an “integrative review” of the research in each topic area. Authors will pull together the existing research on the topic and work to understand the historical trends and patterns in that body of scholarship. Authors will describe how the issue is conceptualized within the literature, how methods and theories have shaped the outcomes of the research, and where the strengths, weaknesses, and gaps are in the literature. Reviews will end with implications for practice and future research derived from the review. (S. Abell & N. Lederman, personal communication, October 15, 2002)

This book is intended as a comprehensive research handbook for the field of science education. Two research handbooks in the field were produced in the previous decade. The first, edited by Gabel (1994), the *Handbook of Research on Science Teaching and Learning*, was published in cooperation with the National Science Teachers Association. It is now over 10 years old and no longer represents the scope of research in the field. The second, edited by Fraser and Tobin (1998), the *International Handbook of Science Education*, although international in its collection of authors, did not present a comprehensive review of the research in science education. Rather it was an in-depth sampling of the work of various researchers, demonstrating a slice in time of research in the field. Both of these volumes responded to the inadequacy of the single review chapters for science education contained in general education research handbooks such as those produced by the American Educational Research Association. The work represented in this volume is international and comprehensive in scope. It provides both veteran and emerging science education researchers with a coherent synthesis of the empirical and theoretical research concerning teaching and learning in science, and paves the way for future research.

OVERVIEW OF THE BOOK

One of our first steps as editors was to map out our construction of the structure of the discipline of science education. We first created five organizing categories in which to place the research in the field: Science Learning; Culture, Gender, and Society and Science Learning; Science Teaching; Curriculum and Assessment; and Science Teacher Education. We thought that this organization would capture most, if not all, of the published science education research (although we were aware that no organizational scheme would achieve consensus among our colleagues). These organizers became the five major sections in this *Handbook*.

The more difficult step was deciding what chapters should appear within each section. The decisions we made were unique, based on our experiences as science educators and researchers. Our decisions certainly would not match the organization other researchers would impose on the field. Current trends and length restrictions led us to make strategic decisions on chapters to include or not to include. For example, given the recent importance of the literature on language and science, we included two chapters on language and science learning. However, as we envisioned, these chapters serve different purposes. The first, by William Carlsen, appears in the first section of the book, Science Learning. It is meant to be a theoretical overview
of language and learning and how such theory has informed science education research. The second chapter on language and science education research appears in the third section of the book, Science Teaching. That chapter, by Gregory Kelly (once Carlsen's doctoral student), reviews classroom-based research on discourse in science education. We also made strategic decisions on chapters not to include. For example, although research on college science teaching has increased in the past decade (demonstrated in part by a dedicated strand at the annual NARST meeting), we chose to include this research by science discipline instead of by grade level, along with subject-specific studies at middle and high school levels, in the Science Teaching section of the Handbook. However, we decided that the research on elementary science teaching was less science discipline-specific and more age-related, and therefore deserved its own chapter.

The organization of this Handbook highlights other recent trends in the field. For example, the second section of the book, Culture, Gender, and Society, acknowledges the contributions of research focused on context to understanding science learners. The chapters in this section demonstrate the importance of learners' gender, culture, and special needs, as well as the larger societal context (urban, rural, postcolonial), in learning science. In the final section of the book, Science Teacher Education, we have presented a comprehensive synthesis of the research in the area of science teacher education for the first time. Twenty years ago, few studies in science education focused on science teacher learning. Currently such research comprises the largest submission to the NARST annual meeting, necessitating the development of two separate dedicated strands. The chapters in this section are thus a unique contribution to the field.

As editors, we also influenced the direction of the book in other ways. Once we had a structure for the Handbook in place, we brainstormed authors for the various chapters. First and foremost, we wanted authors who were leading experts in their research area, and who had published a significant quality and/or quantity of research. As veteran science education researchers with a total of 40+ years in the field, and as past presidents of NARST, our collective expertise was a good place to begin the brainstorming. However, we recognized that our expertise was limited in certain areas of the field and was somewhat North American centric. Thus we also consulted other resources during the author selection process, including the NARST annual meeting programs of recent years, other conference proceedings, and the ERIC database. In addition to selecting high profile researchers, we tried to ensure that our selection represented the international and gender diversity that exists in our research community. We believe that the final list of authors indeed meets these selection criteria.

An additional task we faced as editors was to engage thoughtful reviewers in providing feedback to authors on the first drafts of chapter manuscripts. The peer review process is critical to maintaining quality in our work. The reviewers we selected, along with the editors, provided insight and made recommendations that improved the final chapters in many ways. Some authors also involved their own colleagues in the review processes. The reviewers are acknowledged in the chapters they reviewed. Through section and chapter organization, author selection, and review work, we crafted this Handbook. It represents our current construction of the structure of the discipline of science education.
THEMATIC ELEMENTS

We have had the honor of interacting with many authors and reviewers to shape the contents of this book. We have had the privilege of reading all of the chapters and interpreting various themes that emerged from our reading. In this section we highlight three such themes.

One of the striking features of the field of science education as represented in the chapters in this Handbook is that it is influenced by the prevailing learning theory of the day. Few would argue that perspectives on learning have changed drastically over the past 100 years. Even the most superficial analysis indicates at least five “general families” of learning theory held dominance in educational matters over the past century—mental discipline, natural unfoldment, apperception, behaviorism, and cognitive science. These differing perspectives have influenced how science education researchers view learning, teaching, and the assessment of both.

A second theme of the research reviewed in this Handbook is that the predominance of various research methodologies change over time. Some of this fluctuation corresponds directly with changing views of learning. Early research on teaching and learning focused on the identification and exercise of various mental faculties as a direct result of the dominance of mental discipline theory. In the 1970s, process-product research methodologies clearly reflected the dominance of behavioristic learning theories. The emergence of qualitative methodologies mirrored the replacement of behaviorism with cognitive theories of learning.

A final theme that emerges from the Handbook chapters is that the teaching and learning of science is discipline-specific. What is considered effective instruction in a biology class is not the same as effective instruction in another class, science or otherwise. Teachers do not teach and learners do not learn biology in the same ways as they do physics or social science or humanities. This theme appears in the sections on science learners and learning, in the discipline-specific chapters on science teaching, and in the section on science teacher education. In that section, authors examine the notion of pedagogical content knowledge as a framework for science teacher education research. Lee Shulman, who invented this idea (1986), began his career as a science educator. He cautioned us not to allow the disappearance of subject matter from educational research. The existence of this Handbook is a testimony to the value of science subject matter in our research.

THE FUTURE OF SCIENCE EDUCATION

Much like the authors in the July, 2005 issue of Science demonstrate that science is alive and well, the chapters in this Handbook illustrate the vitality of science education as a discipline. We have learned much about science learners and learning, and science teachers and teaching, over the past 80 or so years of research. According to the chapter authors, many questions remain open for investigation. Surely many other questions we have not yet thought to ask.

As we continue to ask and investigate questions in science education, we believe it is crucial to keep a few guidelines in mind.
1. The ultimate purpose of science education research is the improvement of science teaching and learning throughout the world. We must take care that the proximate causes of our research (e.g., achieving publications that count for tenure, writing conference papers so our universities will fund our travel, preparing new researchers, getting grant dollars) do not derail us from achieving our ultimate purpose. Thus we call for rigor in design, data collection, interpretation, and write up.

2. To achieve the ultimate purpose of improving science teaching and learning, our research must be grounded in the real world of students and teachers and school systems and society. Ours is an applied field, and we must ensure that our research makes sense in the real world. Our research must address, and attempt to answer, the questions and concerns of teachers. To have educational warrant, our research must answer questions of educational importance.

3. To achieve the ultimate purpose of improving science teaching and learning, we as researchers need to be open to new theoretical frameworks, research methodologies, and strategies, even as we embrace existing tried and true methods. We are long past the paradigm wars that dominated education research in the 1980s. Mixed methods research (Chatterji, 2004; Johnson & Onwuegbuzie, 2004) is a new paradigm ripe for application to science education settings. Longitudinal studies that employ mixed methods will be essential to understanding student and teacher learning over time. In addition, theoretical frameworks that embrace postmodern thinking will help us see the world in new ways.

4. Translating our research for teachers is an essential component of our work. If we write only for other researchers, we will never achieve this ultimate goal. Teachers and researchers often describe the gap between research and practice. It is our responsibility to translate our research so that practitioners and policy makers can ultimately decide whether what has been offered is of practical value. This Handbook is written for researchers. We leave it to others to undertake the important work of interpreting and transforming its contents for other stakeholders.

These guidelines, along with the research agendas suggested by chapter authors, can help our field advance. Although we are not quite ready to state the 125 questions that the science education community has a shot at answering in the upcoming 25 years, the guidelines and research agendas can help science education researchers fulfill the mission, reflected in the NARST slogan, to improve science teaching (and learning) through research. If we keep our eyes on this goal, then we will continue to raise new research questions that will diminish our current ignorance while expanding the areas of ignorance yet to be explored.

Sandra K. Abell
University of Missouri, Columbia

Norman G. Lederman
Illinois Institute of Technology
REFERENCES


About the Authors

Sandra K. Abell
Sandra K. Abell is professor of science education at the University of Missouri-Columbia, US, where she directs the university’s Science Education Center. Her research interests focus on teacher learning throughout the career span and across the grade levels. She is a past President of the National Association for Research in Science Teaching (NARST).

Glen S. Aikenhead
I have always embraced a humanistic perspective on science, as a research chemist in Canada and as a science teacher at international schools in Germany and Switzerland. This perspective was enhanced during my graduate studies at Harvard University in the late 1960s and has since then guided my research in science education at the University of Saskatchewan, Canada.

Charles W. Anderson
Charles W. (Andy) Anderson has been a Peace Corps volunteer, middle school science teacher, and professor at Michigan State University, US, since 1979. Dr. Anderson’s primary research interests are in using conceptual change and sociocultural research on student learning to improve classroom science teaching. He is a past President of NARST.

Ronald D. Anderson
Ronald D. Anderson is professor of education at the University of Colorado at Boulder, US. The author of books and numerous research articles on science education reform, he is a past President of both NARST and the Association for the Education of Teachers in Science.

Ken Appleton
After retiring recently, Ken Appleton was appointed an adjunct associate professor at Central Queensland University, Australia. He has published extensively in international journals in his areas of interest that include elementary science teaching and learning, constructivism, elementary science teacher knowledge, and science teacher professional development.
Hilary Asoko
Hilary Asoko is a senior lecturer at the University of Leeds, UK. She is particularly interested in the teaching and learning of science in primary schools and in science teacher education.

J Myron (Mike) Atkin
J Myron (Mike) Atkin, Professor of Education (Emeritus) at Stanford University, US, is a National Associate of the National Academy of Sciences, where he was a member of the National Committee on Science Education Standards and chair of the Committee on Science Education K-12. His current research and writing center on science education curriculum and assessment.

Charles R. Ault, Jr.
Charles Ault is professor of education at Lewis & Clark College, US, where he teaches science education courses in the Master of Arts in Teaching (M.A.T.) program for elementary and secondary teachers. His teaching emphasizes the interpretation of local landscapes and stems from his scholarly interests in learning earth science, with particular attention to children's conception of time and the nature of geological problem-solving.

Dale Baker
Dale Baker is a professor in the Division of Curriculum and Instruction in the College of Education at Arizona State University, US. She is a former editor of the Journal of Research in Science Teaching. Her research focuses on gender equity issues in the teaching and learning of science as well as in engineering education.

Angela Calabrese Barton
Angela Calabrese Barton’s research focuses on the science practices of high poverty urban youth and on the role that community-based and case-based learning experiences can play in the development of science teachers’ understandings of urban youth and their own science teaching. Her work has been published in numerous venues and her most recent book, Teaching Science for Social Justice (Teachers College Press), won the 2003 AESA Critics Choice Award. She is on the faculty of Michigan State University, US.

Beverley Bell
Beverley Bell is an associate professor in the School of Education at the University of Waikato, Hamilton, New Zealand. She has a background in science education conceptual change research for over 20 years, and her current research interests are in pedagogy, learning, assessment, and teacher education.

Paul Black
Paul Black is emeritus professor in the School of Education at King's College in London, UK. He worked as a physicist for 20 years before moving to science education. He has made contributions to curriculum development, and to research into learning and assessment, particularly for teachers' classroom assessments. He has served on advisory groups of the US National Research Council and as visiting professor at Stanford University.
Edward Britton
Edward Britton is senior research associate in WestEd's Mathematics and Science Program, US. He contributed to the Third International Mathematics and Science Study and co-led an international comparison of high school exit examinations in science.

Glenda Carter
Glenda Carter is an associate professor of science education and the associate director of the Center for Mathematics and Science Education at North Carolina State University, US. Her research focuses on the use of language, gesture and tools as mediators of conceptual understanding. She is a member of the Friday Institute Mathematics and Science Collaboratory and the Middle Grades Academy.

William Carlsen
Bill is a professor of Science Education in Penn State's College of Education, US, and is director of the university's new Center for Science and the Schools. His current research focuses on the use of web-mediated peer review of original scientific research by high school students and preservice science teachers.

Michael P. Clough
Dr. Clough is an Associate Professor at Iowa State University, US where he directs the secondary science teacher education program and teaches courses addressing science learning and teaching and the nature of science and science education. His scholarly work examines learning and teaching the nature of science, laboratory learning and teaching, and the teacher’s role in both.

Charlene M. Czerniak
Charlene M. Czerniak is a professor at The University of Toledo, US. She is the co-author of a methods textbook on Project-Based Science, and she has written numerous articles on teachers' beliefs, curriculum integration, teacher professional development, and science education reform.

Onno De Jong
Dr. Onno De Jong is an associate professor in chemical education at Utrecht University, The Netherlands. He has published on education in problem solving, models and modeling, and electrochemistry. His current research interests include the professional development of chemistry teachers.

Reinders Duit
Reinders Duit is a professor of physics education at the Leibniz-Institute for Science Education (IPN) in Kiel (Germany). His research interests include teaching and learning processes from conceptual change perspectives, quality development, teacher professional development and video-based studies on the practice of science instruction.

Barry J. Fraser
Barry J. Fraser is director of the Science and Mathematics Education Centre at Curtin University of Technology in Perth, Australia. He is author/editor of Learning Environments Research: An International Journal, International Handbook of Science Education, Classroom Environment, and Educational Environments. A past President of NARST,
he was 2003 recipient of that association’s Distinguished Contributions to Science Education through Research Award.

**Shawn M. Glynn**
Shawn M. Glynn is a professor of science education and educational psychology at the University of Georgia, US. His specialization is in the application of psychology to science education, particularly in the areas of cognition and motivation. His books include *The Psychology of Learning Science* and *Learning Science in the Schools*.

**Chorng-Jee Guo**
Chorng-Jee Guo is a professor and the president of National Taitung University, Taitung, Taiwan. His research interests in science education are students’ learning of science, science teaching strategies and materials, professional development of science teachers, and science education policy.

**Paul Hart**
Paul Hart is a Professor of Science Education at University of Regina in Canada. He is executive editor of the *Journal of Environmental Education* and consulting editor for several journal in environmental education. He has published widely and is the recipient of several research awards including the Jeske Award from the North American Association for Environmental Education.

**Peter W. Hewson**
Peter Hewson is a professor of science education at the University of Wisconsin-Madison, US. His primary interest is in conceptual change approaches to the learning and teaching of science, and the initial education and professional development of science teachers. He is also interested in fostering international collaborative research opportunities.

**Avi Hofstein**
Avi Hofstein is Professor and Head of the Department of Science Teaching at the Weizmann Institute of Science, Israel. For more than 30 years he has engaged in science curriculum development, implementation, and evaluation. He holds a B.Sc. in chemistry, M.A. in education, and Ph.D. in science education.

**M. Gail Jones**
M. Gail Jones is a professor of science education in the Department of Mathematics, Science and Technology Education at North Carolina State University, US, where she prepares middle and high school science teachers. In addition to an interest in teacher beliefs, her research interests include the impacts of high stakes testing policy, gender, and nanotechnology education.

**Jane Butler Kahle**
Jane Butler Kahle, Condit Professor of Science Education, Miami University, US, is former director of the Elementary, Secondary, & Informal Education division at the US National Science Foundation. In 1991, Miami University awarded her an honorary L.H.D. degree. Her scholarship focuses on gender equity and systemic reform of education. She is a past president of NARST.
Gregory J. Kelly
Gregory Kelly is a professor of science education at Pennsylvania State University, US. He teaches courses on teaching and learning science, qualitative research methods, and uses of history, philosophy, sociology of science in science education. His research examines science learning, classroom discourse, and epistemology in science education.

Thomas R. Koballa, Jr.
Thomas R. Koballa, Jr. is a professor in the Department of Mathematics and Science Education at the University of Georgia, US. His research interests include the science-related attitudes of students and teachers and the induction experiences of beginning science teachers. He is a past President of NARST and co-author of *Science Instruction in the Middle and Secondary Schools.*

Frances Lawrenz
Dr. Lawrenz is Wallace Professor of Teaching and Learning in the Educational Psychology Department at the University of Minnesota, US. Her specialty is science education program evaluation. She has published extensively, received the university's highest award for teaching and has served as department chair and assistant vice president for research.

Reuven Lazarowitz
Reuven Lazarowitz is Emeritus Professor of Science Education in Biology, at the Israeli Institute of Technology, Technion, Haifa, Israel. His research interest is in the structure of high school biology curriculum; teaching and learning biology concepts and principles in individualized, cooperative small groups and computer-assisted learning settings. Recently he was involved in the national committee for developing learning units in the STS approach and educating teachers for teaching those units to the high school students who do not major in science and technology.

John Leach
John Leach is Professor of Science Education and Head of the School of Education at the University of Leeds, UK. His research interests include epistemic aspects of science learning and the use of insights from research in the practice of science teaching.

Norman G. Lederman
Norman G. Lederman is Chair and Professor of Mathematics and Science Education at the Illinois Institute of Technology, US. He is internationally known for his research and scholarship on the development of students’ and teachers’ conceptions of nature of science and scientific inquiry. He is a former President of NARST and of the Association for the Education of Teachers in Science (AETS). He has also served as Director of Teacher Education for the National Science Teachers Association (NSTA) and as Editor of *School Science and Mathematics.*

Okhee Lee
Okhee Lee is a professor in the School of Education, University of Miami, Florida, US. Her research involves language and culture in science education. One of her
current research projects implements instructional interventions to promote science learning and language development for elementary students from diverse languages and cultures.

**J. John Loughran**

J. John Loughran is a professor in education and the Foundation Chair in Curriculum and Professional Practice in the Faculty of Education at Monash University in Australia. He has been actively involved in teacher education for the past decade. His research interests include science teacher education, teacher-as-researcher, and reflective practice.

**Vincent N. Lunetta**

Vincent Lunetta is Professor Emeritus at Penn State University, US. He has received awards for scholarship and leadership in science education and given special attention to: teacher education; goals for science learning; the role of the laboratory, computer technologies, and simulation in learning and teaching; the development of conceptual procedural knowledge; international education; and education policy.

**Aurolyn Luykx**

Aurolyn Luykx is an anthropologist specializing in ethnography of schooling, bilingual-intercultural education, and language planning and policy. Her book, *The Citizen Factory*, was published in 1999 by SUNY Press. She currently holds a joint appointment in the Departments of Sociology/Anthropology and Teacher Education at the University of Texas at El Paso, US.

**Andrea K. Martin**

Andrea K. Martin is an adjunct professor in the Faculty of Education, Queen’s University, Kingston, Ontario, Canada. Her areas of interest and scholarship include the development of teachers’ knowledge, preservice teacher education, special education, and literacy development and interventions.

**J. Randy McGinnis**

J. Randy McGinnis is professor of science education in the Science Teaching Center at the University of Maryland, College Park, US. His research and writing primarily concern science teacher education and equity. He has served on the executive boards of NARST and the Association for Science Teacher Education. He is co-editor of the *Journal of Research in Science Teaching*.

**Elizabeth McKinley**

Dr. Elizabeth McKinley currently teaches research methodologies, curriculum and social issues at the University of Auckland, New Zealand. She researches and writes on indigenous people’s educational issues, particularly with respect to Maori students in science education. She has had extensive experience teaching science in high schools and in bilingual (Maori/English) science curriculum development.

**Hans Niedderer**

Hans Niedderer is a retired professor of physics education at the University of Bremen (Germany). His research interests include students’ alternative conceptions, learning processes, and curriculum development. Currently he works as guest pro-
fessor at two Swedish universities in cooperation with the Swedish National Graduate School in Science and Technology Education Research (FoNTD).

J. Steve Oliver
J. Steve Oliver is an associate professor in science education at the University of Georgia, US. His interest in rural education issues began during a childhood spent around the family farms. His current interests include secondary science teacher education as well as teacher knowledge and practices.

Nir Orion
Dr. Nir Orion holds a professorship in the Weizmann Institute of Science in Israel where he heads the Earth Science and Environment Group of the Science Teaching Department. His activity covers all facets of science education: research, curriculum development, implementation, and teacher education from K-12. His main areas of activity are: Earth and Environmental Sciences; the outdoors as a learning environment; science for all; and teachers’ professional change.

Léonie J. Rennie
Dr Leonie Rennie is Professor of Science and Technology Education and Dean, Graduate Studies at Curtin University of Technology in Western Australia. Her research interests include adults’ and children’s learning in science and technology and the communication of science in a range of out-of-school contexts.

Douglas A. Roberts
Doug Roberts, Professor Emeritus of the University of Calgary in Canada, began his science education career in 1957 as a high school science teacher in Pennsylvania. Doug has been a university faculty member at Harvard, Temple, Toronto (OISE), and Calgary. His research interests include science curriculum policy and the development of science teacher thinking.

Kathleen J. Roth
After teaching middle school science and later completing a PhD in science education, Kathy became a teacher-researcher in elementary classrooms while also teaching teachers at Michigan State University. In 1999, Kathy became the director of the TIMSS video study of science teaching at LessonLab Research Institute in the US, where she currently supports and studies elementary teacher-researchers.

Tom Russell
Tom Russell is a professor in the Faculty of Education at Queen’s University, Kingston, Ontario, Canada. His research focuses on reflective practice and learning from experience in the context of learning to teach. He teaches preservice physics methods, supervises the preservice practicum, and teaches action research in the graduate program.

Kathryn Scantlebury
Kathryn Scantlebury is an associate professor in the Department of Chemistry and Biochemistry and the Secondary Science Education Coordinator in the College of Arts & Sciences at the University of Delaware, US. Her research focuses on gender and equity issues in science education.
Phil Scott
Phil Scott is professor of science education at the University of Leeds, UK. His main research interests lie in drawing on research findings to plan and implement science instruction and analyzing language, teaching and learning in science classrooms. This research informs a wide range of professional development activities with science teachers.

Horst Schecker
Horst Schecker is a professor of physics education at the University of Bremen (Germany). His research interests include multimedia, learning processes in physics, and curriculum development. One of his current projects is about a standardized test of students’ understanding of thermodynamics.

Steven Schneider
Steven Schneider, program director of mathematics, science and technology at WestEd, US, is principal investigator for the NSF-funded Center for Assessment and Evaluation of Student Learning (CAESL) and the National Assessment Governing Board’s development project, 2009–2021 US National Assessment of Educational Progress Science Framework and Test Specification.

Nancy Butler Songer
Dr. Songer is a Professor of Science Education and Learning Technologies at the University of Michigan, US. Focusing on students in high-poverty urban settings, Songer’s research: a) characterizes children’s higher-order thinking in science, b) evaluates simple technologies used as cognitive tools, and c) develops assessment systems to provide developmental evidence of complex reasoning in science.

Gregory P. Stefanich
Dr. Gregory P. Stefanich is professor of science education and former Interim Head of the Department of Curriculum and Instruction at the University of Northern Iowa, US. He joined the faculty at the UNI in 1976. His research over the years has focused on special needs learners and science.

Keith S. Taber
Keith Taber taught science in schools, and a college, before joining the Faculty of Education at Cambridge University, UK. He has been a Teacher Fellow for the Royal Society of Chemistry, is Chair of the Society’s Chemical Education Research Group; and serves as Associate Editor of Chemistry Education: Research and Practice.

David Treagust
David Treagust is Professor of Science Education at Curtin University in Perth, Western Australia and teaches courses in campus-based and international programs related to teaching and learning science. His research interests are related to understanding students’ ideas about science concepts, and how these ideas can be used to enhance the design of curricula and improve teachers’ classroom practice. He is past President of NARST and recipient of the association’s 2006 Distinguished Contributions to Science Education through Research Award.
This state-of-the-art research handbook provides a comprehensive, coherent, and current synthesis of the empirical and theoretical research concerning teaching and learning in science and lays down a foundation upon which future research can be built. Structured to highlight recent trends in the field, the volume is organized around five themes:

- Science Learning;
- Culture, Gender, and Society and Science Learning;
- Science Teaching;
- Curriculum and Assessment in Science; and
- Science Teacher Education

The contributors, all leading experts in their research areas, represent the international and gender diversity that exists in the science education research community. Each chapter presents an integrative review of the research on the topic it addresses—pulling together the existing research, working to understand the historical trends and patterns in that body of scholarship, describing how the issue is conceptualized within the literature, how methods and theories have shaped the outcomes of the research, and where the strengths, weaknesses, and gaps are in the literature. Chapters conclude with implications for practice and posit agendas for future research.

As a whole the Handbook of Research on Science Education demonstrates that science education is alive and well and illustrates its vitality. It is an essential resource for the entire science education community, including veteran and emerging researchers, university faculty, graduate students, practitioners in the schools, as well as science education professionals outside of universities.

EDITED BY
SANDRA K. ABELL
NORMAN G. LEDERMAN