The Culture of Science Education
NEW DIRECTIONS IN MATHEMATICS AND SCIENCE EDUCATION
Volume 3

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Scope

Mathematics and science education are in a state of change. Received models of teaching, curriculum, and researching in the two fields are adopting and developing new ways of thinking about how people of all ages know, learn, and develop. The recent literature in both fields includes contributions focusing on issues and using theoretical frames that were unthinkable a decade ago. For example, we see an increase in the use of conceptual and methodological tools from anthropology and semiotics to understand how different forms of knowledge are interconnected, how students learn, how textbooks are written, etcetera. Science and mathematics educators also have turned to issues such as identity and emotion as salient to the way in which people of all ages display and develop knowledge and skills. And they use dialectical or phenomenological approaches to answer ever arising questions about learning and development in science and mathematics.

The purpose of this series is to encourage the publication of books that are close to the cutting edge of both fields. The series aims at becoming a leader in providing refreshing and bold new work—rather than out-of-date reproductions of past states of the art—shaping both fields more than reproducing them, thereby closing the traditional gap that exists between journal articles and books in terms of their salience about what is new. The series is intended not only to foster books concerned with knowing, learning, and teaching in school but also with doing and learning mathematics and science across the whole lifespan (e.g., science in kindergarten; mathematics at work); and it is to be a vehicle for publishing books that fall between the two domains—such as when scientists learn about graphs and graphing as part of their work.
The Culture of Science Education
Its History in Person

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CONTENTS

Preface ix

INTRODUCTION: History and Auto/biography 1

A. SHAPING FORCES ACROSS THE DECADES 9
   Introduction: Participating in Science Education 11
   A Career Evolves: Five Decade and Still Engaged
   James J. Gallagher 13
   The Road to Reform: A Personal Journey
   Jane B. Kahle 25
   Mentoring and the Multiplier Effect
   Barry Fraser 37
   The Changing Faces of Research in Science Education:
   A Personal Journey
   Kenneth Tobin 47
   In Search of Understanding: Or a Career as an Emergent Phenomenon
   Wolff-Michael Roth 59
   Epilogue: Structuring Science Education 73

B. SCIENTISTS BECOME SCIENCE EDUCATORS 89
   Introduction: Becoming Science Educators 91
   Science Education: An Interdisciplinary Field
   Svein Sjøberg 95
   A Model of Educational Reconstruction as Orientation of Science
   Education Research: A Personal Note on the Development of Science
   Education Research that Aims at Improving Practice
   Reinders Duit 107
   Continuity and Change: From Physicist to Science Educator
   Peter Hewson 121
   As a Woman Becoming a Chemist, a Biochemist, and a Science Educator
   Penny Gilmer 133
   Epilogue: The Emergence of Science Education 147
CONTENTS

C. US-TRAINED SCIENCE EDUCATORS ABROAD 159
   Introduction: Exporting Science Education 161
   A Taiwanese Journey into Science and Science Education
   Chao-Ti Hsiung 165
   Rising to the Top: Science Education in Costa Rica
   Gilberto Alfaro Varela 175
   Becoming a Science Education Researcher in Spain—Experiences
   and Tensions
   Mariona Espinet 185
   Science Education in Columbia: Possibilities and Challenges
   Lilia Reyes-Herrera 197
   A Box of Chocolates: On Making Choices to Become a Science Educator
   Doris Jorde 207
   Epilogue: International Faces of Science Education 219

D. REDUCTION OF GENDER BARRIERS 235
   Introduction: Gender in Science Education 237
   Understanding the Nature of Science Learning
   Lynn D. Dierking 239
   Embracing Serendipity and Celebrating Diversity
   Okhee Lee 251
   Collaborations, Multiple Voices, Tensions, Dialectics, and Fervor:
   The Social Construction of a Science Education Career
   Maria Varelas 263
   Epilogue: Structuring Success in Science Education 275

E. SCIENCE EDUCATION AROUND THE WORLD 283
   Introduction: Globalizing Science Education 285
   Travels in and Between Practice and Research
   Hanna Arzi 289
   Little was Planned—All Simply Happened
   Manuela Welzel 301
   Justin Dillon 311
   Epilogue: Trends 323
This book about the culture and history of science education told through the autobiographies of key persons in the field, as any book, is the result of a historical process that we, as any individual, produce and are subjected to. Much in the same way that history is not made by individuals who act independently but by individuals who concretize cultural possibility, this book is not merely the outcome of two author-editors getting together to put our spin on history. Rather, there is a point in the cultural history of a field where realizing such a book that takes the cultural history as its topic becomes a general possibility, which is then realized in concrete form by particular scholars. When we conceived of this book, we set our goal to be an exploration of some issues in science education as they have developed historically and internationally.

In the past there have been several efforts to capture the culture and history of science education, often in ways that we do not especially value or learn from the experiences of those in the field. A clear alternative is to tell the history through the lives of science educators. Accordingly, we sat down and identified 20 science educators other than ourselves whose participation in science education research has been noteworthy, international, and varied in terms of gender, race, focus and place on the career ladder. The approaches they have taken to research differ too. We thought that it would be interesting to read autobiographies of these people, accounts that capture the ways in which they have participated in science, education and science education as teachers and researchers. These accounts would touch on issues considered salient by the authors, but probably would deal with entry, progress and finding ways to succeed in science education. Issues of mentoring would be of interest, as would contradictions experienced in activities such as tenure, promotion, editing, publishing, participating in national meetings, being a consultant, obtaining external support etc.

We asked the invited authors to write a chapter of no more than 6,000 words in which they were to deal with some or all of the following:

1. Your participation in science and science education;
2. Key research foci at different critical points in your career;
3. Significant peers and roles models—the people and their work (including dissertation advisor);
4. Other biographical experiences that shaped your approach to research and teaching in the field;
5. The road ahead (the field and the people);
PREFACE

6. Review of key accomplishments—a review of your research (up to 2,000 of the 6,000 words)—perhaps identifying up to five key papers or books; and

7. Former doctoral students and postdoctoral associates (presented in terms of their work—not a list).

After receiving each contribution, we worked with each author through a series of iterations until his or her chapter was in a form that met both their own and our approval and the needs of producing a volume that cohered rather than constituted a collection of independent essays.

Works such as this book are impossible without the support of those surrounding us. We are grateful to our respective spouses Barbara Tobin and Sylvie Boutroné for their patience, which has allowed us to spend all that time required by the completion of this volume. Inevitably, the writing of this volume produced its tensions between us. However, as scholars and friends and a commitment to difference, we have produced a strong text and maintain a deep respect for one another and the principle of learning from diverse perspectives.

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“Great people, leaders with exceptional qualities, make history”—following Winston Churchill, many believe that exceptional people make history and that others are mere foot soldiers following in their path. From this perspective, there are some “great” individuals whose actions causally determine the direction a field takes. This perspective leads to the allure of biographies, which tend to celebrate the greatness of the persons showing how their genius or political savvy affected intellectual fields, world events, and history more generally. Biographies of Galileo Galilei, Albert Einstein, or Marie Curie tend to construct and highlight the genius in these people generally omitting other aspects of their lives. Thus, early biographies of Sir Isaac Newton tended to highlight his contributions to mathematics and physics, celebrating his outstanding qualities and genius. On the other hand, they did not at all concern themselves with the religious, mystical, and obsessive sides of the person. A recent biography, however, shows a different person: he was a twisted, tortured mystic with homosexual tendencies, an ability to hold grudges for decades, an egomaniac, and a very petty individual (White, 1999). Newton spent decades and decades with alchemy and the attempt to decipher Old Testament prophecies, thinking that the design of Solomon’s temple was a code for the entirety of recorded human history. The great Sir Isaac Newton was not so great after all. The point is that the biographies of the earlier form are used to construct the image of individuals as shapers of the history of a field; the individuals are portrayed as the causes of history.

There are also individuals believing that—conversely—it is history that makes great people. According to this perspective, there are situations in the history of a country or discipline that provide opportunities for certain individuals to stand out. Thus, to take an example from political history, a rather unassuming and pale George W. Bush, projected to go down as being a president with a transitional role in American history, found his place after the terrorist attacks on the twin towers in New York, an event now referred to as 9/11. That is, it is this historical event that provided the individual currently holding the presidency to take on a special role, allowing him to set in motion a war machinery that devastated two countries in the Middle East. Bush made history and he made himself a name—but only after history provided an appropriate slot for doing so. In such explanations, history is used as the cause to explain why a certain individual has become a noted and notorious politician who shaped worldly events.

Both forms of explanation fall far short of a good account of the relationship between history and persons, whose lives are accounted for in auto/biographies, because both lead to deterministic ways of understanding the world. A more variegated and sophisticated account of the relationship between individual biography
INTRODUCTION

(personal history) and the history of institutions (disciplines, countries) has recently been articulated (Holland & Lave, 2001). Accordingly, historical struggles in person (history in person) and historically institutionalized struggles (enduring struggles) are dialectically related processes that continuously play themselves out in local contentious practice. History thereby turns out to be “history in practice” (p. 6), where practice always means real humans being engaged in realizing whatever cultural-historical form of activities they currently participate. In and through participation, identities are continuously produced and reproduced. Let us concretize this perspective in the following account of an identity- and history-defining event.

For the 1992 annual meeting of the National Association of Research in Science Teaching, we had organized what turned out to be a well-attended symposium focusing on the relationship between beliefs about epistemology, nature of science, and learning as students and teachers articulate them. Michael—a high school teacher at the time—had presented a paper entitled “Physics students’ epistemologies and views of knowing and learning.” In the paper, he provided an account of his physics course, which predominantly consisted of open-inquiry. To counterbalance the realist presentation of physics in the textbook, Michael had asked students to read and discuss articles and book chapters that took a social constructivist perspective on science and knowledge—including, for example, such authors as David Suzuki (Canadian geneticist and environmentalist) and Gregory Bateson (anthropologist, epistemologist). During the discussion period, a science education historian vehemently attacked Michael for “indoctrinating” students into an epistemology that was outright wrong. Struggling with a response, Michael deferred to Ken, who responded in the former’s defense.

This event constitutes a moment of history in the field of science education: a moment of local contentious struggle in which the historically institutionalized struggle between “constructivists” and “realists” was played out and became a defining moment in the historical struggles of personal identities. In attacking, the historian not only articulated Michael as a constructivist demon, denoting him as a member of a particular subculture, but also provided a resource for constructing himself as a realist. That is, even without saying that he is a realist, the nature of the historian’s actions constituted a resource for anyone present to construct his identity. Ken, too, in defending what Michael had done as a classroom teacher, provided resources for anyone present to construct an aspect of his identity. Thus, through his actions, Ken not only provided material that allowed others to say that he was a constructivist—even though in his talk he did not say so—but also provided materials to construct his identity as that of a mentor, advocate for junior members in the field, and so on. Michael, too, even without having to say that he was a constructivist, the account he provided of what he had done in the classroom provided sufficient materials for others, including the historian, to attribute to him the identity of a “constructivist.”

This analysis shows how the historical debates within the field of science education that confronted “constructivist” and “realist” ideas about the nature of science and epistemology played themselves out in local contentious practice—here the
production and reproduction of a symposium at a scholarly conference. In fact, the
ad hominem attack turned this symposium into a particular one, distinguishing it
from others, though other aspects still reproduced it as a culturally recognizable
form. The event also contributed to the construction of identities to the extent that
some NARST members who remember the event refer to it in terms of a battle of
personalities. Thus, persons and personal identities are closely related to the insti-
tutions of which they are a constitutive part—though the relation is not determinis-
tic. But of what sort then is the relation between the two?

The contributions to *Auto/biography and Auto/ethnography* (Roth, 2005a) pro-
vide us with a first answer to this question, as they suggest a dialectical rela-
tionship between individual and collective. Thus, individual lives are concrete realiza-
tions of possible lives, where possibilities always exist at a collective level. More
so, biographies and autobiographies never are singularities but both in content and
form produce and reproduce culturally available contents and forms. If the content
and form of a narrative truly were singular, they would be written in a private lan-
guage, which constitutes an irresolvable contradiction—a completely personal lan-
guage would only be understood by the person speaking it and therefore would not
constitute a language at all.

To better understand the relationship between auto/biography (person) and his-
tory in general and the relationship between the autobiographies of science educa-
tors and the history of science education more specifically, we need to understand
culture as dialectic. In the following, we first articulate a way of understanding the
relationship between individual and collective through the lens of culture as dialec-
tic and, consequently, the relationship between autobiography and history.

CULTURE AS DIALECTIC

The concept of culture has been identified as one of the two or three most difficult
concepts in the English language. There are two fundamentally different senses in
which the term has been used: (a) as a “theoretically defined category or aspect of
social life that must be abstracted out from the complex reality of human exis-
tence” and (b) as a “concrete world of beliefs and practices” (Sewell, 1999, p. 39).
As the history of the category showed, both senses have their limitations because
they exclude important dimensions of culture. Recently, scholars have increasingly
turned to framing culture in dialectical ways. Yet the initially proposed dialectical
theories have been critiqued, among others, because they lend themselves to de-
terministic readings, which do not do justice to the indeterminate and emergent
nature of culture (Sewell, 1992). Fundamentally, a dialectical approach to culture
emphasizes that it is both a system of structurally related symbols and artifacts and
a system of patterned actions (i.e., practices). The main question therefore is not
whether culture should be conceptualized in terms of symbols/artifacts or prac-
tices, but how to theorize the articulation of practices and structure. There are
different ways of cutting a cake; the following constitutes the way it makes most
sense to us.
INTRODUCTION

In a dialectical approach, culture is a concrete universal, that is, it constitutes both a generalized set of action possibilities and a set of actions through which some of these possibilities are concretely realized. From a first-person perspective, an action is both mine and not mine: I recognize in my actions the actions of others; and in the actions of others I recognize my own. Culture therefore always exceeds the ensemble of observable actions. The possibilities reside in—but are not fully determined by—existing structure consisting in symbols, tools, and artifacts.

Concrete actions realize abstract possibilities; they therefore reproduce culture. But actions have outcomes (results), which add to the existing structures in more or less permanent ways. Concrete actions therefore also produce culture by bringing about change in available resources for subsequent actions. Because an action both reproduces and produces culture, action constitutes a dialectical category. Transformation is built into this concept, both practically (an action may differ from anything else observable in the culture) and theoretically (in dialectical logic, inner contradictions such as that of the simultaneous production and reproduction are the engines of change). Culture is therefore continuously reproduced and produced anew, which leads to its constant evolution. These evolutionary changes normally are slower at the level of the individual, but are accentuated when new individuals join a group who may introduce larger variations in the way possible actions are concretely realized. (Adults are much slower to adopt new technology, to change their practices, than are newcomers, young people.)

Culture is a phenomenon of collectives—the term denotes actions and action possibilities that have histories that transcend any individual. The category implies (human, simian) societies in which patterned ways of doing something are reproduced across generations. That is, practices exist at a collective level, they are characteristic of society or particular groups; but, of course, societies or groups do not act: individuals always realize practices in concrete ways. There is therefore a dialectical relation between individual and collective. The adjective dialectical here means that the two opposing terms presuppose each other; none can be thought without the other. Because practices and structures (rules, tools, symbols, language) are characteristic of the collective life form, their lifespan is not tied to the individual and they are therefore preserved even though some individuals depart and others arrive.

Language, too, has a dialectical nature, which French philosophers appreciate in the relationship of langue and parole. Langue denotes language as a generalized (abstract) system, universally accepted within a community; parole denotes the actual linguistic behavior of people. The relation of langue and parole is dialectical because every instance of language use (parole) constitutes a concrete, particular realization of possibilities that exist at the generalized, universal level (langue). The language we use to write these lines, this text, is therefore both ours and not ours—which leads Jacques Derrida (1998, p. 2) to write, “Yes, I only have one language, yet it is not mine.” Language therefore constitutes an unlimited resource for discursive actions, especially because each new (poetic, scholarly, philosophical, artistic) creation of language expands what can be expressed verbally. More so, even linguistic innovations, though new and unheard of before, presuppose
their own intelligibility. Even the most poetic of poems, innovating the language we use for talking about certain phenomena or bringing new phenomena into discourse, presupposes its own intelligibility, and therefore, the possibility for this language at the collective level (culture).

AUTO/BIOGRAPHY AND NARRATIVE FORM

Narrative forms (genres), too, are resources that can be transformed into new forms at the very moment that they reproduce an aspect of culture, producing and communicating narratives. The simultaneous production and reproduction of culture, genre, and language is exemplified in the following episode and analysis, drawing on an interview conducted by a doctoral student with a world-renowned scientist.

01 Scientist: I’m doing what I love doing. And I think everybody should do what they love doing.
02 Interviewer: I’m sure.
03 Scientist: And I’m fortunate that I, been able to develop a career in something that I cherished from my childhood. So . . .
04 Interviewer: Um, that’s great. Your parents were supportive of you doing science rather than medicine?
05 Scientist: Um there were a few arguments here and there. But I said I, this is what I will enjoy doing. Becoming a doctor and you know, it’s not something that I will enjoy doing it, you know . . .
06 Interviewer: Were you the oldest son?
07 Scientist: Nope, nope.
08 Interviewer: Sometimes there are pressures on the oldest . . .
09 Scientist: Yes, yes. I think all of my brothers, actually, we all had, we all had the grades, and excellence in school to go into medicine or engineering. All of us chose actually to be in fundamental science.
10 Interviewer: Oh?
11 Scientist: Yes.
12 Interviewer: Then do you think your siblings had some influence on you?

There are several different levels of events that occur in this episode, all of which can be traced back to the dialectical nature of culture. First, the scientist and interviewer, although they do not know each other, produce an interview; and they do so in a way that allows readers to recognize the event as an interview. The two participants know this as well as the readers although this particular event, recorded on videotape, is highly singular and occurred only once (in this form). Second, the two participants understand what the respective other is saying, even though they may never have heard a particular question or statement before. Thus, the scientist previously has talked about his parents wanting him to be a medical doctor. In turn 04, the interviewer, following the scientist’s statement about having cherished the idea about becoming a scientist, asks whether the parents were sup-
INTRODUCTION

portive of his alternative choice. The scientist has an immediate response, which is concerned with occasional arguments and the explanation he developed for his parents. Third, both interviewer and scientist draw on a particular aspect of telling a biography— influences of parents and peers. The scientist voluntarily provides information about the influence his brother has had or that he has cherished the idea of becoming from early childhood on. Even at the very moment that one of them begins to draw on the family repertoire in auto/biographical accounts, he presupposes the possibility and intelligibility that family members may play a significant role in autobiographical accounts.

At all three levels, the participants realize cultural possibilities for doing interviews and for constructing auto/biographical accounts of their careers. That is, despite the very singularity of this interview and this scientist’s autobiography, we recognize in the event and the narrative produced culturally possible forms of doing interviews and telling auto/biographies. Now the singular nature of the event and autobiography also means that they have not existed before, which means that they are not reproduced but are newly produced forms of interview and auto/biography. Yet the very fact that they are recognizable (recognizable, cognizable again)—do an interview and construct an auto/biography tells us that they reproduce a cultural form.

Auto/biographies are narratives about the lives of individuals, viewed by others and themselves. As we noted, the contents of these auto/biographies inherently are intelligible because they realize cultural possibilities for telling the lives of members of the culture. As such, each auto/biography is a concrete realization of culture as such. When we therefore listen to or tell an auto/biography, we simultaneously are confronted with a singular account of a singular individual, on the one hand, and with the possibilities of culture, on the other. That is, in auto/biographical accounts we are confronted with cultural-historical possibilities of being a person in a particular cultural context and therefore, we are confronted with culture more generally.

This means, however, that biography always also is autobiography: we recognize aspects of ourselves in the autobiographical accounts of others, and we narrate biographies in the ways the protagonists recognize themselves. Our autobiographies are fundamentally biographies of others, because “out of the other as compact exteriority I make my other, just as it makes me its other” (Nancy, 2002, p. 58). My self is told in terms of what I perceive the other to be because “[t]he simple position of the I is an abstraction” and because “the concrete awakening of the I is its awakening to the world and by the world—the world of alterity in general” (p. 60).

The upshot of this analysis is that each auto/biography that is contained in this book not only tells us about the science educator who has written it, but also about the culture of science education at the particular point of history featured in the account. Each auto/biography tells us as much about the particular person as it tells us about the culture, as each individual concretely realizes possibilities that existed at the collective (i.e., cultural) level. This book therefore constitutes a science education culture and history in and through science educators: it is a dialectical pro-
ject where in each narrative we are confronted with history in particular persons, who thereby come to be persons in science education history.

STRUCTURE OF THIS BOOK

A popular adage states that there are many ways in which one can cut a pie; the same is true for ordering narrative accounts of the culture and history of science education through the lives of its members. There are many ways and groupings that one could choose, and even once categories have been constructed, individual contributors could appear in and exemplify one or the other. After repeatedly ordering and reordering the contributors to this volume and articulating possible central themes characteristic of the field of science education and the changes it has undergone over the years, we have decided on six of these: (a) shaping forces across the decades, (b) scientists become science educators, (c) US-trained science educators who make their mark abroad, (d) reduction of gender barriers, (e) science education around the world, and (f) the opening up of conversations across cultures. We then located each contributor in that category that we thought she or he was most representative of, while maintaining a balance of contributors within each category. Thus, for example, we included Jane Kahle in part A, because she has been a shaping force in science education across the decades; but we could have equally well included her in part D dealing with the reduction of gender barriers. Also, Elizabeth McKinley could have been included in part D because of her radically feminist approach, but we felt that she was even more characteristic of part F, because she has been an essential force in the opening of the conversation across the cultures. To provide but another example, Michael Roth was trained as a natural scientist obtaining a master’s degree in physics from a German university before becoming a science teacher in Canada so that he could have been included in part B, scientists who become science educators; he also completed his doctoral studies in the US before returning to Canada where he has been teaching and researching ever since, making him one of the US-trained science educators who make their mark abroad such as all those whom we included in part C. Our ultimate choice was our sense of the science education community and our knowledge we have acquired in and of the field after having been members in the discipline for a combined 50 years.

We begin each of the six parts of the book with a brief introduction to the particular dimension of science education that is characterized in and through the auto/biographies included. In a synthesis that follows the auto/biographies, we then delve at greater length into the cultural and historical aspects of science education, providing further examples and directions to the general possibilities the discipline offers or has offered as exemplified in the featured narratives.
Part A

SHAPING FORCES ACROSS THE DECADES
INTRODUCTION

PARTICIPATING IN SCIENCE EDUCATION

In this part of the book, we gathered the biographies of five science educators who, for one or another reason, has had significant influence on the field of science education. Here we understand influence in a broad way, as it expresses itself, for example, through the impact a person has on a particular theoretical, methodical, or topical dimension; influence may also come from the number of doctoral students a person trained who became researchers in their own right; and influence may be gauged in terms of the number of publications that an individual produces or the number of times his or her work is cited by others. Although other science educators who contributed to this book could have been categorized in this part—e.g., Peter Hewson because he had coauthored a seminal article on conceptual change that has had tremendous impact on the field—we added them elsewhere in the book for the sake of achieving a balance across the different parts. After many iterations of ordering, seeking commonalities and grouping the different contributors, we included in this first part James J. Gallagher, Jane Butler Kahle, Barry Fraser, and both of us.

All five of the science educators featured in the first section of the book were science teachers, participated in curriculum design and evaluation, and maintained active involvement in science teacher education with new and more experienced science teachers. Like so many science educators of this era, Jim Gallagher came to science education rather than pursuing a career in applied science—in his case medicine. His development as a science educator established roots to which he would return throughout his career and connected him with people around which social networks were developed to support his successes as a science educator.

Kahle’s biography also shows a strong allegiance to science, making connections that were affordances in establishing collaborative projects supported by massive funding by the National Science Foundation. Fraser and Roth both studied science and then became science teachers before they created alternative routes to research in science education. Fraser got involved as an evaluator on a national science curriculum project in Australia and these experiences provided a segue into his doctoral research and then a career as a researcher of learning environments, especially in science classes. Roth went from teaching into graduate school, flirted with the goal of pursuing a doctorate in science, opted instead to get his degree in science education, and then took a postdoctoral appointment in the United States. In some respects Tobin’s career trajectory was different from the others. He came into science as an out-of-field high school teacher who studied physics part time as he taught. Like Roth, he considered research in science, but decided to undertake research on the teaching and learning of science. In the early 1970s Tobin also was involved in curriculum, developing resources to support the teaching and learning
of high school science—setting a context for his classroom-based research. Gallagher, Kahle, and Roth also were involved in curriculum design and enactment before research in science education became their primary mission in science education. Gallagher had a chance to work with Jerome Bruner on *Man a Course of Study*, Kahle was on the advisory board for the *Biological Sciences Curriculum Study*, and Roth collaborated with Provincial educators in Canada to develop and evaluate science curricula.

Strong social bonds, with researchers and universities in the United States, Australia and Canada, connect the five researchers included in the first section of the book. The National Association for Research in Science Teaching has been an organization that has fostered relationships among the five scholars. However, several universities also have been involved, hosting large international studies, principally, Curtin, Michigan State, Miami, Penn, Victoria, and Queensland University of Technology. Each of the researchers has nurtured individuals who constitute the next generation of science education research. Like Fraser, all have had a plethora of former doctoral students who have become leading researchers in their own right. However, the five scholars also have been active mentors for emerging scholars in science education, irrespective of where and with whom they studied for their doctorate.
Like many members of our community, I began my career by entering university as a science major immediately after graduating from high school. And like many people of my age and background, my parents and older siblings encouraged me to be a physician. With two uncles in well-established medical practices, the field held some call until my junior year, after taking on a part-time job as a clinical laboratory technician at the local hospital and university infirmary. During my two years in the hospital lab, I found that I did not enjoy the clientele, and was much more drawn to work with healthy, exuberant youth, than with the infirmed. Therefore, I decided that medical school was not for me and that secondary science teaching was my career choice.

Upon graduation with a degree in natural sciences from Colgate University in January of 1954, I continued studies toward a master’s degree in education, with the intention of starting to teach science in a high school the following September. In the meantime, it was apparent that I could complete the coursework for the degree during Spring and Summer semesters, leaving only the master’s thesis to be completed during my first year or two as a teacher.

Teaching secondary school science was both enjoyable and challenging for me. During my first two years, I was the entire science department in a small, rural school in New York State’s Catskill Mountains, teaching general science for grades 7, 8, and 9, biology, and earth science, along with chemistry and physics in alternate years. I treasured the students, my colleagues, and rustic environment. I had excellent support from peers and the administration. However, the range of subjects and ages was somewhat overwhelming, and after two years, I sought more specialization in my teaching.

The search for a new position was easy in the late 1950s, as there was a shortage of qualified science teachers. My new venue achieved a desired degree of specialization—physics, earth science and grade nine general science, three other science teachers who became supportive colleagues, and an excellent environment for teaching and raising our young family.

During the “Sputnik era,” opportunities abounded for science teachers. Summer study became very accessible through the National Science Foundation’s program of summer institutes for mathematics and science teachers. I entered a summer institute program at Antioch College in Yellow Spring, Ohio—a four-year, sequential program that led to a Master of Science Teaching degree. Antioch was an excellent match for my professional needs, as it deepened my understanding of sci-
ence content and provided excellent pedagogical models. In addition, the financial support added to the quality of life for our family. We were succeeding very well, both in the excellent environment for teaching and the stimulating environment for continued professional growth provided by National Science Foundation at Antioch College. At the end of the four summers, I completed the master’s degree with a 4.0 GPA. Life was good and it was about to get better!

Early in 1962, I received an invitation from the Director of Harvard University’s NSF-funded Academic Year Institute to apply for this program. A few weeks later, the die was cast, when my application for the program was accepted. After another NSF supported summer institute at New Mexico Highlands University with visiting professors James Bonner from Cal Tech and Guido Pontecorvo from University of Edinburgh, I began the program at Harvard with fifty other science and mathematics teachers from across the nation. Fall and spring semesters each involved four graduate level courses, and summer added two more in a combination of advanced science content, history and philosophy of science, and science pedagogy.

A few weeks into the Fall semester, I approached Fletcher Watson about admission to the doctoral program in science education, which he headed. During our first meeting, he described the courses needed for the degree and admission procedures. While he made no guarantees about admission, our encounter appeared promising. During my second semester in the Academic Year Institute at Harvard, two milestones were achieved. I was accepted into the doctoral program and I was offered a second year of financial support in the Academic Year Program. I concluded my doctoral studies within three years. The financial support from the National Science Foundation was a key factor for me, as it was for several of my generation of leaders in science and mathematics education, paying tuition, books, and a living allotment equivalent to my teaching salary, thereby eliminating much of the financial burden that usually accompanies graduate school.

During my second year at Harvard, I enrolled in Jerome Bruner’s course in cognitive psychology, and wrote a term paper based on an initial investigation that was the foundation of my dissertation. Bruner read the paper and sent me a letter with praise for my work and requesting I come to his office. In this meeting, he invited me to become part of his Instructional Research Group that was engaged in the development and trial of Man: A Course of Study, a middle grades social studies curriculum being developed with colleagues from several universities. Seminars with this group occupied my Friday afternoons for nearly all my remaining time in Cambridge and also provided exciting employment during one summer. The work of our group was a component of Bruner’s book Toward a Theory of Instruction—a sequel to The Process of Education.

Again, life was good and about to get better. As my dissertation neared its completion, I was fortunate to receive two offers for positions—one at Stanford as a post-doctoral fellow with Paul Hurd and a second one as a staff member of the Science Curriculum Improvement Study with Robert Karplus at University of California, Berkeley. I accepted the former and in late summer of 1965, our family embarked on a transcontinental move from Massachusetts to California.
The two years with Paul Hurd and his colleagues at Stanford were life-changing. Paul was deeply involved in synthesizing research and development arising from the post-Sputnik science curriculum reforms. He had been an important force in developments by the Biological Science Curriculum Study and was on advisory boards for other groups. He was a frequent traveler to Washington with influence on policy and programs at NSF and other agencies. His design for my post-doctoral position was to co-author a book about eight novel elementary science programs being sponsored by NSF at that time (Hurd & Gallagher, 1968). Except for my experiences with Man: A Course of Study and my dissertation research, I had virtually no professional experience with elementary schools, children, or teachers. However, the two years resulted in a sharp learning curve for me in understanding elementary school teaching, learning, and curriculum. Most importantly, it added to my vision and knowledge about curriculum and materials design as important factors in science teaching and teacher education.

To complete this developmental sequence, I moved from Stanford to the Educational Research Council of America in 1967, where I was part of a science curriculum development group, with my work focusing on staff development in elementary science, with some additional responsibilities in a newly designed course for low achieving high school students. After two years in this position, the organization came on hard times financially, and I took over as director of a much reduced science group for one year. In 1970, I joined a new university being formed in Illinois: Governors State University. Six years later, I moved to Michigan State University, where I served as Director of the Science and Mathematics Teaching Center for six years and professor of science education for 24 additional years until my retirement on January 1, 2006. I now continue working in a part-time role as Co-director of the Center for Curriculum Materials in Science.

PEOPLE AND EXPERIENCES THAT SHAPED MY CAREER

Given my long career, there are many people who have served as significant peers and role models, and many experiences shaped my research and teaching. I make no attempt at ranking them in importance or influence, as that is both difficult and dangerous! However, these do appear somewhat chronologically. Unfortunately, due to limitations in space established for this book, I am able to describe only a few of the people and events that influenced me. To my regret, many are omitted.

The Early Years—Prior to 1965

Ruth Griffith, my junior high school science teacher, and professors including John Woodruff at Colgate and Oliver Loud at Antioch stand out because of their influence in nurturing my love of science. Oliver Loud added a special dimension, introducing me to the history and philosophy of science, and connecting me with Everett Mendelsohn and Leonard Nash at Harvard, who also enriched that domain of my knowledge. These three significantly influenced one of my most important publications (Gallagher, 1971). Paul Joslin, my closest colleague as a secondary
school science teacher, stands out as a mentor and role model. We worked together, sharing laboratories, teaching space, equipment, ideas, and teaching strategies for four years in LeRoy High School. We then followed similar careers in higher education. He taught me so much about teaching, learning, and how to relate effectively with all kinds of people.

The Harvard years were also enriched by my work with Jerome Bruner, Fletcher Watson, and a fellow graduate student, neighbor, and co-commuter to Harvard Square, Andrew (Chick) Ahlgren. Obviously, there were many others during the three years there, including other graduate students, faculty, and visiting scholars who came to work or lecture there.

Support during my dissertation came from three sources: Maurice Belanger, my dissertation director who was restricted in mobility for several months with vertebral surgery. As a result, unlike many graduate students, my dissertation director was readily accessible, and even glad to see me! A student and colleague of Jean Piaget, Maurice was an excellent source of information, ideas, and methods for my research. Another high level of support came from Mary Henle, a visiting professor from the New School for Social Research. Her work related to children’s logic, and one important lesson she provided was that children’s logic is sound, but it often is based on premises that differ from those held by adults. That principle was important to me as parent, teacher, and researcher. Both Maurice and Mary were very interested in my dissertation topic—children’s explanation of science phenomena—and were extremely generous in their time and effort. Last, and certainly not least, Barbara, my wife, not only guided our children and made our home a place for productive writing of the dissertation, but she also typed the many drafts of the dissertation, including the final, letter-perfect one, on an electric typewriter—a technology that preceded word processing computers!

Embarking on My Post-doctoral Career 1965–1976

The experience at Stanford has already been touched on, and one can only imagine the impact of a first post-doctoral position with Paul Hurd, a larger-than-life mentor at a great university, on a person only three years removed from high school teaching. The change was huge, and the support from Paul and my young family was both superb and needed.

After two years at Stanford, I moved to Cleveland, Ohio and became part of the Science Staff at the Educational Research Council, which was headed by Ted Andrews. After three years there, I joined a newly forming faculty at Governors State University, where Andrews had become Dean of the College of Science. Obviously, he had a very strong influence on my professional life. In the former position, we were involved in science curriculum development and guiding teachers with its implementation. In the latter position, we worked together to create a college, literally from the ground up. Governors State was established by the State of Illinois as an upper division university to serve the unmet educational needs of low income and minority students from the Chicago area. It was a laboratory for trying out new approaches for teaching an older, diverse population whose average age
was above 30. With Dean Andrews’ encouragement, I assumed responsibility for guiding development and enactment of the curriculum for the college’s several degree programs: environmental science, urban planning, nursing, health care administration, and science education.

During my years at Governors State University, I also began working with Robert Yager, who influenced me in many positive ways during his term as president of NARST and then later as president of NSTA. We worked closely over these years and he helped me enter the international science education community advance my place in the national community. Those were some of the people who influenced me in the first two decades and more of my career. Now to my thirty


During my initial six years at Michigan State University, I continued in an administrative role as director of the Science and Mathematics Teaching Center. Working in this capacity, the center expanded its capabilities with several large grants, including a biomedical sciences project for low-income and minority high school students and grants dealing with environmental and energy education. Using salary savings from these grants, I was able to sponsor six post-doctoral fellows at the Science and Mathematics Teaching Center. Four of these went on to be key leaders in science education—James Stewart (University of Wisconsin), David Treagust (Curtin University of Technology), Patricia Heller (University of Minnesota), and Charles “Andy” Anderson (Michigan State University). David and Andy continued to be close associates over the years and greatly influenced my thinking and actions.

Michigan State University provided many wonderful opportunities for me to develop in new areas. Three stand out. First, I transformed my research approach from one based in quantitative, experimental method, learned as a graduate student at Harvard, to a qualitative, ethnographic method. With the encouragement of Dean Judith Lanier, I enrolled in Fred Erickson’s three-course sequence on educational ethnography during the 1981/1982 academic year, which enabled me to embark on this new research trajectory.

The second opportunity led me into the realm of international science education. Dean Lanier, her successor, Dean Ames, and Jack Schwille, Associate Dean for International Programs, supported me in two efforts that were transforming. They encouraged me to engage in several international ventures that included extended assignments with David Treagust, Ken Tobin, and Barry Fraser at Curtin University, leadership of the NSTA International Committee, and several projects in Latin America, Southeast Asia, Europe, Africa, and the Middle East. The most extensive of these involved over twenty trips to Thailand and Vietnam. In addition, I undertook two substantial projects in Latin America. All of these activities were excellent, enriching opportunities cross-culturally and to expand my understanding of teaching and learning. They also continued a long tradition of international education at Michigan State University.
Another part of my international work began in 1983, with the organization of a course plan that was repeated eleven times with an enrollment of over 300 participants, mostly Americans teaching overseas. The course was offered in exotic venues—Hawaii, Europe, Africa, Australia, and Alaska. My key colleague on these endeavors was Arthur Reed, a professor of marine biology at the University of Hawaii. Together, we organized a very popular, yet demanding course that helped teachers increase understanding of the natural environment, people’s impact on it, and how to use the local environment as a laboratory to support learning. In each new venue, Art and I had to prepare new readings, learn new environmental connections and examples, and make contact with new local experts about the specific issues we studied.

The third opportunity was also life changing, as it required long-term interactions with practicing teachers. Starting in 1984 with an ethnographic study of secondary science teaching sponsored by the MSU Institute for Research on Teaching, a team of graduate students that included Okhee Lee, I established the groundwork for fifteen years of applied work in a wide array of urban and rural schools at home and abroad. The research with these graduate students, coupled with research with Ken Tobin in schools in Western Australia, began a series of activities that continued through most of the remainder of my career. This long-term work with teachers and administrators created a detailed understanding of their work, their successes, and the obstacles to success. This enabled work to assist them in improving their teaching and their students’ learning, which became a hallmark of my career—my research and my professional mission for more than two decades.

Five related enterprises emerged from this research, adding to my experiential base and enriching my understanding of, and ability to apply, contemporary theories to educational improvement. These include:

• A project with the Toledo Public Schools and its teachers’ union, the American Federation of Teachers, beginning in 1988, continuing for twelve years. It involved guiding development of a team of teacher-leaders, known as “support teachers” within the district. The effort focused on improving teaching effectiveness and the development of leadership skills where these teachers could help others improve their teaching and students’ learning. Extended association with middle school science teachers in Toledo for this long duration was extremely influential in my development of understanding of teaching science for understanding.

• A temporally overlapping research assignment at the Otto Middle School in Lansing, Michigan, as part of MSU’s Professional Development School program, provided quite different experiences with teachers. This collaborative work with middle school science teachers and graduate students, on a near-daily basis, complemented my work in Toledo.

• Winning a grant from NSF to develop formative assessments in science and mathematics involving teachers from these two school districts. The research and development for this project extended work with these teachers in partnership with my colleagues, Joyce Parker, Perry Lanier, and Sandy Wilcox. This four-year project had a major impact on my professional growth, and signifi-
cantly increased my humility. The key lesson was about how complex the job of teaching science really is. This work also resulted in a series of booklets for teachers, staff development personnel, and teacher educators to support the use of embedded assessment in teaching (Gallagher & Parker, 1996).

- Involvement in a Local Systemic Initiative provided the context for extended collaboration with Charles (Andy) Anderson and Sarah Lindsay the Science Coordinator for the Public Schools in Midland, Michigan. We planned and learned together as we tried many new approaches to helping this large group of K–8 teachers from this single, well-supplied, “lighthouse” school district develop the skills and knowledge to teach science for understanding.

- Working with two eminent research scientists from MSU’s Kellogg Biological Station and with nearly 100 teachers were from relatively small rural schools on an NSF Supported Retention and Renewal project. Because of our success with the Local Systemic Initiative, it was only natural to bring Andy Anderson into this project. His efforts advanced my understanding of how to help teachers develop the knowledge, skills, and vision that are part of teaching science for understanding.

In the final years of my career, three additional projects continued to influence my growth. Robert Floden, Joan Ferrini-Mundy, and I conducted a Study of Leadership Development in Science and Mathematics Education under NSF Sponsorship. I also worked with Robert Yager, and Senta Raisen on the Salish Project. In addition, I was a consultant on the TIMSS-R Video Project, directed by Kathleen Roth, a former graduate student and colleague, from whom I learned so much about teaching and learning over many years.

Beginning in 2002 and continuing to the present, my association with colleagues in the Center for Curriculum Materials in Science constitutes another very important source of learning and influence on my thinking. It renewed a deep working relationship with Ed Smith, with whom I had worked in varied projects over all of my years at MSU and brought me into almost daily contact with colleagues at Project 2061, University of Michigan, and Northwestern University—partners in this project.

Over the years, my work has taken several turns. With two master’s degree theses, a doctoral dissertation and a forty-year, post-doctoral career, there has been significant evolution in my research approach. In addition, as a “devout opportunist,” I took up many research opportunities in the interest of pursuing potentially promising new lines of inquiry. In the limited space that this chapter allows, I will focus on a few of these, including my dissertation research, my transformation from quantitative to qualitative research, and selected projects that occurred over the years that followed the transformation.

SELECTIONS FROM MY RESEARCH

I already have indicated how my research approach changed over time. In the paragraphs that follow, I provide a few windows into this research beginning with
my dissertation, followed by some examples of the changing research scope during the years that ensued.

Dissertation Research

My dissertation was a watershed experience for me. As indicated earlier in this chapter, I had keen support from committee members and my wife in all aspects of it. Unlike what many doctoral students report, I enjoyed all parts of the work, from beginning to end.

The research began with a paper for Jerome Bruner’s course in which I explored explanations of students at various grade-levels regarding a small set of exemplars of scientific phenomena. For this term paper, I hoped to determine how students’ explanations developed over the years of schooling. Therefore, I interviewed about eight students in the odd-numbered grades (1–11) from a school district in a working class suburb of Boston asking them to explain the causes behind the operation of exemplars of a small set of phenomena exemplified in the Crookes’ radiometer, a palm glass, and two bar magnets.

These data, from what was to become a pilot study of my dissertation, showed a slow progression in the use of science concepts and reasoning through the grades. However, with some of the exemplars, the conceptual base was not supported by school science to any significant degree and so progression was limited. For example, students’ school learning about magnets went little beyond “like poles repel and unlike poles attract,” which most students learned by fifth grade. As a result, students in higher grades gave explanations that differed little from those of fifth graders. The conceptual level of explanations appeared to be limited by the conceptual levels incorporated in the school curriculum, in these years before diverse television programming and the creation of the Internet. Moreover, students’ explanations were also limited by a lack of understanding of the logic of explanation.

As a result of this study, my dissertation took on two aspects of this work—an empirical portion involving the chronological development of students’ explanations based in a small set of concepts and an experimental portion involving how these explanations can be modified through instruction. In my dissertation study, I omitted magnets from the study because of the conceptual difficulties that surround explanations beyond repetition of the law of magnets. I added explanation of the bi-metallic strip to the study so that the explanations were all heat-related, thus delimiting the instructional aspect of the study. A considerable amount of effort went into the baseline study resulting in a simple scale of explanation that paralleled ideas of children across the school years relating to the three exemplars—the Crookes’ radiometer, the palm glass, and the bi-metallic strip. This became basis of the pre-test and post-test for the study.

The experimental part of the study entailed a pre-test, treatment, post-test design, intended to foster modification of explanations by middle school students in grades 7–9. The instructional treatment involved two parts—a rather traditional, short, lesson sequence on concepts related to heat that was directly related to the three exemplars and a second, short lesson sequence based on the “Mousetrap
“A Broader Base for Science Teaching,” which dealt with the inclusion in the science curriculum of the nature of science and its applications in technology and society. The paper was published without modification and it received no apparent response from the readership of that journal (Gallagher, 1971). I thought it was of no consequence until several years later I attended a session on Science-Technology-Society at an international meeting run by Avi Hofstein. He began his talk by saying that one of the conceptualizers of S-T-S was sitting in the front row, a reference to my 1971 article. Until then, I had no idea that the article had any impact. The claim was also reiterated in George DeBoer’s history of science education (DeBoer, 1991). This may be an interesting issue related to information transfer in our field, or it may only be an artifact of my naiveté!

About this same time, as part of our curriculum development work at the Educational Research Council, I took on the task of studying how an experienced teacher in a local high school was enacting a new curriculum for low achieving students. This was part of the trial of innovative, new materials being developed by my colleagues. This was my first ethnographic study, and although I was conceptually ill-prepared to conduct it, what I was doing “seemed right.” I learned so much about the program and its reception by the teacher and his students as a result of watching, listening, and taking careful notes. While this study was in progress, I received a call from Willard Jacobson, then a senior professor at Teachers College. He indi-
cated he was organizing a session for NARST on studies of teacher practice and he had heard I was engaged in this type of work. After hearing about his plan and my co-presenters, I was pleased at the prospect and accepted his offer.

The day of the presentation, I sat at the front of a large ballroom at a plenary session at NARST with about two hundred members present, as Roger Anderson and Arno Bellack from Teachers College presented their quantitative, carefully developed work, and I brought up the rear with my qualitative report based on loosely structured observations in one classroom. As you might expect, I received a negative response for my study from a few of those in the audience, with at least one person saying what I was doing was neither science nor research. This may have marked the beginning of a conflict within the NARST community over qualitative research in science education that went on for over fifteen years.

A Major Transformation in Career Direction and Research Approach

Twelve years later, with my Dean’s encouragement, I spent a substantial portion of my time studying ethnographic research under the guidance of Fred Erickson for a year. As part of this work, I engaged in small studies of classrooms to sharpen my skills and deepen my understanding of research methods. Then, in 1984, two events came into play that had a large impact on my research and ultimately impacted my understanding of the field. First, I received support from Michigan State University’s Institute for Research on Teaching for a substantial study of middle and high school science teaching. The support enabled me to work with four graduate students as co-investigators over a period of three years. We studied 27 teachers in three school districts, and learned a tremendous amount about the attitudes and beliefs of these teachers. One key finding was that most secondary science teachers believed that learning was dependent on their “coverage” of science content, and it appeared that responsibility to nurture and support students in learning was not part of their responsibility as teachers. Most teachers in our study noted this in statements such as “My job is to teach, while learning is the students’ responsibility.” Couple this with statements also added by many teachers, “The good students will learn, while the rest won’t.” This appeared to be an abdication by teachers of responsibility to support learning beyond presentation of content to students. This seemed to be an inappropriate stance, and a serious misunderstanding of the role of science teachers. Moreover, it seemed commonplace, and therefore worrisome.

The second watershed event of 1984 was my first trip to Curtin University, then known as Western Australian University of Technology, where I worked with Ken Tobin on classroom-based studies in high schools, grades 8–12. Ken and I spent much of my two-month stay in one local high school that had seen change in student demography from upper-middle class to lower middle-class. Teachers there were struggling with the new population, while trying to maintain the same approaches that had worked well for them in an earlier era. We observed classes and met with teachers informally almost daily and gathered a huge amount of data. When combined with the studies that had begun at Michigan State University, be-
ing carried out by my team there (Okhee Lee and others) we added considerably to our knowledge about teachers in two diverse settings, half a globe from each other. This effort led to several publications including Tobin and Gallagher (1987a, 1987b), Gallagher and Tobin (1987), and Gallagher (1989). It also led to the publication of the NARST monograph on Interpretive Research (Gallagher, 1991), which was widely distributed by NARST that was concurrent with a significant change in the research approach and productivity of members of the organization.

Applications Grounded in Ethnographic Methods at Home and Internationally

This ethnographic work led to three additional areas of work—with teachers, with formative (embedded) assessment, and internationally—as I already have delineated. Much international work emerged as a result of the ethnographic studies between 1984 and 2004 including staff development for researchers in Brazil, Panama, South Africa, and Taiwan and projects in Thailand and Vietnam. In addition, I coordinated two international conferences—a hemispheric conference on science education in the Americas (Gallagher et al., 1985) and a US-Japan Conference on Science Education (Gallagher & Cline, 1988). These were at least loosely tied to my ethnographic work.

One other track of development and application beginning in 2000 was my development and enactment of three on-line courses at the master’s degree level as part of the Michigan State University On-line master’s degree program. My three courses were Teaching Science for Understanding; Inquiry, Nature of Science and Science Teaching; and Action Research in School Subjects. These courses applied much of my experience with teachers and school students, my ethnographic work, and my work in embedded assessment in science. They also provided a new challenge—establishing a working rapport with teachers whom I never met face-to-face! And finally, these experiences informed two final efforts in the field, my work with the Center for Curriculum Materials in Science and my development of a book for teachers and teacher educators that carries the title Teaching Science for Understanding (Gallagher, 2007).

It has been a long, varied and exciting journey. This essay only includes selections from what could be a longer description. On reflection, there is little that occurred that I would change, the exception being to give more attention to publication. And thinking back, I am so pleased that I did not follow a medical career. My life has been so enriched by all of the opportunities that came my way and people encountered as a teacher-researcher and member of the international science education community. Around each bend in this long road, there have been exciting challenges and great opportunities.

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