Theory and Methods for Sociocultural Research in Science and Engineering Education

Edited by
Gregory J. Kelly
and Judith L. Green

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THEORY AND METHODS FOR SOCIOCULTURAL RESEARCH IN SCIENCE AND ENGINEERING EDUCATION

Introducing original methods for integrating sociocultural and discourse studies into science and engineering education, this book provides a much-needed framework for how to conduct qualitative research in this field. The three dimensions of learning identified in the *Next Generation Science Standards* (*NGSS*) create a need for research methods that examine the sociocultural components of science education. With cutting-edge studies and examples consistent with the *NGSS*, this book offers comprehensive research methods for integrating discourse and sociocultural practices in science and engineering education and provides key tools for applying this framework for students, pre-service teachers, scholars, and researchers.

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Routledge
Taylor & Francis Group
NEW YORK AND LONDON

First published 2019
by Routledge
52 Vanderbilt Avenue, New York, NY 10017

and by Routledge
2 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN

Routledge is an imprint of the Taylor & Francis Group, an informa business

Library of Congress Cataloging-in-Publication Data
A catalog record for this title has been requested
Names: Kelly, Gregory J., editor. | Green, Judith L., editor.
Title: Theory and methods for sociocultural research in science and engineering education / edited by Gregory J. Kelly and Judith L. Green.
Description: New York, NY : Routledge, 2019. | Includes bibliographical references and index.
Identifiers: LCCN 2018035430| ISBN 9780815351894 (hardback : alk. paper) | ISBN 9780815351924 (pbk. : alk. paper) | ISBN 9781351139922 (ebk)
Subjects: LCSH: Science—Study and teaching—Social aspects. | Science—Study and teaching—Research. | Engineering—Study and teaching—Social aspects. | Engineering—Study and teaching—Research. | Next Generation Science Standards (Education)
Classification: LCC Q181 .T45 2019 | DDC 306.4/50721—dc23 LC record available at https://lccn.loc.gov/2018035430

ISBN: 978-0-8153-5189-4 (hbk)
ISBN: 978-0-8153-5192-4 (pbk)
ISBN: 978-1-351-13992-2 (ebk)

DOI: 10.4324/9781351139922

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FOREWORD

Meeting Methodological Challenges

María Pilar Jiménez-Aleixandre

The first paper authored by Greg Kelly that I read was published in 1993, when I was beginning my career in the University of Santiago de Compostela, moving from conceptual change towards the study of argumentation. Kelly, Carlsen, and Cunningham (1993) proposed, twenty-five years ago, to take into account the contributions from Science Studies – history, philosophy, and sociology of science – in science education research, framing it in a sociocultural perspective. That paper, together with Duschl's (1990) proposal and a postdoc visit to Peter Hewson in 1992, which gave me the opportunity of being inside Sister Gertrud Hennessey's classroom, changed my ways both of "seeing" events in science classrooms and of "seeing" science education research. As Galileo tells 10-year-old Andrea in Bertolt Brecht's play *Life of Galileo*, "to look is not to see." Andrea argues that he can see the sun moving, and that understanding the earth orbit is far too difficult for he is not yet 11, and Galileo replies that this is exactly why he wants Andrea to understand it.

For, since I began teaching in high school in the 1970s, I had been interested in learning and knowledge justification. In understanding how 11-year-olds learn science, in learning how to support them in "seeing" scientific phenomena through particular theoretical lenses. Graduating in biology in 1969, at a time when in Spain pedagogical training for teaching and science education research did not exist, I bought two books, Piaget's *The Origins of Intelligence in Children* and Neil Postman and Charles Weingartner's *Teaching as a Subversive Activity*, in an effort to learn some theory about education. During the five years of the biology degree, I only had the opportunity to enroll in one course about history of science and to read Benjamin Farrington's *Science and Politics in the Ancient World*. From Piaget I learnt that knowledge is actively constructed by the learner. In Postman and Weingartner's book I found ideas from Dewey,

and a recommendation that school should develop in students the anthropological perspective, observing their own culture as if it were a foreign tribe, a suggestion that would be brilliantly developed by Latour and Woolgar (1986).

My trajectory can be representative, or in Heap's terms an example, of Spanish – and most European – science education scholars beginning to build research communities in the 1980s. Our background consisted solely of science concepts, methods, and approaches. Thus, many of the first research efforts were grounded in methods drawn from science. Heap (1995) pointed out that educational research – even when identifying itself as qualitative – often retained empiricist conceptions and criteria. In my context this trend was heightened in most of science education work, which attempted to legitimize science education research within empiricist frameworks. Different types of obstacles, epistemic, related to research traditions, experiential, and even affective, among others, needed to be overcome in order to engage in science-in-the-making studies, as suggested by Kelly and colleagues (1993). A few years later, after meeting Greg Kelly and cooperating with him in the first argumentation session in a NARST conference in 1997, I became familiar with Judith Green's insightful approaches. An influential example of their work together is the framework for examining students' discursive practices in a physics laboratory (Kelly, Crawford, & Green, 2001). Since then, scholars interested in what happens inside science classrooms, and how to account for it, have learnt much from both their theoretical contributions and their methodological proposals. Kelly and Green have developed insights and research methods to examine classroom discourse, and the book structure organized around eight empirical chapters illustrating specific methods gives it an innovative nature, while the rigor and depth of the contributions anticipate that it will soon become a classic.

Although I mentioned above science classrooms and science education, it needs to be noted that an original feature of the book is including engineering in its focus, which reflects one of Kelly's current research interest (Cunningham & Kelly, 2017a; 2017b), aligned with the *Next Generation Science Standards (NGSS)* (NGSS Lead States, 2013).

Methodology matters, and there is a thirst for robust reference books about it. Educational research about science and engineering has tended to have a stronger focus either on theoretical approaches or on empirical findings about learning and teaching. Methodological issues specific of these fields have, as a consequence, been given less attention. A substantial amount of scholarly work about science and engineering is grounded in domain-general research methods, from which we have much to learn but that are less suited to address some domain-specific issues. Domain-specificity is one of the methodological challenges that this volume seeks to meet, and which makes it a work of unique value. A second one is to tackle the three-dimensional learning, integrating core ideas, crosscutting concepts and practices, emphasized in the *NGSS*. A third challenge is to show

how rigorous qualitative research can make visible how science and engineering concepts, processes, and practices are socially constructed.

The volume is particularly strong from a methodological perspective, addressing issues that have been previously unresolved or understudied, or approaching more familiar problems in a new way. An instance is the construction of identities-in-practice of kindergarten girls as science learners, investigated by Alicia McDyre, in the Chapter 2. As she points out, most gender research in science has been about adolescents, and I will add that Early Childhood Education has received little attention. It should be noted, and praised, that gender is addressed in that early chapter, the first one reporting a study. Equity is also the focus of Peter Licona's chapter about the methodological decisions made in his study with bilingual students engaging in argumentation about the socioscientific issue of endangered species. The examination of emotional expressions, undertaken by Elizabeth Hufnagel in the context of environmental science and climate change, is another understudied issue. Hufnagel articulates a framework for the study of emotions in science classrooms, creating in the process the notion of *aboutness* to refer to the object of the emotion. Elementary engineering provides the context of two chapters: Johnson explores the joint social construction by students and teachers of failure and improvement in engineering design projects, and Vanderhoof carries out a multimodal analysis of engineering design, with a view towards transferability to other studies involving student–student interactions and a focus on student-produced artifacts. Asli Sezen-Barrie and Rachel Mulvaney tackle an original issue, how to build coherence among scientific concepts and related epistemic practices, in the area of climate science, through Informal Formative Assessments (IFAs). Learning science and engineering is dependent on how teachers teach, therefore on how teachers are enculturated, and two chapters propose new ways of looking at teacher education: Arzu Tanis Ozcelik and Scott McDonald focus on how pre-service science teachers develop what they term *professional pedagogical vision* related to ambitious science teaching, and the new challenges posed by the *NGSS*. Amy Ricketts analyzes a professional learning community, and how the teachers belonging to it developed a culture of reflective critique through conversations of a generative nature.

The emphasis on methodological challenges means that the focus of each of these chapters is a *reflection* about the process of research itself, discussing not only the final form of research questions, rubrics, or tools for analysis, but in particular the *decisions* made during the process, and even – as examined by Hufnagel – the changes in the logic of inquiry, as data were collected and analyzed. In other words, we get access to the science-in-the-making of these studies and dissertations, to the metaknowledge that went into this research, or that was generated during it. This explicit layout of reflections is another feature that makes this book unique. As Kelly and Green point out in Chapter 1, their goal is to make visible ways of developing and explaining processes

involved in designing, conducting, and constructing warranted accounts from discourse analysis. Reflection about the research processes combines the three types of critical discourse identified by Kelly (2006): *critical discourse within group*, concerning developmental and definitional work regarding a research group's central theories, assumptions, and key constructs; *critical discourse regarding public reason* concerning the epistemological commitments of the field of education regarding research methods; and *hermeneutical conversations across groups*, designed to learn from differences across traditions.

The book offers a systematic approach to the study of educational events, an approach that is empirical and emphasizes methodologies, but that is also theoretically grounded; for methods have foundations on particular theories. The research reported in these contributions is grounded in a sociocultural perspective, bringing together approaches from discourse analysis, interactional ethnography, and epistemology, weaving them in a coherent whole. The qualifier "systematic" is relevant for, as Kelly and Green discuss in the Chapter 1, some qualitative studies suffer from problems such as lack of systematic sampling, lack of theoretically grounded approaches for the study of large data sets, or failing to situate instances of learning in ongoing sociocultural practices.

All scholars who have been extensively involved in reviewing manuscripts for refereed journals, in evaluating research proposals for National Agencies (such as NSF), or even in supervising doctoral students, know that most flaws of research proposals or manuscripts relate to methodological issues. This book will be useful for researchers, first because of its systematic approach to methodology, as illustrated for instance in the questions discussed in Chapter 1, ranging from asking ethnographic questions to recognizing relevant data sources, elaborating data representations, or finding patterns. Second, it will be useful for the book's range of examples, which develop all these questions and analyze a variety of dimensions about how the construction of science and engineering is accomplished.

An undercurrent running through the chapters is a commitment to equity, social justice, and a sustainable world. Two of the studies, Hufnagel's, and Sezen-Barrie and Mulvaney's, are situated in the context of climate change. In particular, Sezen-Barrie and Mulvaney take on the challenge of building coherence across concepts and epistemic practices utilized to justify the claim that humans are the main cause of current climate change. Denialism of anthropogenic climate change is an educational problem but, more seriously, it is a social and political issue impacting the earth's future. As Sezen-Barrie, Shea, and Borman (2017) point out, climate change skepticism is not scientific skepticism, but rather denial. This raises a theoretical issue: concerns are currently shifting from a focus on understanding the tentativeness of scientific knowledge towards a focus on epistemic education empowering students to face "post-truth." Chinn and Barzilai (2018) propose that a fully apt epistemic performance, on this dimension, would see abeyance as an option, but would judge that the scientific community consensus is sufficiently warranted. In order to examine such complex epistemic

performances in classroom practice, we will need sophisticated methods, as those analyzed in detail in this book.

As Galileo Galilei – at least the Galileo imagined by Brecht – struggled to teach a 10-year-old to "see" beyond the apparent, and to uncover the relationships between earth and sun, so educational researchers strive to uncover how science and engineering are socially, conceptually, and discursively constructed in classrooms. In doing so they will find guidance in the accomplished scholarship brought together in this volume and, in particular, in the reflections about what the authors-ethnographers learnt from their analyses.

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1

FRAMING ISSUES OF THEORY AND METHODS FOR THE STUDY OF SCIENCE AND ENGINEERING EDUCATION

Gregory J. Kelly and Judith L. Green

Introduction

The *Next Generation Science Standards* (NGSS Lead States, 2013) prominently feature three-dimensional learning—the integration of disciplinary core ideas, crosscutting concepts, and scientific and engineering practices. This tripartite emphasis raises methodological challenges for researchers and educators seeking to examine, and thus uncover, the ways in which science and engineering content, processes, and practices are ongoing social constructions in educational settings. The methodological challenges include understanding the cognitive, social, and interpersonal factors supporting or constraining the learning of these disciplinary ideas, concepts, and practices.

This volume brings together contributors who explore how science and engineering concepts, processes, and practices are socially constructed through coordinated interactions among students, teachers, curricula, texts, and technologies (Kelly, 2016a). Our goal in assembling this particular group is to make visible ways of developing and explaining processes involved in designing, conducting, and constructing research leading to warranted accounts of educational phenomena (Heap, 1995). A series of chapters that describe various dimensions of the construction of science and engineering make visible how, in what ways, for what purposes, and with what outcomes, science and engineering in educational settings are socially, discursively, and conceptually constructed.

This research approach takes seriously the ways that discourses and social practices are constructed over time by members of a sustaining social group. Such classroom cultures are formed through locally interpreted and recognized ways of talking, being, and knowing (Santa Barbara Classroom Discourse Group, 1992a, b). These reforms in science education emerged from a recognition, developed over

DOI: 10.4324/9781351139922-1

fifty years of theoretical and empirical research on discourse processes and ethnographic studies of education (Green, 1983; Gumperz & Hymes, 1986; Hymes, 1974), of the important ways that educational experiences are created through discourse. This research tradition examines ways that educational and social experiences are shaped through discourse in and across interactions among actors in developing events and times (Bloome, Carter, Christian, Otto, & Shuart-Faris, 2005; Cazden, John, & Hymes, 1972; Heath & Street, 2008; Green, 1983; Green & Joo, 2016; Green & Bloome, 2004; Gumperz & Hymes, 1986; Hymes, 1974; Kelly & Chen, 1999; Lemke, 1990).

Early work on classroom discourse in science education focused on teacher talk. For example, Lemke's (1990) seminal work examined how and in what ways the thematic content of scientific knowledge was communicated. Such functional linguistic analysis showed how teachers came to frame science as difficult to understand and as accessible to only a cognitive elite by limiting classroom conversations to narrow conceptions of disciplinary knowledge. Since this early work, the field has greatly expanded to include a range of studies looking at issues such as student groupwork in laboratory settings, argumentation, assessments, uses of questioning, and studies of identity development (for review, see Kelly, 2014a).

Science and engineering education each have a history of ideas, recommendations, instructional design and practice, and suggested reforms. This book provides a set of selected studies, each of which examines some of the current practices in science, engineering, and teacher education. At the core of this volume is an understanding that, whether focused on students' engineering design challenges, identity construction as a scientist, or development of teachers' professional vision, everyday educational events are, and have always been, constructed through discourse processes, within the cultural practices of life within these and related settings (e.g., home, community, laboratories, social spaces).

The book's authors make visible ways of conducting ethnographically informed, discourse studies of science and engineering education as socially constructed in everyday life in classrooms (kindergarten through university). The research approach provides systematic ways to use large-scale video and qualitative data to examine salient issues for making sense of science and engineering. Chapter topics include argumentation, gender in science, engineering design, science accessibility for emergent bilingual students, the role of emotion in science learning, and teacher education.

Our review of the literature, and our experience as researchers, surfaced the need for a book providing multiple instances of systematic empirical studies of educational phenomena. Large-scale quantitative studies often lack the sensitivity to examine the ways that access to knowledge, affiliation and identity, and learning through design are constructed through social interaction. While such studies often report declarative statements about the current state, as measured within the boundaries set by the research instruments, they fail to explain why or how the

current state was constructed. Alternatively, some qualitative studies do not utilize systematic sampling and/or theoretically grounded approaches for the study of large-scale video data sets. These studies often zoom to important instances of learning, showing how in such an instance learning occurred, but fail to situate the instance in ongoing sociocultural practices. In contrast, we seek to make transparent ways of systematic sampling and theoretically grounding approaches for analyses of large-scale video data sets or archived records (e.g., video, audio, written work by students). The approach lays out ways of recording, documenting, sampling, and analyzing video and artifact data through discourse analysis that addresses questions applicable to the understanding of three-dimensional learning (integration of disciplinary core ideas, crosscutting concepts, and scientific and engineering practices).

Epistemology, Methodology, and Educational Research

Educational research seeks to produce knowledge about learning, activities, people, institutions, and systems. Research methodologies are designed to produce new knowledge. Such knowledge is grounded in human perception, experience, practices, and identities. Thus, to the extent that research methodologies are about producing knowledge, they are epistemological. Like the study of knowledge (epistemology), research methodologies are concerned with the origins, production, evaluation, and limitations of knowledge (Boyd, Gasper, & Trout, 1991).

This book takes up the challenge posed by Kelly (2006) in an introductory chapter in the *Handbook of Complementary Methods in Education Research*. He identified three types of critical discourse with conversation metaphors for articulating, comparing, assessing, and improving research methodologies in educational research: *critical discourse within group, critical discourse regarding public reason*, and *hermeneutical conversations across groups*. We describe each of these critical discourses and explain how the chapters in this volume advance the challenge of building more rigorous, coherent, and transparent approaches to research methods in science and engineering education.

Critical discourse within group are conversations concerning developmental and definitional work regarding the creation, specification, and extension of a research group's central theories, assumptions, and key constructs (Kelly, 2006). Within-group critical discourse provides a forum for development of a research area's core theories and commitments. For example, in the subsequent section, *Discourse, interaction, and interactional ethnography*, we describe the central theoretical commitments of interactional ethnography and apply them to specific studies in the later chapters. In within-group conversations, there is a premium on the development of new ideas, metaphors, and redescriptions (Rorty, 1989). In these critical conversations, researchers create new vocabulary to make sense of our world. For example, notions such as "aboutness" (Hufnagel, this volume), "failure" (Johnson, this volume), and "professional

pedagogical vision" (Tanis Ozcelik & McDonald, this volume) are re-imagined and re-articulated in science and engineering education in new ways that advance the respective conversations about emotions in science, engineering design, and teacher learning. We invite the readers to consider the ways that each chapter contributes to the creation of the substantive central theories, assumptions, and key constructs in the respective domains.

Critical discourse regarding public reason focuses on the development of epistemological commitments to assess the value of educational research within and across different research traditions (Kelly, 2006). These conversations concern the criteria used to judge research. Likely candidates for criteria would be insightfulness, empirical warrant, theoretical salience, consistency with other knowledge, transparency, and usefulness for practitioners. For example, later in this chapter we consider some critical methodological themes for research in education (Kelly, 2014b) as related to the empirical chapters (Chapters 2–9) in this book. Thus, critical discourse regarding public reason concerns the epistemological commitments of the field of education regarding research methods. What counts as valid and useful research in this area? What are the bases for decisions about the value and usefulness of studies of science and engineering education? How are studies of discourse, social practices, access, and equity across contexts and timescales valuable to engage the field in critical discussions about the epistemology of social science research?

Hermeneutical conversations across groups are conversations designed to foster learning from differences across traditions. They also consider the multiple audiences of research. There are many ways in which research in science and engineering education can contribute to conversations about educational research within and across research traditions. Based on this conceptual argument, we propose different directions for conversations about how research on science and engineering education ties into other traditions in the field. The first conversation supports consideration of how research on science and engineering can be informed by, and inform, the development of specific research methods for educational research more generally. Science and engineering represent compact disciplines, with relatively high degrees of consensus (Rorty, 1991; Toulmin, 1972). Each field represents unique ways that knowledge is generated, communicated, and applied. The uniqueness of some of the features of the disciplines of science and engineering presents models and challenges for educational research.

A second form of conversation can consider how different theoretical traditions within science and engineering education (cognitive, sociocultural) have examined substantive issues and how similar substantive issues articulated in the chapters of this book relate to that body of work. There are many ways that the social phenomena described in the chapters of this book could have been studied. By undertaking comparisons across traditions from linguistics, psychology, anthropology, and sociology about how key constructs are recognized, examined, and constructed in and through research, we can examine how these comparisons

can inform hermeneutical conversations. A third form of hermeneutical conversation could explore how studies of discourse and sociocultural practices of science and engineering connect with studies across broad social phenomena beyond the specifics of these disciplines. Developing a research program addressing these problems may require examining how different approaches are mutually supportive and synergistic within and across disciplines in studying social phenomena. For example, studies of workforce development and policy can show how science and engineering interact with legitimizing institutions in society. At the center of these three forms of hermeneutical conversations, therefore, is a common critical theme—the understanding of relationships between research methodology and the production of knowledge through studies grounded in different traditions.

The connectedness of knowledge production and research methodology is made visible in each of the chapters in this volume. The selected studies adopt a common (although not identical) approach to the study of disciplinary knowledge, practices, and identities that permits ways of understanding the investigation of discourse from this epistemological point of view. Each author drew from, interpreted, and modified aspects of interactional ethnography. By holding the orienting theories for the study of knowledge construction constant, the collective work provides knowledge about how to research science and engineering ways of knowing, doing, and being. We now turn to an overview of interactional ethnography, which informed the subsequent empirical studies.

Overview of Perspectives: Discourse, Interaction, and Interactional Ethnography (IE)

Interactional ethnography is an approach to the study of culture. It considers the social contexts discourse uses as cultures-in-the-making. The orientation to understanding culture begins with the recognition of the importance of discourse processes, texts, and signs and symbols for the construction of norms and expectations; roles, relationships, and positionings; and rights and obligations as well as the construction of meaning among members. Interactional ethnography is informed by sociolinguistics, cultural anthropology, ethnomethodology, and critical discourse analysis.

Sociolinguistics investigates ways that everyday life is accomplished through discourse processes. Gumperz (1982) defines sociolinguistics as a "field of inquiry which investigates the language usage of particular human groups" (p. 9). Discourse is often defined as language-in-use that includes verbal exchanges, written texts, signs and symbols, and other semiotic resources (Jaworski & Coupland, 1999). These semiotic resources include contextualization cues, such as gesture, eye gaze, prosody, lexicon, grammar, kinesics, and proxemics (Bloome *et al.*, 2005; Gumperz, 2001; Green & Castanheira, 2012; Green & Wallat, 1979; Strauss & Feiz, 2014). To understand how specific discourse processes function,

they need to be examined in contexts of use; thus, discourse studies are tied to ethnographic descriptions of what members of a social group propose, recognize, acknowledge, and interactionally accomplish as socially, academically, personally, and interpersonally significant. In such instances, interpretations of semantics and accompanying contextualization cues are highly culturally dependent. Meaning is derived from interactions that include the highly active interpretative nature of communication.

Cultural anthropology also informs interactional ethnography. Ethnographers produce data, from which texts about cultural processes and practices are constructed (Ellen, 1984). That is, anthropologists write culture (Clifford & Marcus, 1986). From this point of view, there is an active, participatory role of the ethnographer in the construction of the account of the putative cultural practices. Cultural knowledge is socially constructed through the languaculture of particular groups (Agar, 1994; Green, Skukauskaite, & Baker, 2012). This awareness of the reflexivity of the ethnographic point of view suggests the need for the analysts to make transparent the logic-in-use informing the methodological decisions of the study (Green, Dai, Joo, Williams, Liu, & Lu, 2015). Part of this orienting theory is the need to take an emic perspective to construct ways of knowing grounded in the local cultural practices. Green and Bridges (2018; following Heath & Street, 2008) identify what constitutes such an emic (insider) understanding, which includes suspending assumed-to-be-known categories of meaning to construct situated meanings from the local setting, recognizing differences between ethnographers' knowledge and that of the participants, and developing ways of representing what is known by the local (insider) actors. This awareness of the role of the ethnographer in the construction of the knowledge speaks to the need to engage in the critical discourses noted previously.

Ethnomethodology influences interactional ethnography in important ways. Ethnomethodology is the study of the ways that people accomplish everyday life. It is not a "research methodology"; rather, it focuses on the methods used to get through social contexts. In the study of scientific practices, ethnomethodology has attended to the products of science that emerge from interactional and discursively formulated events. Consider the following from Lynch (1992): "Ethnomethodology's descriptions of the mundane and situated activities of observing, explaining, or proving enable a kind of rediscovery and respecification of how these central terms become relevant within particular content of activity" (p. 258). Such respecification entails more than just producing declarative statements (empirical and contingent) of findings about the work of scientists. A different type of warranted claim is needed—ethnomethodology (and interactional ethnography) produces both logical and normative claims about the workings of social groups (Heap, 1995). Rather than empirical generalizations, claims are constructed through the study of culture and produce propositions revealing previous unrecognized patterns in everyday life. Although ethnomethodology presents the interactionally accomplished nature

of everyday life and provides theoretical tools to understanding conversations, classroom discourse occurs in institutions and settings where power, control, and structures mediate the direction and nature of the discourse processes. This suggests a need to understand how power works in social settings.

Critical discourse analysis (CDA) examines how ideologies and power relations are manifest in ways that language is used in various contexts. In educational research, theories of power, culture, and social life inform ways that critical discourse analysis can be applied to life in schools (Rogers, Schaenen, Schott, O'Brien, Trigos-Carrillo, Starkey, & Chasteen, 2016). An ethnographic point of view recognizes that language and discourse entail meanings that have power for real people in real settings. Fairclough (2010) identified relational, dialectical, and transdisciplinary properties of critical discourse analysis (p. 3). First, the approach focuses on social relationships and the ways they use texts, genres, power relations, and institutions to establish and maintain these relationships. For example, science teachers have institutional power, established by their role as an authority in a classroom. Certain discourses afford teachers the ability to control others through the power instantiated by this role. However, the discourses of science, used by the teacher or texts of the classroom, may also be positioned to appear distant, objective, and unassailable. In this way, the genres of scientific explanation communicate an ideology.

Second, critical discourse analysis is dialectical. The uses of discourse and power in social relations and institutions are interconnected. As discourse is employed it creates consequences beyond that of mere discourse—that is, there are material consequences of ideologies. For example, academic success or failure has implications for who can participate in further debates about scientific or other matters.

Third, critical discourse analysis is transdisciplinary, drawing from multiple disciplines, such as sociology, linguistic anthropology, political science, gender studies, and/or education (Fairclough 2010; Rogers *et al.*, 2016). Interactional ethnography takes up Fairclough's (1992) three dimensions of critical discourse analysis methodology through analysis of text, analysis of text production, and social analysis of the discursive events, conditions, and consequences for participants. The application of interactional ethnography to science and engineering education in this book highlights different aspects of text, text production, and social analyses.

Taking an Interactional Ethnographic Perspective on Science and Engineering Education

Uses of discourse in the moment of interaction are always situated in a social and cultural setting. They are constructed in particular ways with conventions that align with the norms and expectations of the participants. And they have consequences for subsequent actions by the participants. Interactional ethnography begins by asking ethnographic questions, such as: What is happening here?

How are the norms and expectations constructed, developed, acknowledged, and legitimized? What counts as knowledge? For whom, under what circumstances, with what outcomes, with what consequence?

The process begins with an initial period of ethnographic research that seeks to understand insights into local communicative ecologies, discover recurrent communicative patterns, and identify how local actors define problems (Gumperz, 2001). These analyses become the basis for selecting sequentially bounded units or events, denoted by co-occurring shifts in content reference (spoken, written, or graphic/visual), prosody, or other stylistic markers, which are represented by transcripts. Thus, ethnographic description provides a basis for selection decisions and theoretical sampling in large ethnographic archives from which data sets are constructed (Gee & Green, 1998; Kelly & Chen, 1999). By drawing from the ethnographic descriptions, the detailed discourse analysis is informed by the broader contexts of use of the discourse processes in question.

To research the accomplishment of everyday life, a number of substantive assumptions define the orientation (Kelly & Green, 1998): As members of a group affiliate over time, social interaction helps them develop patterned ways of producing language-in-use (Bloome *et al.*, 2005). Such language use both shapes and is shaped by social order (Fairclough, 2010; Jaworski & Coupland, 1999), as social groups create particular ways of talking, thinking, acting, and being (Gee & Green, 1998; Santa Barbara Classroom Discourse Group, 1992a). These ways of acting come to define cultural practices, become resources for members, and evolve as members internalize the common practices and transform them over time. The cultural practices that constitute membership in a community are created interactionally through discourse processes. Local group members are also members of other groups, and thus bring frames of reference to each interaction, including experiences, beliefs, values, knowledge, and practices (e.g., ways of knowing, doing, interpreting, and so forth) that may match or clash with local ones (Castanheira, Crawford, Dixon, & Green, 2001; Kelly, 2014b). These substantive assumptions provide an orienting framework to examine three basic ways of investigating cultural practice: observing what people do, say, and make. Such assumptions about the construction of everyday life support the creation of common frameworks for interpretative research and are shared by research programs across academic disciplines (Baker, Green, & Skukauskaite, 2008; Bloome *et al.*, 2005; Green & Dixon, 1993; Kelly, 2014b). By supporting a common framework, we can build theory in education oriented to making knowledge accessible to learners. The framework is interpreted, modified, and integrated with other theories across the chapters of this book. In this way, the overall orientation demonstrates the importance of a common framework, but also the ways that such a framework can be taken up and at times extended to examine particular phenomena of interest to researchers across settings, perspectives, and topics in educational research.

Science and engineering are constituted by social practices, occurring in cultural contexts. Thus, through everyday practices of doing science or engineering,

members of local communities propose, communicate, assess, and legitimize knowledge claims, engineering designs, and solutions to locally relevant extant problems (Kelly, 2016a, b). In professional and educational communities, the actions taken can become coordinated through concerted activity, thus developing patterned cultural practices of members for the group (Kelly & Green, 1998; Smith, 1996). Thus, through language use and other actions, social groups create meaning, and build identity and affiliation as well as academic knowledge and practices that contribute to larger societal needs. Rather than viewing science and engineering as disembodied knowledge, the authors in this book view disciplinary knowledge and practice as the products of concerted activity, and therefore subject to investigation through the study of the locally created, interactionally acknowledged and recognized cultural practices leading to the relevant knowledge and solutions to problems defined in such contexts.

Research Considerations, Approaches, and Methods

Interactional ethnography offers the possibility to build common frameworks for interpretative research to investigate the various ways that disciplinary knowledge and practice can be communicated in educational settings. There are multiple views of culture, and numerous approaches for how to define, do, or interpret ethnography. We find the distinction by Green and Bloome (2004) of (a) doing ethnography, (b) adopting an ethnographic perspective, and (c) using ethnographic tools to be especially helpful for the application of ethnography to school and other educational settings. Doing ethnography has traditionally referred to in-depth, long-term studies of culture often done by cultural anthropologists through extended field study. Within anthropology, adopting an ethnographic perspective means drawing from theories of culture and inquiry practices of anthropology to guide research in a given local setting. Using ethnographic tools refers to the methods and techniques employed in field work. For the most part, the examples in this book adopt an ethnographic perspective, viewing the local educational settings for research as open to interrogation through ethnographic questions (Heath, 1982; Bloome & Green, 2018). In each instance, the ethnographic methods employed are situationally defined.

In the next section, we provide an example of taking an ethnographic perspective from our previous work to illustrate some of the key features of interactional ethnography relevant to the study of science and engineering education. Subsequent chapters will further illustrate and elaborate upon these seven features. The example comes from a study by Kelly, Crawford, and Green (2001) where we examined the discourse processes of four groups of physics students studying oscillatory motion. The groups completed a series of tasks using force and motion detectors that graphed physical events instantaneously on a computer screen. The activity allowed students to vary aspects of the physical world and examine how these affected the graphical representations.

To apply an ethnographic perspective to these events, we engaged in the following types of research activity.

Asking Ethnographic Questions

Ethnographers ask questions. In this case, we asked: What's happening here? What are the roles and responsibilities as locally defined and construed by the students and teacher? What knowledge is relevant to completing the school task? How might the school task be related to disciplinary knowledge? Through data collection and analysis, the ethnographic research team refined the questions so that they were those most salient to understanding how knowledge was constructed, shared, and assessed (Kelly, Crawford, & Green, 2001). Thus, our set of ethnographic questions was emergent, relevant to our evolving knowledge of the students' construction of the physics, and open to debate and changes as we worked through the discourse analysis of the video episodes. In contrast, the study of physics often asks other sorts of questions; questions that do not consider science as culture and practice. From a cognitive perspective, researchers might ask a third set of questions, leading to different data and different results, thus showing how knowledge in social science is constructed, contingent, and informed by theoretical commitments. Cognitively oriented questions might include: What was the initial knowledge state of each of the students? What misconceptions about the physics of force and motion were addressed through the lesson? How did the students' self-efficacy lead to choices about solutions to the physics problems? How did the teachers' pedagogical content knowledge (PCK) inform choices about what to say to the students and when?

Identifying Sites for Knowledge Construction and Negotiating Access

To use interactional ethnography, the research team needed to identify sites and gain access for the study of knowledge construction. Much has been written about gaining access for qualitative research, for example, Corsaro (1985) and Emerson, Fretz, and Shaw (1995), so we will not elaborate here. For our physics study, we chose a site for research and thought about how to gain access to the sorts of data relevant to our research questions. We negotiated access with a high school teacher and her students. This involved learning about their curricular goals, understanding the content the students were studying, identifying areas of mutual interest (laboratory work with technology), and assessing the physical and technological constraints of the learning environment.

In this example, students needed to interpret the physical events (oscillating masses), symbols (real-time, computer-generated graphs), verbal and written prompts (teacher lab guidesheet, student talk), and embodied motion (student imitation of motion through physical movement of hands). Students based many

of their knowledge claims in data acquired by the representation technologies. The computer-generated visual texts were a consequence of the live complex physical phenomena and offered sufficient interpretative flexibility (Knorr-Cetina, 1995) to provoke sustained conversation. This suggested to us the importance of creating a retrievable record of the events through video recordings and the collection of the lesson prompts and student-produced artifacts.

Recognizing the Relevant Data Sources for Interactional Ethnography

The video records of the events were relevant data sources because key features of the social phenomena included a series of knowledge claims made by the students. The series of student claims about physical phenomena often entailed false starts, changes in initial thinking, questioning, re-doing of data trials, rebuttals, and re-interpretations. Therefore, students' deliberation about the physical and representational phenomena was central to the activity. Relevant to the study of student discourse from a sociolinguistic perspective was consideration of the verbal and non-verbal communication, which included the signs and symbols, proxemics, and prosody of the conversations (Green, Weade, & Graham, 1988; Gumperz, 2001). Previous studies of scientific practice supported our methodological orientation. For example, Garfinkel, Lynch, and Livingston's (1981) study analyzed the "local, interactionally produced, recognized, and understood embodied practices" (p. 135) of astronomers as they discovered, named, and textually identified a pulsar. Much like the astronomers, the physics students made sense of the phenomena by proposing a series of claims that were considered and modified over time by the group members.

Discourse and Sociocultural Practices in Everyday Life, in Time, and in Space

The students' discourse processes in the small groups were not just constructed in the moment without referents, previous knowledge, or literary practices. Rather, knowledge claims made in the moment-to-moment interactions were embedded in speech genres, sociohistorical traditions, and ways of being that were drawn into and invoked in the local setting (Bakhtin, 1986; Bazerman, 1988; Kelly, 2008). For example, the data representations of the oscillatory motion stemmed from a long tradition of mathematical knowledge regarding ways of plotting variables for common understandings. The data acquisition technology concretized such knowledge and rendered visual images for the students to interpret. Such interpretation required not only making sense of the immediate displays, but also understanding the assumptions built into the mathematical traditions of data representation and graphing conventions. Thus, making sense of the oscillatory motion (displacement, velocity, acceleration, force) required drawing from