This concise volume describes and critiques various theoretical frameworks used in chemistry education research. The book also reviews and discusses the potential applications of each theoretical framework to different types of chemistry education research. Our goal is to help practicing chemists and chemistry instructors learn how to do research in their own laboratories and classrooms.
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Prologue

In a typical experiment performed by a practicing chemist, the researcher chooses a particular analytical instrument, or a particular software package, or a particular approach to synthetic chemistry that meets the needs of the experiment being done. The choice of instrument or computational technique obviously influences the kind of experiment that can be done and, thus, the data that can be gathered about the compound being studied. One would not expect to obtain mass data from an HPLC, for example; nor would one expect to obtain retention time information from a mass spectrometer. The choice of instrument affects the type of data the researcher will obtain and later analyze and interpret.

For qualitative research studies in education, the theoretical framework plays a role analogous to the role of the instrument. A theoretical framework is a system of ideas, aims, goals, theories and assumptions about knowledge; about how research should be carried out; and about how research should be reported that influences what kind of experiments can be carried out and the type of data that result from these experiments. Crotty (1998) defined a theoretical framework as “the philosophical stance informing the methodology and thus providing a context for the process and grounding its logic and criteria” (p. 3). Because a theoretical framework has great influence on the design, data collection, and data analysis of qualitative studies, each qualitative researcher must make explicit the framework he or she has chosen for a particular study.

Clearly, qualitative research in chemistry education is strongly influenced by the researcher’s choice of theoretical frameworks. For this reason, researchers need to be familiar with the various theoretical frameworks available to guide a study. Investigating and comparing individual theoretical frameworks can be time-consuming, however, because adequate descriptions of these frameworks are distributed across a wide spectrum of journals and research monographs with which chemistry educators are not familiar. Furthermore, few of the descriptions of theoretical frameworks that are readily available are discussed within the context of chemistry education research.

We have therefore tried to create a concise volume in which various theoretical frameworks used in chemistry education/science education research are described and critiqued. In this book, we will also review and discuss the potential applications of each theoretical framework to different types of chemistry education/science education research. Our goal is to help practicing chemists, chemistry instructors, and chemistry educators learn how to do basic educational research within the context of their own instructional laboratories and classrooms.

This book is an outgrowth of a series of discussions with graduate students and faculty from Departments of Chemistry, Schools of Education, and, more recently, Colleges of Engineering, that inevitably seemed to focus on the question: Where can I obtain the information that would enable me to make an intelligent choice about the theoretical perspective or framework upon which I can build the study I want to carry out?
We have asked the author of each chapter to provide the following information:

- A description of the theoretical framework;
- A brief history of the framework (when and why it was developed);
- The ontological assumptions of the framework;
- The methodologies and analysis techniques associated with the framework;
- The advantages and disadvantages of using the framework;
- A description of studies in chemistry education and/or science education that have used the framework;
- A discussion of the types of chemistry/science education studies for which the framework might be appropriate and, equally important, the types of studies for which the framework might not be appropriate.

The first symposium on research in chemical education at an American Chemical Society meeting was held slightly more than twenty years ago. This symposium contained a total of six papers and filled a half-day of the chemical education program. Since then, the number of people who have devoted their careers to doing research on the teaching and learning of chemistry has increased significantly. There have also been significant developments in the methodology for doing research in this area — and in the sophistication of the questions being investigated — in the last two decades. The topics being addressed in this book, however, are not unique to the field of content-based educational research in chemistry nor are they unique to educational research that involves qualitative research techniques or methodologies, although the emphasis of many of the chapters in this book will be on qualitative research.

The goal of this book is to help those who want to learn how to design educational research studies that are consistent with the call for rigorous research issued by the National Research Council Committee on Scientific Principles for Education Research (Shavelson & Towne, 2002). The NRC report argued that scientific research in education poses a significant question that can be investigated empirically; that this research is linked to relevant theory; and that it uses methods that permit direct investigation of the question. It called for research that provides a coherent, explicit chain of reasoning; can be replicated/generalized across studies; and is subject to professional scrutiny and critique. Research of this nature should also meet the criteria set forth by Diamond (2002), who calls for research that requires a high level of discipline-related expertise; that is conducted in a scholarly manner with clear goals, adequate preparation, and appropriate methodology; that has significance beyond the setting in which the research is conducted; that is innovative; that can be replicated or elaborated on; that is appropriately and effectively documented, including a thorough description of the research process and detailed summaries of the outcomes and their
significance; and is judged to be meritorious and significant by a rigorous peer review process.

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References


Part

I

CONSTRUCTIVIST FRAMEWORKS
The Role of Theoretical Frameworks in Chemistry/Science Education

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Biography

George Bodner is the Arthur E. Kelly Distinguished Professor of Chemistry, Education, and Engineering at Purdue University. He began his academic career as a history/philosophy major at the institution now known as the University at Buffalo. He found, much to his amazement, that chemistry was fun, and changed his major under the mistaken impression that jobs were easier to find as a chemist. After a mediocre career as an undergraduate (B.S., 1969), he entered graduate school at Indiana University (Ph.D., 1972) where he apparently did well enough as a double major in inorganic and organic chemistry to gain an appointment as a visiting assistant professor at the University of Illinois (1972-1975). Two things became self-evident during his tenure at Illinois. He found that teaching was fun, and he realized that his research could best be described as searching for definitive answers to questions no one ever asked. When the time came to leave Illinois, he therefore took a job as two-thirds of the chemistry faculty at Stephens College where he lasted for two years (1975-1977), teaching general, organic, inorganic, and biochemistry. He moved to Purdue University in 1977 to take a position in something known as "chemical education." He is the author of more than 120 papers and 48 books or laboratory manuals. His interests include the development of materials to assist undergraduate instruction, research on how students learn, and the history and philosophy of science. Several years ago, he was selected to receive the Nyholm Medal from the Royal Society of Chemistry, the Pimentel Award in Chemical Education from the American Chemical Society, and the Distinguished Alumni Award from his alma mater, the University at Buffalo.

Introduction

This chapter tries to summarize some of what the author has learned while working with graduate students pursuing research-based M.S. and/or Ph.D. degrees in chemical education. It tries to describe the three fundamental elements of a good research study —
Chapter 1: Role of Theoretical Frameworks

the theoretical framework or orientation, the methodological framework, and the guiding research questions — and examines the process by which the choice of a theoretical framework is made.

**Fundamental Assertion about Research Design**

There is general agreement among individuals who teach graduate courses on educational research that a good Ph.D. dissertation proposal contains three fundamental components: a theoretical framework upon which the study will be built; guiding research questions that the study will try to answer that are consistent with the theoretical framework; and a methodology that is appropriate for probing the guiding research questions. Although this is the order in which these components might be described in a dissertation proposal, it isn’t the order in which the elements are generated. The first step toward a research proposal often involves the construction of a draft of the guiding research questions, which will be discussed in the next section.

**Guiding Research Questions**

The most fundamental assertion about guiding research questions is also the most obvious: It is difficult to find answers to questions you don’t ask. You can’t base a study on the assumption that you’ll just “observe what happens.” It is also important to recognize that a given study is a single slice through a lifetime of research, and the individual designing the study will be lucky to make progress toward answering two or perhaps three well-crafted questions within the course of that study.

Research questions not only can but should evolve over the course of a study. Indeed, our experience suggests that when changes do not arise in the research questions during the course of a study, we’ve probably not asked the right question. To illustrate how research questions evolve during a study, let’s look at the work of David Gardner, whose Ph.D. dissertation was entitled “Learning in Quantum Mechanics” (Gardner, 2002). In his dissertation, Gardner notes that his original question was “How do students learn quantum mechanics?” He then points out that preliminary data suggested that the answer was “not very well.” Unfortunately, this answer provided no insight into the problems students encounter with quantum mechanics or how to correct them. The guiding research question was, therefore, refined and narrowed as the study evolved.

With time, his work became directed by three questions. The first question — “What are the experiences of students learning quantum mechanics?” — came from one of the theoretical frameworks for his study: phenomenography. The second question — “What conceptual difficulties do students have with quantum mechanics?” — came from the other theoretical framework: constructivism. The third question — “How do students approach learning quantum mechanics?” — is consistent with both theoretical frameworks for the study, but arose as a result of interpretations of the data as it was being collected, which
indicated that many of the students' problems with quantum mechanics were the result of inappropriate strategies they used for studying and doing homework. They were not the result of difficulties with the concepts of quantum mechanics (Gardner & Bodner, in press).

Useful insight into the construction of research questions is provided on the website for the *Annals of Research in Engineering Education* (AREE, 2006). Smith (2006) has noted that this organization was created “to engage the engineering-education research community in a consensus-seeking conversation about the nature of high-quality engineering-education research.” When last accessed, this website contained a set of guidelines for reflective essays that included the following guidelines for research questions.

- What research question did you start with?
- How did the research questions develop?
- What allowed you to see the opportunity for this research project?
- How did the questions change as you designed and implemented the research?
- What were the final research questions you investigated?
- To whom is the question significant and why?

**The Choice of Methodology**

Ten years ago, an article with the title “Cancer Undefeated” appeared in *The New England Journal of Medicine* (Bailar & Gornik, 1997). This paper was a response to the call for ways to measure progress against cancer (National Cancer Institute, 1990). The approach to answering this call taken by Bailar and Gornik was based on an analysis of age-adjusted mortality rates due to cancer from 1950 through 1994 because they argued that it “focuses attention on the outcome that is most reliably reported” (p. 1569). An earlier article (Bailar & Smith, 1986) had concluded that “35 years of intense effort ... must be judged a qualified failure” (p. 1230). Bailar and Gornik concluded that “with 12 more years of data and experience, we see little reason to change that conclusion ... ” (p. 1573).

As noted elsewhere (Bodner, Maclsaac, & White, 1999), the work of Bailar and Gornick provides a metaphor on which discussions of the choice of methodology for a research study can be based because it illustrates the effect that this choice can have on the conclusions reached in the study. There is reason to believe that different conclusions might have been reached, for example, if Bailar and Gornik had chosen to examine other forms of progress against cancer that are more difficult to quantitate, such as changes in the quality of life after cancer has been diagnosed.
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**Quantitative Research**

Twenty years ago, graduate students involved in educational research began their introduction to research by taking at least two courses in statistics. They then went on to take a course on research design that was often based on the book by Campbell and Stanley (1963), which originally appeared as a chapter in the first edition of the *Handbook of Research on Teaching* (Gage, 1963). This work summarized the classic experimental/control approach to research design and, in general, probed ways in which experimental design could be made more scientific, more quantitative, and more objective. When circumstances precluded the design of a true “experimental” study, Campbell and Stanley suggested ways in which it could become at least “quasi-experimental.” The experimental or quasi-experimental approach to research design endorsed by Campbell and Stanley is still in use today; a new version of this classic text was published several years ago (Shadish, Cook, & Campbell, 2002).

Any discussion of the choice of research methodology should start by recognizing that there is nothing inherently wrong with traditional statistics-based quantitative research. But, then again, there is nothing inherently right about quantitative research, either.

Quantitative work isn’t intrinsically better, or worse. As Patton (2002) notes, some questions lend themselves to quantitative techniques; others can only be answered using qualitative methods. Patton (2002) raises an interesting point, however, when he argues that quantitative research gives answers to questions of *more* — which class learns *more* material, which approach leads to the retention of *more* students or helps students retain *more* information. Qualitative research provides answers to questions of *better* — do PChem students make *better* decisions about the way they study quantum mechanics?; do organic chemistry students exhibit a *better* understanding of the arrow-pushing formalism?; and so on.

Proponents of quantitative methods are likely to agree with Patton (2002), who noted that quantitative methods are “succinct, parsimonious, and easily aggregated for analysis; quantitative data are systematic, standardized, and easily presented in a short space” (p. 20). And yet, there are potential problems with quantitative research. It tends to focus on the average student and can lead to erroneous conclusions if the change being studied benefits some students and not others. It is often atheoretical — as opposed to qualitative research, which is based on an explicit theoretical perspective. By its very nature, quantitative research focuses on things that can be measured quantitatively, such as student performance on exams, which are often influenced by so many confounding variables it is difficult to tease out the effect for which one is looking. When the sample size is large, one can obtain results that are statistically significant, but not necessarily important. When the sample size is small, one often gets no statistically significant difference, even when there is anecdotal evidence that an effect exists.
For some, quantitative research is better because it is based on “cold,” “hard,” “objective” data. Namenwirth (1986), however, has questioned the myth of the objective scientist. Scientists are no more protected from political and cultural influence than other citizens. By draping their scientific activities in claims of neutrality, detachment, and objectivity, scientists augment the perceived importance of their views, absolve themselves of social responsibility for the applications of their work, and leave their (unconscious) minds wide open to political and cultural assumptions. ... while scientists firmly believe that as long as they are not conscious of any bias or political agenda, they are neutral and objective, ... in fact they are only unconscious. (p. 29)

To illustrate the effect of the choice of methodology on research results, let’s examine just one of many possible examples. Treagust, Harrison, and Venville (1996) studied the effect of using analogies to teach students. They found that there was no difference in the quantitative achievement scores on a traditional exam on optics for students who had been taught with analogies and those who had not. If this had been their only source of data, they might have concluded that the use of analogies had no effect on the learning of optics. They combined their analysis of exam scores, however, with qualitative interviews that showed that students who had been taught with analogies were able to demonstrate a higher level of conceptual understanding than those who were not.

*Shift in Educational Research*

Although the chapter on experimental and quasi-experimental designs by Campbell and Stanley appeared in the first edition of the *Handbook of Research on Teaching* in 1963, a similar chapter did not appear in either the second (Travers, 1973) or the third editions (Wittrock, 1986) of that book. This can be taken as evidence for a gradual shift in the way educational research is designed and carried out. In the *Handbook of Research Design in Mathematics*, Lesh and Kelly (2000) describe this shift as moving away from assumptions of “objectivity”; from viewing the student as a lone, passive learner; from relying on simple correlational models; and from relying on one-time measures of achievement such as standardized tests. They advocate moving toward viewing the researcher as a participant-observer who practices self-reflexivity; toward viewing the learner both as an individual and as a social learner in a complex classroom environment; and toward collecting thick, ethnographic descriptions that recognize the theory-ladenness of observation.

*Qualitative Methodology*

Patton (2002) argues that:

Qualitative data describe. They take us, as readers, into the time and place of the observation so that we know what it was like to have been there. They capture and communicate someone else’s experience of the world in his or her own words. Qualitative data tell a story. (p. 47)
Schwandt (2001) notes that the term *qualitative* is a “not-so-descriptive adjective” attached to various methods of scholarly inquiry that rely on data in the form of words, as opposed to quantitative techniques that generate a product expressible in numbers. The primary sources of data for qualitative research are in-depth, open-ended interviews or “think-aloud” problem-solving sessions; artifacts of the interview process — which consist of drawings, equations, calculations, or ideas jotted down by the subject of the interview during the interview session; field notes taken during observations of classes or during interviews the researcher has conducted; and written documents in the form of reflective journals.

Qualitative research sacrifices the “objectivity” that results from rigid statistical research designs for a combination of flexibility, depth, and detail. The flexibility of qualitative research was captured by Lincoln and Guba (1985) who argued that “… the design of naturalistic inquiry … cannot be given in advance; it must emerge, develop, unfold” (p. 225). The depth and detail that are characteristic of qualitative research were captured by Geertz (1973), who noted that qualitative studies produce rich, detailed descriptions of people and places — which he called “thick descriptions” — that enable readers to interpret for themselves the meaning and significance of the research.

Qualitative research is done by individuals with a preference for inductive, hypothesis-generating research, rather than hypothesis-testing research (Glaser & Strauss, 1967). This approach to research, in which one approaches the study with no predetermined hypothesis in mind, is often referred to as “grounded theory” (Charmaz, 2000; Strauss & Corbin, 1990; Taylor & Bogdan, 1998). The increasing number of books devoted to qualitative research methods is testament to the growth in the popularity of this technique (see, for example, Creswell, 1998; Denzin & Lincoln, 1998a, 1998b, 2000; Flick, 2002; Hatch, 2003; Huberman & Miles, 2002; Merriam, 1998; Silverman, 2000, 2001; ten Have, 2004; Yin, 2002).

**Mixed Methods for Educational Research**

In the late 1970's, most of the papers presented at meetings of the National Association for Research in Science Teaching were based on quantitative research designs. The 1980's, however, were a period of the “paradigm wars” (Gage, 1989), during which proponents of the traditional, quantitative, experimental or quasi-experimental paradigm fought pitched battles with advocates of a naturalistic, qualitative approach to research.

At the height of the paradigm wars, it was common to encounter individuals who argued that one had to choose between quantitative and qualitative techniques; that the two techniques could not be combined in a single study. Patton (2002) questions this attitude and argues that qualitative and quantitative methods “constitute alternative, but not mutually exclusive, strategies for research” (p.14). Evidence that the paradigm wars may have ended is the appearance of books that explicitly describe combining qualitative and quantitative approaches (Tashakkori & Teddlie, 1998, 2003) and the *User-Friendly Handbook for Mixed Method Evaluations* that can be found on the NSF web site (NSF,
Chapter 1: Role of Theoretical Frameworks

1997). An example of a study in which classic statistical techniques were combined with qualitative data can be found in the study of the epistemic development of chemistry students and research chemists by Samarakunav, Westby and Bodner (2006).

Bricolage

Even better evidence of the end of the paradigm wars is the emergence of an approach to educational research described as bricolage (pronounced “bree-koh-LAHZH”). Academic interest in bricolage can be traced back to the work of Lévi-Strauss (1966) for whom a bricoleur might best be defined as a handyman; someone who could make do with what is at hand. Whereas the terms “handyman” and “jack of all trades” are often used in a pejorative sense in English, the terms “bricolage” and “bricoleur” do not carry a similar negative, derogatory or uncomplimentary meaning in French.

The term bricolage has been used across a broad spectrum of academic disciplines, including evolutionary biology and genetics (Wilkins, 1998), technology entrepreneurship (Garud & Karnøe, 2003), and design (Büscher, Gill, Mogensen, & Shapiro, 2001; Louridas, 1999). Bricolage involves the construction of something by using whatever materials happen to be available. Strasser (1999) captured the essence of the term when she defined cooking with leftovers as a form of bricolage, “... a dialogue between the cook and the available materials.”

A bricoleur is someone who is creative and resourceful, who puts things together in ways for which they might not have originally been designed. When applied to educational research, bricolage implies “... complex, multimethodological, multitheoretical forms of inquiry” that focus on “... webs of relationships instead of simply things-in-themselves ...” (Kincheloe, 2005). In many ways, bricolage is an extension of our current methodologies for educational research, focusing on the value of bringing together diverse approaches to this research, using the appropriate methodological tool-at-hand, or even tools-at-hand, to answer a particular research question.

Action Research

A few years ago, we published a paper on Action Research that began as follows (Bodner et al., 1999): “Each time we make significant changes in what we teach or how we teach we are faced with the same question: How can we find out whether the innovation we have brought into our classroom is worthwhile?” (p. 31). One of the advantages of learning how to do educational research is the opportunity to master some of the techniques needed to answer questions such as this.

Chemists have traditionally assumed that the best way to address these questions is to compare student performance on a common exam for an experimental versus control group. Bodner et al (1999) described this as the “sports-mentality approach,” which
assumes that one can easily determine the “winner” when different approaches to instruction are compared.

There are three mistakes in the sports-mentality approach to program evaluation. First, and perhaps foremost, it assumes that assessment and evaluation are synonyms. Decisions on the efficacy of a program (evaluation) are therefore based solely on measures of student achievement (assessment). Second, the data collected seldom address the question being asked. As we have noted elsewhere (Bodner et al., 1999), this approach fails to measure differences in what is learned; what knowledge is retained; or whether there is a difference between the extent to which knowledge we value is gained, rather than knowledge that can be easily tested. Potentially erroneous conclusions are therefore obtained from preliminary experiments because this approach presumes that the new instructional material or technique will do better the first time it is used.

Action Research is based on the assumption that any significant change in instruction will have an effect. Whereas the traditional experiment presumes that the change being made either benefits students or it does not, Action Research assumes that some students will benefit from the change, while others will not. It therefore allows one to target a change toward a particular group of students, e.g., the “C” students in one case, the “B” students in another.

Action Research is a cyclic process, in which a change is made, the effect of the change is studied, and modifications are made with the goal of increasing the positive effects and minimizing any negative effects on the target population. Questions that lie at the heart of Action Research methodology include: What is the effect of this intervention? What happens to the teacher? What happens to the students? What components of the intervention are responsible for the positive effects observed? Is there any way to change the intervention to get an even larger positive effect? What components of the intervention gave rise to the negative effects? Is there any way to minimize these effects?

We have described Action Research as an informal, qualitative, formative, subjective, interpretive, reflective, and experiential model of inquiry in which all individuals involved in the study are knowing and contributing participants (Bodner et al., 1999). There are no hidden controls or preemption of direction by the researcher. All participants in the project — students, teachers, and researchers — contribute to the selection of intervention strategies.

There are four fundamental stages in an Action Research cyclic: Plan, Action, Monitoring, and Revised Plan. The cycle starts with the development of an understanding of the problem and the creation of plans for some form of intervention. The intervention is then carried out. Pertinent observations are then collected in various forms. The data are then examined for trends and new strategies are developed that are carried out. The cyclic process is repeated until a sufficient understanding — or implementable solution for — the problem is achieved.
Whereas traditional quantitative approaches to research or program evaluation withhold the innovation from half of the population in the hope that statistical evidence for its efficacy will arise during the course of the study, Action Research assumes that the innovation will have an effect, and tries to maximize its benefits and minimize its disadvantages (Bodner et al., 1999).

Constructivists (see Chapter 2) have argued that knowledge is the result of reflection on action; Action Research can be described as reflection in action. Reflection on experience is used to generate models, which are used to frame a problem. Intervention strategies are then implemented, which have inevitable consequences that are subjected to further analysis (Bodner et al., 1999).

Theoretical Perspectives or Frameworks

Kuhn (1970) differentiated between research that is based on a paradigm and that which is not. He argued that the use of paradigms makes research more effective by helping researchers select problems that can be solved and by suggesting appropriate methods for collecting data to solve these problems. In educational research, the theoretical framework serves a similar function. It provides the assumptions that guide the research, helps the researcher choose appropriate questions for a given study, and directs the researcher toward data collection methods that are appropriate for the study.

Those who are learning how to do educational research face two major challenges. They must first try to understand some of the theoretical perspectives on which they might base their research. They then have to decide which of these frameworks are inappropriate for addressing the questions they want to answer and select the theoretical framework(s) that is (are) appropriate.

The first reference given to anyone who comes to the author for advice on research design is the book on qualitative research by Patton (1990, 2002), which provides brief descriptions of a variety of theoretical frameworks or orientations such as those listed in Table 1. This book contains chapters on theoretical frameworks that are not explicitly mentioned in Patton’s book and excludes some of frameworks he describes because of our emphasis on research design that informs chemistry or science education.

Table 1: Examples of Theoretical Frameworks for Research and Evaluation, based in part on Patton (2002)

<table>
<thead>
<tr>
<th>Framework</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autoethnography</td>
<td>Insights that can be extracted from analysis of one’s own experiences.</td>
</tr>
<tr>
<td>Constructivism</td>
<td>Focuses on individuals making sense of their experiences.</td>
</tr>
<tr>
<td>Critical Theory</td>
<td>Overcoming the uneven balance of power between groups of individuals.</td>
</tr>
</tbody>
</table>
Chapter 1: Role of Theoretical Frameworks

Ethnography: The study of the culture of a group.

Ethnomethodology: The study of people making sense of their experiences to behave in socially acceptable ways.

Feminism: An example of an “orientational” inquiry theory that seeks to understand women’s perception of a phenomenon.

Grounded Theory: Analysis of fieldwork that is used to generate a theory.

Hermeneutics: Providing a voice to individuals or groups who either cannot speak for themselves or are traditionally ignored.

Narratology: Analysis of a narrative or story to reveal something about the world from which the individual comes.

Phenomenology: The search for the common thread or essence of a shared experience.

Phenomenography: The description of different ways people interpret shared experiences.

Positivist/Realist/Analytic Approaches: The search for the “truth” about the real world, insofar as we can get at it.

Pragmatism: Answering practical questions that are not theory-based.

Symbolic Interactionism: The search for a common set of meanings that emerge from interactions within a group.

Systems Theory: Analysis of a system, not the individuals who comprise the system.

The remaining chapters in this book are devoted to a more detailed, in-depth look at some of the theoretical perspectives that either have been or could be applied to educational research in chemistry and science education. We have divided these frameworks into three general categories, as shown in Figure 1. The first category includes theoretical frameworks that can be tied to the constructivist theory of knowledge (Bodner, 1986), the second category includes theoretical perspectives linked to hermeneutics, and the third category groups frameworks or perspectives related to critical theory.
Chapter 1: Role of Theoretical Frameworks

Constructivism and Social Constructivism
- Symbolic Interactionism
- Models and Modeling
- Pedagogical Content Knowledge

Hermeneutics
- Phenomenology
- Phenomenography
- Action Research
- Narratology
- Ethnology and Ethnomethodology
- Situated Cognition
- Communities of Practice

Critical Theory
- Feminism
- Afrocentric Views

Figure 1. Theoretical perspectives for research in chemistry/science education grouped into categories of constructivism, hermeneutics and critical theory

As the authors of the individual chapters in this book will attempt to show, certain theoretical frameworks are better suited to particular kinds of guiding research questions. Ferguson argues in Chapter 2, for example, that constructivism provides a useful framework for studies that concentrate on meaning-making, on how students come to know. In Chapter 5, Miller describes how pedagogical content knowledge can be used as a theoretical framework to probe the knowledge that teachers bring to the classroom.

Each of the theoretical frameworks also have inherent limitations that can have an effect on their suitability for a particular study. As Bhattacharyya notes in Chapter 10, ethnography and ethnomethodology have been criticized as trying to be too neutral, whereas Mayo points out in Chapter 13 that critical theory has been criticized for not being neutral enough.

Some of the theoretical perspectives in Table 1 are incompatible, but others are not. Thus, there is nothing inherently wrong in having more than one theoretical perspective for a long-term research project, or even for a particular study within that project.

You don’t have to accept all of the assumptions of a given theoretical framework, as it is described by various authors, when you apply it to a study. But you need to be explicit about which assumptions are applicable to a given study.
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It is also important to accept the notion that Patton (2002) argues for so cogently: some studies simply are not theory-based because they “involve asking open-ended questions of people and observing matters of interest in real-world settings in order to solve problems, improve programs, or develop policies” (p. 136).

Examples of Theoretical Perspectives

Conversations with colleagues who teach research methods courses have suggested that there are relatively few places to which you can refer beginning researchers to help them choose an appropriate theoretical perspective (Atkinson, Delamont, & Hammersley, 1988; Crotty, 1998; Jacob, 1987; Patton, 2002). There was, therefore, support for the notion of an article (Bodner, 2004) or even a book, such as this one, which describes a handful of popular theoretical perspectives. The order in which these theoretical perspectives are discussed in the remainder of this chapter is somewhat arbitrary, and, in most cases, more than one study from our group could be used to illustrate a given perspective.

Constructivism

The theoretical framework known as constructivism (Chapter 2) can be summarized as follows: “knowledge is constructed in the mind of the learner” (Bodner, 1986, p. 873; see also, Bodner, Klobuchar, & Geelan, 2001; Matthews, 1998; O’Loughlin, 1992; Solomon, 1987; Steffe & Gale, 1995; Tobin, 1993; von Glasersfeld, 1984, 1995). This theoretical framework assumes that we don’t “discover” existing knowledge; we actively construct it. We invent concepts and models to make sense of our experiences and then continually test and modify these constructions in the light of new experiences.

In his first paper on constructivism (Bodner, 1986), the author focused on a view of this theory of learning that has become known as personal constructivism, which concentrates on the individual knower and acts of cognition. In that paper, he traced the evolution of constructivism back to the work of Jean Piaget and described a version of this theory known as radical constructivism. A second paper described an alternative form of personal constructivism that arose from the work of the clinical psychologist George Kelly and introduced another form of constructivism known as social constructivism, which focuses on social interactions that explain how members of a group come to share an understanding of specific life circumstances (Bodner et al., 2001).

It is tempting to think about radical constructivism (von Glasersfeld, 1984, 1995) and social constructivism (Solomon, 1987; O’Loughlin, 1992) as opposite ends of a continuum. At one end, learners construct knowledge in isolation, based on their experiences of the world in which they live. At the other end, learning is embedded in social and cultural factors. Most situations in which learning occurs, however, fall somewhere between these two extremes. Learning is a complex process that occurs within a social context, as the social constructivists point out, but it is ultimately the individual who does the learning, as the radical constructivists would argue.
Research studies based on the constructivist theory often examine the process by which an individual makes sense of their experiences. Research design in this area is guided by the assumption that studies of “sense-making” involve more than just collecting observations. Schwandt (2001) offers the example of the phenomenon of raising one’s right hand above one’s shoulder as performed by someone hailing a cab, by a student volunteering to answer a question in class, and by a witness testifying in court. In each instance, the same physical phenomenon is observed, but the meaning of the action is fundamentally different. The only way to make sense of the observation would be to talk to the individual.

**Symbolic Interactionism**

The theoretical perspective known as symbolic interactionism (Chapter 3) comes to us from social psychology. This framework is based on four assumptions: (1) that we act toward the objects and individuals in our environment on the basis of the meaning these objects and individuals have for us; (2) that these meanings are not determined by an individual’s experiences; they are the result of social interactions among individuals; (3) that meanings are created and modified through an interpretative process undertaken by an individual member of the group; and (4) that it is these constantly evolving meanings that determine people’s actions (Blumer, 1969; Denzin, 1969; Gallant & Kleinman, 1983; Schwandt, 1997).

The term *symbolic* reflects the idea that we communicate through language that is, itself, symbolic. The term *interactionism* emphasizes the role that social interactions have in the construction of knowledge and conceptual understanding. The main goal of the symbolic interactionism researcher is to use observable interactions to identify implied symbolic behavior (Denzin, 1969). Researchers who bring a symbolic interactionist framework to a particular study have to actively enter the setting of the people being studied to see their particular definition of the situation, what they take into account, and how they interpret this information. To understand the process of meaning-making, the researcher must carefully attend to the overt behaviors, speech, and particular circumstances of behavior in the setting in which interactions take place.

Symbolic interactionism assumes that the researcher must view things through the perspective of those under study. As a result, participant observation becomes a key method here; it allows the researcher to place the data being collected into the context of the operating classroom and to participate in the interactions between and among the subjects.

Del Carlo and Bodner (2004) used symbolic interactionism to study the ethical philosophies — the “objects” in symbolic interactionist terms — students develop through interactions with other students, research advisors, professors, or TA’s in the laboratory setting. This argued that interactions within the classroom lab environment play an important part in the evolution of meanings for the individuals involved in the interaction. This meant that the data on which this study was based had to consist of both observations of actions in the
laboratory environment and in-depth interviews outside of the classroom that were designed to uncover individual meanings.

**Hermeneutics**

The term *hermeneutics* (Chapter 6) is often traced back to “Hermes,” the messenger of the gods in Greek mythology. Hermes not only delivered decrees from Mount Olympus, he interpreted for humans the meaning and intention of the messages he brought (Polkinghorne, 1983). Hermes has, therefore, been described as the guide to intelligent speech (Parada, 1993), and the Greek word *hermeneuein* is translated as “to interpret.” Hermeneutics has been described as “the art, theory and philosophy of interpreting the meaning of an object (a text, a work of art, social action, the utterances of another speaker, etc.)” (Schwandt, 2001, p. 115). Schleiermacher (1997) argued that hermeneutics is necessary when there is the chance of misunderstanding the meaning of the object. The development of hermeneutics began in the period after the Renaissance, when the principles of interpretation of text were applied to the study of sacred (biblical) texts and texts from classical antiquity (Polkinghorne, 1983). Dilthey (1976) expanded the scope of hermeneutics by raising the question: If the techniques of hermeneutics could be used to systematically interpret written texts, why not apply them to speeches, conversations, or interviews or even to the “text” of a person’s life or experiences?

An important feature of hermeneutics is the notion of the hermeneutic “circle” or “spiral.” In order to understand the meaning of a text, the interpreter needs to understand its parts; and yet, in order to understand the different parts of a text, the interpreter needs to understand the whole text. The first interpretation of the text is based on the prior knowledge the researcher brings to the text, but this prior knowledge is changed by reading the text. As a result, the researcher brings a different perspective to the second reading, which changes the knowledge the researcher brings to a third reading, and so on, *ad infinitum*. In practice, however, there is a point at which further readings do not substantively change one’s understanding.

Hermeneutics is often used in educational research in the sense of providing a “voice” to those who either cannot speak for themselves or who have not been listened to. It was, therefore, an appropriate framework for a study conducted by Hunter, in which he looked at what happens when “discovery” labs are integrated into the curriculum at a large research university (Bodner, Hunter, & Lamba, 1998).

**Phenomenology and Phenomenography**

Suppose that you were familiar with the structure of a typical organic chemistry course. You knew something about the subject matter covered, the kind of textbooks used, the way the course was usually taught, the kind of questions that were likely to appear on exams, and so on. You would have what is called a first-order understanding of the phenomenon of organic chemistry courses. Now, suppose that you were interested in understanding what it means from the students’ perspective to “take” organic chemistry. Your goal would be a
second-order perspective — an understanding of the students’ experience with the course, not your own. The traditional paradigm that guides research designed to understand the meaning of human experience is known as phenomenology (Marton, 1996; Sokolowski, 2000; van Manen, 1990).

Phenomenology (Chapter 7) is based on the work of philosophers such as Husserl, Schutz, Merleau-Ponty, Gadamer, and Ricoeur (Polkinghorne, 1983). The characteristics of phenomenology might best be described by paraphrasing the comments of van Manen (1990). He defines phenomenology as the study of the world as we experience it, not as we conceptualize or reflect on it. The goal of phenomenology is “a deeper understanding of the nature or meaning of everyday experiences” (p. 9). The focus is on the lived experiences while they are being lived, not after one reflects on them. Phenomenology searches for the “essence” of a phenomenon, the “something” that makes the phenomenon what it is, the “something” without which the phenomenon could not be what it is.

The term phenomenology has been used by many researchers to describe studies that don’t quite fit the classic definition. Studies that don’t assume that “essence” is singular; that don’t assume there is a common thread that describes the meaning of the experience for everyone who lives it. Our group has, therefore, been quite careful to differentiate between traditional approaches based on phenomenology and those that look similar but are based on a slightly different perspective known as phenomenography (Marton, 1986; Marton, Hounsell & Entwistle, 1997).

The focus of phenomenography (Chapter 8) is still on the meaning of an experience. The goal of phenomenography is to understand how people experience, interpret, understand, perceive, and conceptualize a phenomenon (Orgill, 2003). Phenomenography assumes that knowledge results from thinking about experiences with people and objects in the world in which we live.

Whereas phenomenology looks for the common essence that characterizes the phenomenon for all who experience it, phenomenography assumes that people can and will experience the same phenomenon in a limited number of ways that are qualitatively different (Säljö, 1997). Marton (1981) captures the essence of phenomenography by noting that it searches for the middle ground between the extremes of “the common” and “the idiosyncratic.”

The goal of phenomenography is to understand the phenomenon from the participant’s point of view. The researcher therefore tries to act as a “neutral foil” for the ideas expressed by the participants of the study. This does not mean, however, that the researcher is an objective observer akin to a video camera (Lowrey, 2002). In the course of an interview, the researcher’s knowledge may be used to help the participants better explain what they mean. Entwistle (1997) argues that richer descriptions can be obtained when the interviewer contributes to the effort to explain the student’s interpretation of experiences.
Phenomenographers do not claim that the results of their research represent “truth”; only that their results are useful (Svensson, 1997). Marton (1994) noted that it isn’t important whether the participant’s conceptions are viewed as “correct” or “incorrect” by others; the goal of the research is to identify the possible conceptions members of a group have of a given phenomenon.

The primary source of data for phenomenography is an open, intensive interview (Booth, 1997). It is open in the sense that there is no prearranged structure to the interview; it is intensive in the sense that the interview follows a given line of questioning until the participant has nothing more to say. Data analysis begins by having the researcher identify the qualitatively different ways in which different people experience a given concept. One of the potential pitfalls of phenomenography is the tendency to assume that students’ accounts of their experiences are the same as the students’ experiences.

Säljö (1997) notes that there sometimes appears to be a discrepancy between what researchers observe when they watch a participant go through an experience and the way participants describe their experiences. Säljö, therefore, suggests that we refer to studying people’s “accounting practices” of phenomena, instead of referring to studying people’s “experiences.”

There are several ways in which the results of phenomenographic research can be useful. Entwistle (1997) noted that students are generally encouraged to develop a conceptual understanding, and that teachers often try to help their students develop concepts that are consistent with those held by experts in the field. Students, however, often have conceptions of a phenomenon that are not consistent with those held by experts. Marton (1996) claims that “a careful account of the different ways people think about phenomena may help uncover conditions that facilitate the transition from one way of thinking to a qualitatively ‘better’ perception of reality” (p. 33).

Critical Theory

The critical theory movement was founded in 1923 at the Institut für Sozialforschung in Frankfurt, Germany. The first generation of critical theorists included Adorno, Marcuse and Fromm; the most influential modern spokesperson for critical theory is Jürgen Habermas (McCarthy, 1979; Roderick, 1986; Young, 1990).

Critical theory (Chapter 14) calls for reasoning that is practical, moral, and ethically and politically informative. The goal is individual and social transformation via self-knowledge. Critical theory rejects the idea that one can have a disinterested observer who contemplates the system from a distance.

Critical theory often focuses on situations where there is an uneven sharing of power. It therefore often involves discussions of “emancipation.” The author endorses the application of critical theory to educational research because of the structure of the traditional teacher-
centered classroom, where power lies in the hands of the instructor who decides what is taught (or learned), the order in which it is taught (or learned), the amount of time devoted to a given topic, and so on (Young, 1990).

Habermas talks about technical knowledge (*technē*) and knowledge that comes from one’s view of what is right or good (*phronesis*). But he also talks about *emancipatory* knowledge, which literally frees the individual. The author’s favorite example of emancipatory knowledge is learning how to ride a bicycle as a child. At that moment, the individual is free. There is no longer the need to ask a parent or adult for help getting somewhere; the individual is free to make decisions about where he or she is going on their own. It therefore isn’t surprising that Mayo (2004) chose critical theory as the framework upon which to build a Ph.D. dissertation that examined the impact of figures from chemistry texts on the learning by visually impaired students; students who have historically been excluded from chemistry classrooms and lab courses.

Critical theory seeks a diversified education for all that creates individuals who can think critically. It assumes that schools can become institutions in which knowledge, values, and social relations are taught to educate students for critical empowerment (Giroux, 1988). The ultimate goal of critical theory is a transformation of society into one that is just, rational, and humane.

*Ethnography and Ethnomethodology*

Ethnography (Schensul & LeCompte, 1999; see also Chapter 10) is often thought of as a methodological framework, but it has strong theoretical aspects. It has its basis in cultural anthropology, where the goal is describing the behavior of a culture on the basis of first-hand experiences with members of that culture through field studies.

A related theoretical framework known as ethnomethodology (Chapter 10) was developed by Garfinkel (1967) as the basis for sociological research. It focuses on how people accomplish the interactions we take for granted in everyday life. Ethnomethodology “... gets at the norms, understandings, and assumptions that are taken for granted by people in a setting because they are so deeply understood that people don’t even think about why they do what they do” (Patton, 2002, p. 111). It is based on descriptive accounts that organize and render observable the features of society and social settings (Leiter, 1980).

Ethnomethodology was chosen as the theoretical perspective for a study of how graduate students learn to solve organic synthesis problems (Bhattacharyya, Calimisiz, & Bodner, 2004). This choice of theoretical perspective was based on the assumption that the community of synthetic organic chemists constitutes a culture to which students become acculturated as their understanding of the field develops. This perspective recognizes that synthetic organic chemists routinely use language that is unique to their community; that a well-trained chemist from another discipline wouldn’t be able to participate in a conversation between practicing synthetic chemists unless explicit attempts were made to include that...
individual in the conversation; and that synthetic organic chemists use tools such as retrosynthetic analysis and the arrow-pushing formalism that are unique to this community.

Conclusion

Readers who have reached this point should not be surprised to find that the noted expert on research design Lee Cronbach (1982) has argued that designing a study is as much an art as it is a science. So far, I have discussed three of the basic pieces of a study: the theoretical framework, the methods of data collection, and the guiding questions. If these pieces form a coherent, unified whole, then so should the data and the data analysis (Crotty, 1998). The theoretical frameworks I have focused on in this chapter are those with which my research group has had the most experience. The remaining chapters of this book are devoted to more detailed descriptions of a variety of theoretical frameworks that either have been used in chemistry and/or science education.

An important point needs to be recognized before the reader proceeds to the discussions of the individual theoretical frameworks that comprise the bulk of this book. In the years since I wrote the first draft of this chapter I have come to realize that I ignored an important element in the design of any educational research study. Educational research does not occur in a three-dimensional world dominated by concerns with the dimensions of guiding research questions, theoretical framework, and methodology. It occurs in a four-dimensional world in which the fourth dimension is the preparation, submission, and eventual approval of the study by an appropriate Institutional Review Board or IRB. Our experience suggests, however, that effort devoted to making decisions about guiding research questions, theoretical framework, and methodology should be compensated for in the ease with which a suitable IRB proposal can be written.

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References


Chapter 1: Role of Theoretical Frameworks


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Chemistry Curriculum Reform Update: Where are we now and where are we going? Washington, DC: American Chemical Society.


Chapter 1: Role of Theoretical Frameworks


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Chapter 1: Role of Theoretical Frameworks


Constructivism and Social Constructivism

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Biography

Robert Ferguson is an Assistant Professor of Science Education at Cleveland State University. After receiving his Bachelor of Arts in Biological Sciences and a teaching credential in Life Science and Chemistry from San José State University he taught high-school science for seven years. Wanting to both learn some chemistry and become a teacher of teachers, he applied for a spot in the Chemical Education program at Purdue University. He accomplished both goals with a M.S. thesis that focused on organic synthesis and a Ph.D. dissertation that studied chemistry majors’ understanding of reaction mechanisms. Upon graduation he accepted his current position at Cleveland State University, where he teaches elementary and secondary science methods courses and directs the Northeast Ohio Elementary Science Olympiad.

Introduction

Constructivism is a theory of learning with its origin in the cognitive sciences that eventually was discussed, parsed, and applied in both science education and chemistry education. This chapter starts with a description of the basic tenets of constructivism and its ontological considerations. The history of constructivism as a theoretical framework is then used as the basis for introducing research methodologies associated with constructivism. The chapter then concludes by examining examples of research studies that have used constructivism as a research lens.

A Description of Constructivism

As a theory of learning, constructivism provides a basis for understanding how people incorporate new knowledge into existing knowledge and then make sense of that knowledge (Nussbaum, 1989; Tobin, 1990; von Glasersfeld, 1992). It provides a theoretical framework for thinking about how people engage with objects in the world around them and make sense of these objects (Bodner, 1986; Bodner, Klobuchar, & Geelan, 2001). In the previous chapter, Bodner (2006) argued that constructivism is based on the assumption that people don’t “discover” existing knowledge, they actively
construct it. He went on to argue that they “invent concepts and models to make sense of their experiences and then continually test and modify these constructions in light of new experiences” (p. 13) According to Fosnot and Perry (2005), the aim of constructivism is “cognitive development and deep understanding” (p. 10, italics in the original). Bodner (1986) tried to capture the spirit of the constructivist theory by arguing that “knowledge is constructed in the mind of the learner” (p. 873).

The term constructivism has been applied to a wide range of concepts and ideas with each “form” (Good, 1993) or “brand” (Staver, 1998) having its own tenets, assumptions, and implications. Geelan (1997) reviewed the six most prevalent forms and explained how each form varies in the way it prioritizes the individual learner, the social milieu, the role of language, and the balance of power during the process by which knowledge is constructed. He also associated each of these forms with the individual with whom it was most closely associated.

- Personal constructivism: Kelly and Piaget
- Radical constructivism: von Glasersfeld
- Social constructivism: Solomon
- Critical constructivism: Taylor
- Contextual constructivism: Cobern
- Social constructionism: Gergen

Whereas the five forms of “constructivism” on this list focus on sense-making or meaning-making within the individual, social “constructionism” presumes that knowledge is held collectively within a group or society and that language serves as its mediator (Geelan, 1997). Crotty (1998) provides a distinction between constructivism and constructionism when he argues:

> It would appear useful, then, to reserve the term constructivism for epistemological considerations focusing exclusively on ‘the meaning-making activity of the individual mind’ and to use the term constructionism where the focus includes ‘the collective generation [and transmission] of meaning.’ (p. 58)

Both the personal constructivism of Piaget or Kelly (1955) and the radical constructivism advocated by von Glasersfeld focus on the sense-making or meaning-making that occurs as individuals try to understand their experiences with the world in which they live. Within the context of a classroom environment, proponents of personal constructivism might argue that knowledge is never transmitted intact from the instructor to the learner.
Social constructivism was proposed as an alternative to personal constructivism by Solomon (1987) and O'Loughlin (1992). At first glance, one might question how a constructivist theory of knowledge can be called “social” constructivism. However, as Bodner (2006) noted in the previous chapter:

It is tempting to think about radical constructivism (von Glasersfeld, 1984, 1995) and social constructivism (Solomon, 1987; O'Loughlin, 1992) as opposite ends of a continuum. At one end, learners construct knowledge in isolation, based on their experiences of the world in which they live. At the other end, learning is embedded in social and cultural factors. Most situations in which learning occurs, however, fall somewhere between these two extremes. Learning is a complex process that occurs within a social context, as the social constructivists point out, but it is ultimately the individual who does the learning, as the radical constructivists would argue. (p. 13)

In order to avoid getting bogged down in a debate over social versus personal constructivism, it might be more useful to focus on their commonalities. Clearly, social and personal constructivism share theoretical underpinnings (Marín, Bennaroch, & Jiménez-Gómez, 2000; Staver, 1998). Staver (1998) highlights the common ground by arguing that all forms of constructivism assume that: (1) individuals and communities build up knowledge; (2) social interactions, whether they are individual, social or cultural, play an important role in the construction of knowledge; (3) the learning construction and the language surrounding the knowledge being constructed must be useful, practical, and “adaptive”; and (4) learning and language serve to bring coherency to the individuals’ experiences and the knowledge base of the community.

Because the goal of this chapter is to introduce constructivism as a research lens, no form of constructivism will be assumed to be superior to another. For the purposes of this chapter, the use of the term “constructivism” will be assumed to refer to a theoretical framework consistent with the four characteristics outlined by Staver.

The Ontological Assumptions of Constructivism

Bodner, Geelan and Klobuchar (2001) compared differences between traditional and constructivist theories of knowledge to differences between the realist and relativist positions in the philosophy of science. They argued that “realists and relativists agree on one point: our knowledge of the world is based on the experiences of our senses. They differ, however, on their beliefs about the extent to which the world is knowable” (p. 1107)

Von Glasersfeld (1995) has noted that critics have accused proponents of the constructivist theory of denying the existence of “reality.” They have even gone so far as to accuse constructivism of solipsism (Martínez-Delgado, 2002), a form of egotism that rejects the existence of everything except the individual. This is not an accurate reflection of the constructivist theory, however. Most constructivists do not question the existence of reality, they only question our ability to judge or know reality and therefore
our ability to judge whether something is “true” or “false” (Tobin, 1990). Staver (1998) rebuffs the critics by noting, “constructivists are sometimes labeled as solipsists because they challenge realists’ wishes, refuse to embrace truth as correspondence, and advise silence on ontology” (p. 506). Constructivists do not deny a reality; they are relativists (Lincoln & Guba, 2000). Constructivism as a theory does not allow the researcher to engage in ontological debates; in terms of ontology the theory is “mute” (Schwandt, 2000).

Von Glasersfeld (1984) argued that traditional theories of knowledge search for a correspondence between knowledge and reality in much the same way that one might match samples of paint; they are either the same or they must be different. The constructivist theory approaches the search for knowledge from the perspective of coherence in the sense of the metaphor of a lock and a key; there can be many keys with slightly different shapes that open the same lock.

From the constructivist perspective, truth is based on coherence with our knowledge not correspondence between knowledge and objective reality (Edmondson & Novak, 1993; Staver, 1998). Constructivists believe that knowledge only exists within us, the cognizant beings. Knowledge is non-confirmable, non-provable, and is not "discovered" (Nussbaum, 1989).

A Brief History of Constructivism

Constructivism did not start as a theoretical framework for doing educational research; it originated as a theory in cognitive science whose goal was to explain the incorporation of knowledge. Because the history of constructivism is somewhat lengthy (see Cobern, 1993), only a brief synopsis is provided here.

Socrates receives credit as the first to articulate the idea of the learner as the builder of knowledge (Nola, 1997). Von Glasersfeld (2005) credits the pioneering work of Piaget in the 1940’s as the beginning of constructivism. Piaget’s contributions stem from his work with the cognitive development of children (Fosnot & Perry, 2005). Specifically, Piaget set forth the key ideas that learning occurs in stages, and that knowledge is organized as cognitive structures (Brooks & Brooks, 1993). Piaget also provided us with the notion that learning occurs through a dynamic interaction between the individual and the environment, and that “knowledge is constantly being constructed and reconstructed from previous and new experiences” (Llewellyn, 2005, p. 36).

Later, as cognitive scientists incorporated the work of Vygotsky (Llewellyn, 2005), constructivism grew to include both a language component and a social interaction component. Vygotsky (1986) believed that social interactions had a strong influence on both how and what an individual learned. He was less concerned about stages in learning than Piaget, but, instead, focused on how a learner was cognitively limited to a zone known as the Zone of Proximal Development. In Vygotsky’s model of the learning process, this zone is bounded on one end by skills or knowledge possessed by the learner and on the other end by skills or knowledge that can only be gained with outside
aid (Llewellyn, 2005; Parks, 2001). A situation that is beyond the first boundary lacks any cognitive demand from the learner; the learner either already possesses the skill or understands the concept. If the learner is placed outside the second boundary, the cognitive demand is greater than the capabilities of the learner.

Although theoretical discussions of the constructivism of Piaget, Vygotsky and von Glasersfeld could be found in the science education literature by the middle of the 1980’s (Bodner, 1986), science education research received its first look at the implication of von Glasersfeld radical constructivism through the work of Ken Tobin (see Matthews, 2002). In his 1988 article, Tobin and co-workers offered constructivism as a framework to analyze the teaching methods of an exemplary, yet traditional, high-school science teacher (Tobin et al., 1988). Since that time, a plethora of studies have been conducted with constructivism as the theoretical perspective or lens. The bulk of these studies look at employing constructivism as an epistemology in the classroom (see Herron & Nurrenbern, 1999). These studies offer constructivism as a guide to making changes in the curriculum that take the classroom environment away from a traditional teacher-centered, lecture-driven course toward a student-centered, experiential classroom. An example of using constructivism as a curriculum intervention strategy can be seen in the work of van Keulen (1996), who rewrote an ester synthesis experiment for a college-level organic chemistry laboratory class with the goal of minimizing the number of traditional, verification or cookbook laboratories used in the laboratory component of the course.

The Guiding Questions of Constructivism

Researchers contemplating constructivism as a theoretical framework should consider the type of questions for which constructivism is most appropriate. Constructivism is best suited for studies that focus on sense- or meaning-making, concept construction, or elucidation of alternative concepts. Constructivism should be used when the goal of the study is to describe the cognitive structures of the concepts held by the learner (Cobern, 1983).

Constructivism can be used to answer the following types of questions: “How have people in this setting constructed reality? What are the reported perceptions, ‘truths’ explanations, beliefs, and worldviews? What are the consequences of their constructions for their behavior and for those with whom they interact?” (Patton, 2002, p. 96). Specifically for science and chemical education research, constructivism can be used to ask, “… What is a student’s construction of (say) gravity and how does that construction compare with the epistemological truth of science?” (Cobern, 1993, p. 53). Only studies that focus on research questions related to how learners make sense of phenomena should use constructivism as a research lens.

Some examples of chemical education research from a constructivist perspective were based on the following guiding research questions:
• What are the identified alternative conceptions regarding gas, dissolution, and chemical change held by 8th grade Turkish students and student teachers? (Çalik & Ayas, 2005).

• How do secondary students, undergraduates and graduate students employ mental models of their conceptions of bonding? (Coll & Treagust, 2002, 2003).

• What are children’s (ages 11-14) concepts of substance, melting and boiling and what are their concepts of chemical change with a focus on the use of elements, compounds, and bonding? (Johnson, 2000, 2002).

• How do students from grade 1 to grade 10 develop their understanding of matter? (Liu & Lesniak, 2006).

• How aware are chemistry instructors of students’ alternative conceptions in chemical equilibrium? (Piquette & Heikkinen, 2005).

• When using chemical change phenomena, what are the processes, and characteristics of concept organization? (Stavridou & Solomonidou, 1998).

• What are the patterns found at the intersection of individual and group meaning-making taking place among 3rd graders in the context of an urban school? (Southerland, Kittleson, Settlage, & Lanier, 2005).

Methodologies

The aim of constructivism is “understanding and reconstruction” (Lincoln & Guba, 2000). As with any naturalistic inquiry, the use of the correct methodology is imperative in order to be consistent with the basic tenets of constructivism. Methodology, according to Crotty (1998), is “the strategy, plan of action, process or design lying behind the choice and use of particular methods and linking the choice and use of methods to the desired outcome” (p. 3). The methodology of data collection used in a study based on constructivism as a research lens needs to be designed to aid in understanding the concepts held by the research participant (or learner) and allow the researcher to reconstruct the cognitive structures with fidelity. Lincoln and Guba (2000) suggested that this methodology must be “hermeneutic and dialectic.” The etymological root of hermeneutics (see Chapter 6) stems from the mythical messenger of the Greek gods, Hermes, who brought the message of the gods to the mortals in an understandable form (Crotty, 1998). Research based on a constructivist perspective fulfills a similar role, bringing a message from one audience, the learner or participant, to another audience, the reader.

Webster’s New 20th Century Dictionary (1983) defines “dialectic” as the art or practice of examining opinions or ideas logically, often by the method of question and answer, so as to determine their validity. Kemmis and McTaggart (2000) provided additional insight
into the meaning of “dialectic” by noting that it includes the act of “… seeing things intersubjectively, from one’s own point of view and from the point of view of others (from the inside and the outside)” (p. 574). For the researcher, dialectics describes the process by which one arrives at a common answer or consensus via discussion.

A dialectic methodology includes sharing the control of the conversation or the answer between researcher and participant (Lincoln & Guba, 2000). The dialectic methodology can be seen in an interview where a researcher listens to a participant explain answers to various questions; in a post interview where a researcher shares findings with a participant; in a dialogue between colleagues where the researcher confirms newly emergent themes with a peer; or in co-collaborative conversations during which the researcher and participant mutually interpret data. Through these discussions, the researcher tries to see the world from the perspective of the individual whose sense-making or meaning-making is being studied. The dialectic methodology can therefore be used as part of a variety of research tools, including interviews about instances, interviews about events (see Osborne & Freyburg, 1985), think-aloud protocols (Larkin & Rainard, 1984), and concept maps and other graphical organizers (Novak & Gowin, 1984).

A careful selection of the methods used in a study based on a constructivist perspective enables the participant to produce both artifacts, which demonstrate knowledge, and conversations that build consensus. Methods that align with a hermeneutical and dialectical methodology afford the researcher a glimpse into the conceptions held by the participant. They help illuminate the knowledge that is constructed in the mind of the learner, and thereby align with constructivism as a research lens.

Methods and Analysis

So far, I have argued that constructivism focuses on questions that pertain to meaning-making, sense-making, concept construction, or the elucidation of alternative conceptions. I have also argued that researchers who use constructivism to guide a study should use methodologies for data collection that are both hermeneutic and dialectic. This section provides comments on various examples of design strategies, data sources, data analysis, and validity issues.

Constructivism permeates science education research (Matthews, 2002). Constructivism as an epistemology, constructivism as a theoretical framework, and constructivism as a theory of learning has produced hundreds, if not thousands, of articles, reports and manuscripts. In this section, I have focused on those chemistry-related studies that used hermeneutic and dialectic methodologies (Lincoln & Guba, 2000). Although this literature review is far from exhaustive, the studies presented here provide insight into the key elements in the research based on a constructivist perspective.
Design Strategies

Design strategies that met the selection criteria described above could involve the use of either a purely qualitative methodology or a mixture of qualitative and quantitative data collection techniques. (A purely quantitative approach would not meet the selection criteria because it would not be dialectical.) An example of a mixed-method approach to constructivist research can be found in a study of college-level chemistry instructors approach to teaching chemical equilibrium (Piquette & Heikkinen, 2005). The design strategy included a survey of 52 college and university chemistry instructors using open-ended responses, a four-point Likert scale, a set of mock student responses, and a series of demographic questions. The survey focused on awareness, identification, and strategies of remediation for students with alternative conceptions of chemical equilibrium. Following the analysis of the surveys, six respondents were invited to participate in individual, semi-structured phone interviews. The follow-up interviews allowed the participants to clarify their earlier responses, and provided the researchers with an opportunity to triangulate their data.

Çalik and Ayas (2005) tested 50 eighth-grade students and 50 student teachers from the East Black Sea region of Turkey in order to identify alternative conceptions of gas, dissolution, and chemical change. In their study, Çalik and Ayas placed a greater emphasis than the previously described study on answers to free-response questions, students’ presentation of ideas via diagrams, and substantial dialogic exchanges between the students and the researchers. They started their research with a pencil-and-paper test that did not contain either Likert-scale or multiple-choice questions. The students’ responses involved either explanations of answers to open-ended questions or the creation of a drawing. After the administration of the paper-and-pencil exam, Çalik and Ayas interviewed small groups of participants using an “interview about events” technique. The interviewers brought two containers to the interview, an open aqueous NaCO₃ system and a closed aqueous NaCO₃/HCl system. The participants discussed their ideas concerning the concepts of gas, dissolution, and chemical changes initially with their peers, and then with the interviewer. The analysis of the open-ended questions, the participant’s drawings, and the transcription of the group interviews exemplified the use of a hermeneutic methodology in this study.

Familiarity with Participants

The work of Piquette and Heikkinen (2005) and Çalik and Ayas (2005) are examples of studies in which the researchers were relatively unfamiliar with the participants, or conversed briefly with the participants. Other approaches to the design of a study are based on a larger degree of familiarity with the participants in the study. Consider the longitudinal study reported by Johnson (2000, 2002), for example, in which 147 children between the ages of 11 and 14 were tracked for three years in an effort to describe their concept of “substance” — specifically their use of the terms elements, compounds, bonding, melting and boiling. In the course of this study, Johnson periodically interviewed the same 33 students over the course of the three years. The long-term relationship between the researcher and the subjects of this study not only allowed
Johnson to intimately know the curriculum, the teachers, and the students, but it allowed his participants to know him, as well.

Southerland et al. (2005) incorporated discourse analysis in their study of third-graders’ understanding of condensation and phase change in order to probe “... the patterns found at the intersection of individual and group meaning making ...” (p. 1035). The work of Sutherland, et al., is another example of a research design in which the researchers were familiar with the subjects of the study. Before the lesson on condensation was taught, Settlage had worked with the classroom teacher for three years and co-taught science lessons on a weekly basis in the classroom. The students were therefore accustomed to his presence in the classroom and his constructivistic pedagogy. Settlage’s consistent, long-term interactions with students provided the researchers with a deeper knowledge of the context in which data were collected.

Data Sources

Data sources for studies of meaning-making can include interviews and/or artifact production. Interviews and artifact production can occur simultaneously or independently, and one of these data sources can lead to the other. Interviews are a rich, primary source of data. Reported methods of interviewing go beyond the semi-structured interview to include think-aloud protocols, interviews about instances, and interviews about events.

Think-aloud protocols (Larkin & Rainard, 1984) involve the participant solving a problem. Bowen (1990), for example, used a think-aloud protocol to explore what graduate students considered as they solved synthesis problems in organic chemistry.

In studies that use the interview-about-instance (IAI) technique, the interviewer offers the participant a choice in a particular situation. For example, Stavridou and Solomonidou (1998) gave their participants cards featuring a physical or chemical change and then asked their participants to identify those examples of chemical change.

In the interview-about-events (IAE) approach to data collection, the phenomenon is dynamic. In an IAE, a series of events are displayed or demonstrated to the participants, who are asked to describe their observations, and provide an explanation of what they have observed. Coll & Treagust (2002, 2003), for example, had each participant view a drawing on a card of the formation of a copper ammonium complex, observe a demonstration of the complex-formation reaction, and then explain the process they observed.

Researchers can use think-aloud protocols and either interview-about-instance or interview-about-events approaches to “deliberately activate” concepts (Stavridou & Solomonidou, 1998). Each of these interview methods is designed to stimulate dialogue and engage the participant in a conversation.
Valanides, Nicolaidou, and Eilks (2003) employed a variation of the interview-about-events technique. Their data were collected in a high-school chemistry classroom where nine 12th-grade Cypriot chemistry students predicted, performed, and explained what happened when a piece of copper wire or a piece magnesium strip was heated with a Bunsen burner. This study used a traditional chemistry experiment as a prompt to explore understanding about oxidation-reduction reactions. The interviews included questions about macroscopic and microscopic changes associated with the reactions. Participants were also provided opportunities to discuss any inconsistencies between their pre-experimental predictions and post-experimental explanations.

Another source of data is artifact production; the production of something that is both physical and tangible. Having participants produce artifacts is neither separate from nor exclusive to interviews; interviews and artifact production can be used in tandem, if not synergistically. Using the interview-about-events technique, for example, produces dialogue and drawings (see Coll & Treagust, 2002, 2003). Artifacts include but are not limited to drawings (Çalik & Ayas, 2005; Coll & Treagust, 2002, 2003; Ferguson, 2003); models (Nicoll, 2003); and concept maps (Novak & Gowin, 1984).

Excellent examples of drawings-as-artifacts can be seen in the movies, “Minds of our Own” (Schneps, 1997), and “A Private Universe” (Schneps, 1987). These videos demonstrate the power of having the participant draw and explain their conceptions of the cause of the seasons, electrical circuits, or photosynthesis. These videos also provide good examples of the conversational exchange (or dialectic) between the interviewer and the participant and the production of the drawing or the artifact by allowing the viewer to see the different conceptions of the participants unfold during the interview.

Asking the participant to create models allows the participant to describe phenomena in three dimensions. For example, Nicoll (2003) interviewed 56 college chemistry majors with the objective “... to determine how students conceived of the submicroscopic world and whether these conceptions changed over increasing chemistry instruction ... " (p. 205). During the semi-structured interviews, she gave the participants two tasks: (1) draw the Lewis structure of formaldehyde, and (2) build the Lewis structure using modeling clay (Play-doh). The clay structures helped to elucidate the participants’ concept of molecular geometry by augmenting the verbal descriptions and the 2-D drawing in the Lewis structure of the molecular geometry.

Various graphical organizers have been used to study understanding, meaning-making, and alternative conceptions in chemistry, but few are as prevalent as concept maps (Novak & Gowin, 1984). Many examples of the use of concept maps to probe understanding in chemistry can be found in the literature (e.g., Markow & Lonning, 1998; Nakhleh, 1994; Nakhleh & Krajcik, 1994; Nicoll, Francisco, & Nakhleh, 2001b; Pendley, Bretz, & Novak, 1994; Regis, Abertazzi, & Roletto, 1996; Stensvold & Wilson, 1990). The work of Nicoll et al. (2001b), however, exemplifies the use of concept maps as a means of expressing conceptual understanding. Nicoll et al. (2001b) explored the
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effect concept maps had on students’ ability to organize several chemistry topics: bonding, electronegativity, electrons, and molecular structure.

Data Analysis and Interpretation

Once the artifacts have been collected, and the interview is completed, the recording of the interview is transcribed to produce a text of the conversation. Grounded theory (Strauss & Corbin, 1994, 1998) is then used as a data analysis technique to develop descriptions of the participants’ concepts. This inductive approach, also known as a constant comparison method (Patton, 2002), is more cyclic than linear. The process of data analysis consists of three deceptively simple phases: data collection, coding, and memoing. In grounded theory, the researcher moves back and forth between these three phases. Initially, the researcher will spend more time in the data-collection phase (interviews and artifact production). As the study progresses, the researcher will dedicate more time to the coding and memoing phases.

Strauss (1987) described coding as provisionally conceptualizing the data and producing categories and subcategories. These coding schemes are, by design, meant to be tentative and malleable or even disposable. According to Strauss and Corbin (1994), this coding act produces insight for the researchers and sends them back to collect more data, until such a time that further data collection produces no new insights. Strauss and Corbin (1998) defined memoing (or the act of making memos) as “the researcher’s record of analysis, thoughts, interpretations, questions, and directions of further data collection” (p. 110). Memoing helps the researcher organize ideas and guide conclusions and assertions.

Although most qualitative research asks the type of questions that are difficult if not impossible to subject to statistical analysis (Patton, 2002), the frequent use of concept maps in chemical education necessitates a brief discussion of quantifying a qualitative artifact. The following discussion of scoring concept maps is not meant to be a discussion of organizing qualitative data into tables, matrices, and charts (see Miles & Huberman, 1994), but a brief introduction to quantification of qualitative artifacts.

Novak and Gowin (1984) suggested scoring concept maps based on the organization of the map by awarding points for valid hierarchical levels and significant crosslinks. A “relational scoring method” was used by McClure, Sonak, and Suen (1999). An alternative scoring system proposed by Nicoll, Francisco, and Nakhleh (2001b) assesses the use, stability, and complexity of each link. Other scoring systems are described elsewhere (see Kinchin, 2000; Klein, Chung, Osmundson, Herl, & O’Neil, 2001; Yin, Vanides, Ruiz-Primo, Ayala, & Shavelson, 2005). It should be noted, however, that researchers who decide to use a concept map as a data source or as analytic tool need to create an “expert” map before asking for a concept map from the participants (McClure, Sonak, & Suen, 1999; Nakhleh & Krajcik, 1994).
Validity Issues

Guba and Lincoln (1994) proposed two general sets of criteria for measuring the goodness of qualitative research: “trustworthiness” and “authenticity.” Denzin (1994) likened trustworthiness to the internal and external validity checks one would find in a statistical study. A variety of approaches can be taken to trustworthiness, including peer-review of codes, categories, and emergent themes by a colleague; member checking, a process by which participants review the analysis and assertions extracted from interviews in which they participated; and triangulation (the use of multiple sources of data). Guba and Lincoln (1994) equated the second criteria, authenticity, with the effect or influence the study had on the researcher, other instructors, or even the participants. Thomas and McRobbie (2001) and Venville (2004) provide examples of how data sources, data collection techniques, and data analysis can be applied to a theoretical perspective to probe the trustworthiness of a study.

A Detailed Example of a Constructivist Study

In their study of how students propose a mechanism for an organic reaction, Bhattacharyya & Bodner (2005) noted that:

> The ability to use the curved-arrow/electron-pushing formalism is one of the most vital skills in the organic chemist’s repertoire. Their introduction to this formalism occurs when they first encounter reaction mechanisms. As they gain experience, the arrow-pushing formalism eventually becomes the primary technique organic chemists use to do retrosynthetic analysis, to predict the chemoselectivity of a reaction, and to create novel methodologies. (p. 1402)

An example of the curved-arrow/arrow-pushing formalism taken from the work of Bhattacharyya & Bodner is shown in Figure 1.

![Figure 1: An example of the curved-arrow/arrow-pushing formalism](image)

My motivation to study students’ understanding of the arrow-pushing formalism (APF) used by organic chemists (Ferguson, 2003) stems from my non-traditional route into synthetic organic chemistry research. Unlike many of my peers in graduate school, whose introduction to the APF was the result of extensive coursework, I learned the curved-arrow/arrow-pushing approach to organic mechanisms in an unstructured environment, while working in a synthetic organic research group.
My goal in designing my research was to investigate differences in the way undergraduates in a sophomore-level organic chemistry course made sense of the arrow-pushing formalism. I therefore formulated the following research questions:

- How do students make sense of the arrow-pushing formalism?
- What are the misconceptions?
- What are the processes that the students use to complete an arrow-pushing mechanism?

Constructivism was an appropriate research lens for investigating something as unstructured and unquantifiable as “understanding mechanisms.” Because the research questions focused on individual’s “sense-making,” either Kelly’s personal constructivism or von Glasersfeld’s radical constructivism were appropriate choices. I chose Kelly’s version of personal constructivism as the theoretical framework for this study.

The personal constructivism of Kelly asserts that “individuals construct knowledge for themselves through construing the repetition of events, and that knowledge is individual and adaptive rather than objective” (Geelan, 1997, p. 17). Individuals interact with the world in an iterative and reflective process, continually adjusting the fit between the world and the knowledge they construct. Bodner, Klobuchar, and Geelan (2001) summarized Kelly’s personal constructivism as follows:

Kelly argues that we each create our own ways of seeing the world; the world does not create them for us. Each of us builds our own constructs, tries them on for size, and eventually revises them. (p.15)

Constructivism was consistent with the goal of my study: to understand how learners made sense of the arrow-pushing formalism. It also guided the choice of methodology to explore sense-making within the context of the arrow-pushing formalism.

My study was based on interviews with 22 undergraduate chemistry majors who volunteered to participate in problem-solving sessions in which they were asked to solve questions based on reaction mechanisms that were typical of a sophomore organic chemistry course (e.g., hydride reduction, Dieckmann condensation, Robinson annulation). During the semi-structured interviews, the participants constructed curved-arrow diagrams (artifacts) while they explained the flow of electrons using the think-aloud protocol. I audio-taped, video-taped, and then transcribed each interview.

Six students returned for a second, “member-checking” interview. The following vignette illustrates a typical member-checking interview (I = Interviewer; P = Participant):

I: So in your opinion, right here, I put “no consideration of pKa.” Would there be a better way for me to phrase this? Or are you O.K. if I leave this? How would you like me to put it?
P: I am trying to think. Because I think that I consider but I don’t consider as much pKa as just … I don’t know how to term that either.

I: O.K., you do have some considerations, there but it seems like you more strongly, you rely more greatly on things like δ+/δ-, resonance, electronegativities. Those are things that you utilize more and pKa kind of toward the end of the list, low priority.

P: yeah … that sounds closer to,

I: more reasonable to you?

P: yeah.

The methodology used in this study was consistent with Lincoln & Guba’s (2000) call for constructivist frameworks coupled with both hermeneutics and dialectics. The diagrams students created when they proposed mechanisms, the transcripts of the interviews, and the video-tapes of the interviews served as artifacts for the hermeneutic component of this methodology. These artifacts represented the “text” — both in the form of written diagrams and verbal responses — generated as the students answered the questions on mechanisms. This text became the data of this study, and ultimately the message of the students.

The initial and follow-up interviews were dialectic in their nature. Participants were asked:

- What is the first thing you do when solving a reaction mechanism problem?
- What do you do when you get stuck?
- What do you interpret this problem to mean?
- What are some clues that you look for when solving these problems?

I used the second interview to discuss the accuracy of my analysis and to check my understanding directly with the participants — a form of member checking. During the second interview, I reviewed my initial findings, categories, and understandings with the participants. At this meeting I asked the participants whether they agreed with my analysis. The participants inspected the data and any summations and interpretations that I derived. Member checking provided a method to appraise my observations and analysis, and to corroborate my ideas of the participants’ understanding with the participants themselves. Through these conversations, the participants and I talked about each other’s perspective and discussed possible answers to my research questions. Through this dialectical exchange, we came to a consensus.
Ultimately, I found that the undergraduates made sense of the arrow-pushing formalism in a complex and complicated manner. Because they lacked a firm grasp of the fundamental concepts they were expected to master, the undergraduate students viewed the arrow-pushing formalism as a meaningless exercise. From a pragmatic point of view, they understood what they were supposed to do; their artifacts showed a starting material being transformed into a product. They knew some of the fundamental rules of organic chemistry and applied them sparingly. They did not understand the concepts, theories, and rules that interacted during a reaction, however. When solving specific mechanism questions, they either did not remember the necessary concepts and rules, or they only remembered a part of this information. Concepts that they remember were often misapplied or confused it with a competing idea.

Conclusion

With its origins in the cognitive sciences, constructivism is unquestionably the dominant epistemology in science education. Since its incorporation into science education it has not only become a driving force in curriculum design but has been applied as a theoretical framework for research. Constructivism asks the question: How do individuals or groups understand reality? Researchers have employed a variety of methods such as interviews, think-aloud protocols, concept maps, and model-building to collecting data in research studies based on a constructivist framework. Constructivism is therefore a useful theoretical framework to consider for the researcher who is seeking to understand alternative conceptions, conceptual change over time, or the construction of knowledge.

References


Chapter 2: Constructivism


Symbolic Interactionism

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Biography

Dawn Del Carlo is an assistant professor of Chemistry at the University of Northern Iowa where she is a Jill of all trades, teaching chemistry, physical science and secondary science educational methods courses. She received her B.A. in Chemistry from Augustana College (in Illinois), and her M.S. in Inorganic Chemistry and Ph.D. in Chemistry Education both from Purdue University. Her doctoral dissertation examined the concept of academic dishonesty held by chemistry majors toward their classroom laboratory experiences. Immediately after graduation, she accepted a position as assistant professor in chemistry at Montclair State University in New Jersey where she extended her research to include high school students. After 3 years she returned to the Midwest, shifted the focus of her research slightly, and is currently looking at students’ perceptions of their undergraduate research experiences with special emphasis on how pre-service and in-service teachers are affected by these experiences.

Introduction

Historically grounded in elements of George Herbert Mead’s Chicago School of Sociology, the term “symbolic interactionism” was coined in 1937 by Herbert Blumer, a student of Mead’s, as a pragmatist’s theoretical and methodological approach to the study of social phenomena (Blumer, 2004). Symbolic interactionism is concerned with the construction of shared meanings (symbols) through social interaction and interpretation, and draws on the ideas and theories of William James, Charles Horton Cooley, John Dewey, and W. I. Thomas (Herman-Kinney & Verschaeve, 2003; Jacob, 1987; Meltzer, Petras, & Reynolds, 1975).

Goals of Symbolic Interactionistic Research

Patton (1990) argued that the goal of symbolic interactionism is to answer the basic question “What common set of symbols and understandings have emerged to give meaning to people’s interactions?” In other words, how do people define their world and
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how does that definition shape their actions? (Charon, 1998). The focus of symbolic interactionism is “making society intelligible, rather than testing relationships between variables” (Jacob, 1987, p. 29). Consequently, the meanings people hold about their world are of central importance in symbolic interactionism and are governed by three premises (Blumer, 1969, 2004; Patton, 1990):

- Humans act toward the objects and people in their environments on the basis of the meanings these objects and people have for them.

- These meanings derive from the social interaction (communication, broadly understood) ... between and among individuals.

- Meanings are established and modified through an interpretive process undertaken by individuals in dealing with the things one encounters (Blumer, 1969, p. 2).

These statements imply that meaning is established only through social interaction. More explicitly, meanings are not held in individuals’ minds alone, but are social entities themselves and are consequently contextualized in the social environment. Therefore, any particular meaning is not determined by an individual’s experiences alone, but also by the social interactions or communications the individual has with his/her peers and the reflection of that individual on the interaction (Blumer, 1969; Gallant & Kleinman, 1983). In essence, symbolic interactionism:

… describes the intricate interrelationships between the individual and society: Society makes the individual through creation of the self, mind, symbols, generalized other, perspectives, and symbolic role taking. Conversely, it is the human individual who makes human society through active interpretation, self-direction, role taking, aligning his or her own acts with others, and communicating. (Charon, 1998, p. 232)

Results arising from the use of a symbolic interactionistic approach to research are centered around constructing a basic understanding of how people act based on the definitions and meanings they hold of the world around them.

Assumptions of Symbolic Interactionism

Two main assumptions of symbolic interactionism involve its treatment of reality and the nature of interaction and behavior. Rooted in the philosophies of pragmatism and interpretivism, symbolic interactionism defines reality as an evolving entity that depends on social interaction. Reality is socially constructed and is based on what we find to be “useful” (Charon, 1998):

We converse with ourselves, we make decisions along a continuous stream of action. Truth for us always changes, our symbols do, rules change, our use for our environment changes. What we are today is different from what we were
yesterday … People are not thought to be brainwashed and conditioned so much as actively involved in testing and reassessing their truths. (p. 32)

As an over-simplified example, children might use large cardboard boxes strung together to create a “fort” in which to play after their parents unpacked the boxes that were originally used when the family moved into a new house or apartment. The same object, or symbol, has a different meaning (or reality) for the person, depending on his or her interaction with the object, and consequently, different behaviors involving the symbol — here, the cardboard box — are observed. The reality, or reason for existence of this box, is different for the parents than for the children who each interact with this object differently. The reality of the box is not innate to the box itself but exists in how the box is used by a particular person or group of people.

Symbolic interactionism is heavily influenced by elements of behaviorism. Mead (1934) argued:

Social psychology is behavioristic in the sense of starting off with an observable activity … to be studied and analyzed scientifically. But it is not behavioristic in the sense of ignoring the inner experience of the individual … On the contrary it is particularly concerned with the rise of such experience within the process as a whole. (pp. 7-8)

Unlike “traditional” behaviorism, which is based on the premise that stimulus-response behavior is the result of previous conditioning or instinct, symbolic interactionists believe interpreted meaning begets social behavior, which, in turn, further constructs meaning through the social interaction. It is this process of meaning construction and resultant behavior that symbolic interactionists seek to understand (Jacob, 1987).

These elements of behaviorism are what separate symbolic interactionism from frameworks such as social constructivism (Chapter 2) and situated cognition (Chapter 11) which are more focused on the cognitive aspects of social construction of knowledge or reality (Lave & Wenger, 1991; Schwandt, 1994). Symbolic interactionism, on the other hand, is focused on observable behavior, the cognitive meaning behind the behavior, and the interplay between the two.

**Methods of Symbolic Interactionism**

Symbolic interactionism seeks to understand the underlying meanings of observable behavior and interactions. Therefore, qualitative methods of data collection — including participant observation, interviews, and life histories — are the most useful methodologies, although, on occasion, mixed-methods and social experiments such as the laboratory experiment and the quasi-experiment, are also used (Herman-Kinney & Verschaeve, 2003; Ulmer & Wilson, 2003). It should be noted, however, that Blumer’s original conception of symbolic interactionism adamantly opposed the use of quantitative measures, which were commonplace in sociology and psychology at the time (Blumer, 1969).
Participation observation, in which the research actively participates in and is, in part, socialized into the group under study, plays a central role in symbolic interactionist methods (Herman-Kinney & Verschaeve, 2003; Jacob, 1987). As Blumer noted:

> The empirical social world consists of ongoing group life and one has to get close to this life to know what is going on in it. If one is going to respect the social world, one’s problems, guiding conception, data, schemes or relationships, and ideas of interpretation have to be faithful to that empirical world. (1969, p 38)

Also referred to as “sympathetic introspection” (Meltzer et al., 1975), or *verstehen* — meaning “understanding on a personal level the motives and beliefs behind people’s actions” (Taylor & Bogdan, 1998, p. 4) — participant observation is clearly ethnographic in nature (see Chapter 10), and is used to generate an “understanding of the ways of life of others” (Schwandt, 2001, p. 186). The challenge of participant observation is that the researcher must become part of the studied group enough to understand it as a member of that group, but yet, also be able to step back and describe and analyze the observations such that they are understandable to outsiders. Detailed and reflective field notes are especially helpful in this regard and should be diligently taken for all observations. It is often easiest to take shorthand notes during the observation period and then transcribe the notes shortly thereafter, filling in the detail while it is still fresh in the researcher’s mind. Never assume that something is significant enough to be remembered at a later time (Patton, 1990).

Depending on the extent to which the researcher participates within the population being observed, the meaning constructed from social interaction may or may not be readily apparent. Other techniques such as interviews (open-ended, structured or semistructured in nature), or collected artifacts such as life histories, public documents, and journals/diaries are often used to supplement observation notes. Through interviews and the completion of artifacts, study participants reflect on their behavior and are given the opportunity to explain the meaning their behavior or artifact holds for them (Herman-Kinney & Verschaeve, 2003). For example, a researcher may ask participants to keep a journal throughout a particular experience which describes their thoughts, feelings, actions, and decisions. These journal entries will inevitably illustrate the meaning these experiences had for the participants. Moreover, focus group interviews can be used to ascertain socially constructed meaning in a more researcher-controlled atmosphere than the naturalistic or original observed setting. This allows the researcher to probe participants for meaning without losing the social aspect of the construction of meaning (Herman-Kinney & Verschaeve, 2003; Morgan, 1988).

**Data Analysis**

Blumer considered himself an empiricist and believed that a researcher’s conclusions should be a direct result of the observed social world (Blumer, 1969). The goal for symbolic interactionists is therefore “to develop theory that accounts for behavior rather than to develop descriptions of behavior with the goal of verifying theory” (Jacob, 1987, p. 31). Consequently, researchers use a grounded theory approach — utilizing their
collected data as the starting point of analysis — and do not approach their study with a predetermined hypothesis in mind (Charmaz, 2000; Strauss & Corbin, 1990; Taylor & Bogdan, 1998). Instead, the research design and focus must remain somewhat flexible, with preliminary data informing the direction of future data collection through a “sensitizing framework” (Jacob, 1987; Patton, 1990). Blumer (1969) refers to this as the exploration phase of analysis:

It is the way by which a research scholar can form a close and comprehensive acquaintance with a sphere of social life that is unfamiliar and hence unknown to him. On the other hand, it is the means of developing and sharpening his inquiry so that his problem, his directions of inquiry, data, analytical relations, and interpretations arise out of and remain grounded in, the empirical life under study. Exploration is by definition a flexible procedure in which the scholar shifts from one to another line of inquiry, adopts new points of observation as his study progresses, moves in new directions previously unthought-of, and changes his recognition of what are relevant data as he acquires more information and better understanding. (p 40)

As data are collected, they are reviewed almost immediately, so that data collection and data analysis occur concurrently throughout the study. The researcher examines and re-examines the data (which may include not only texts but objects, pictures and diagrams depending on the nature of the study), looking for themes of action and possible meanings to emerge. These themes then shape how the researcher approaches future data collection with regards to the types of behaviors, conversations, and interactions that are observed and noted (Patton, 1990). It should be noted that this method is not used to pin-point specifically what to look for or questions to ask, but only to suggest a direction in which to look (Jacob, 1987).

Symbolic interaction is unique in that analysis is viewed through a lens where the group or individual being examined is seen "as a moving process in which the participants are defining and interpreting each other’s acts" (Blumer, 1969, p. 53). When an individual’s act is understood by the researcher as it is understood by the individual himself, data collection and analysis is complete (Blumer, 1969).

**Criticisms of Symbolic Interactionism**

The focus of symbolic interactionism is on meaning that is socially constructed; therefore, little attention is paid to psychological phenomena which are specific to the individual, such as human emotion and the unconscious (Meltzer et al., 1975; Stryker, 1980). In fact, Mead specifically describes both the “I” and “me” as being socially constructed identities. The difference between the two originates from the stage of reflection of the individual (Mead, 1934):

I talk to myself, and I remember what I said and perhaps the emotional content that went with it. The “I” of this moment is present in the “me” of the next moment … The “I” is the response of the organism to the attitudes of the others; the “me”
is the organized set of attitudes of others which one himself assumes ... it is the presence of those organized sets of attitudes that constitutes that “me” to which he as an “I” is responding. (pp. 174-175)

Mead describes the “I” as the persona interacting socially; the persona that others see. The “me,” on the other hand, is the current persona or self which reflects on the interactions of the “I,” and changes existing attitudes and beliefs accordingly. Consequently, the “me” of the present is governed by the past social interactions of the “I”, which makes both entities socially constructed.

Cooley (1998) described the idea of an “I” as a “social self,” further embedding identity and constructed meaning within a social context. This ignores all reference to the unconscious aspects of human behavior important in the psychological theories of Freud and Jung which is the premise of Brittan's critique of symbolic interactionism (Brittan, 1973). In essence, by embedding meaning within a social context, symbolic interactionism treats human emotions, desires, motives and aspirations — which Freud describes as the “Id” — as social entities, ignoring the individualistic traits inherent in each. Consequently, the individual is lost within the socially determined norms.

Since meaning and reality are dependent on the particulars of social interaction, the concept of reality is not an objective one and existing realities, such as social structure and class, are largely ignored (Meltzer et al., 1975; Stryker, 1980). This results from the pragmatic influence on symbolic interactionism, and, while an objective reality is acknowledged, that objective reality is not examined under this framework (Charon, 1998; Johnson & Picou, 1985):

Instead, we define the situation “as it exists” out there, and that definition is highly influenced by our social life...we learn in social interaction what to see in objective reality and how to define what we see. (Charon, 1998, pp. 42-43)

As a result, the specific situation under study also becomes an element of analysis, and since two situations are never identical, symbolic interactionism does not generate testable hypotheses or generalizable results (Denzin, 1969; Meltzer, Petras, & Reynolds, 1975). This critique is carried over to the specific research methodologies, namely participant observation, where the researcher is part of the situation, and may influence the interaction, such that results can sometimes reflect researcher bias rather than observed behavior (Patton, 1990; Stryker, 1980). Consequently, it can be argued that whatever theories emerge will necessarily be different when the study is performed by another researcher. In fact Meltzer et al. (1975) states that symbolic interaction “often results in an over-emphasis on the situation and an obsessive concern with the transient, episodic, and fleeting” (p.85).

Since symbolic interactionism relies on the analysis of the interaction between individuals, it is not appropriate for understanding large-scale social organizations — such as governments, school districts or large corporations — and their effect on an individual’s behavior or on other organizations. Instead, this framework is best suited for
developing an understanding of the specific social structures themselves and the individuals that compose it (Stryker, 1980).

**Potential Educational Benefits of Symbolic Interactionistic Research**

Unlike much of the educational research one traditionally thinks of with regard to learning, cognition, and individual student academic outcomes, educational studies framed by symbolic interactionism focus on the social interactions within schooling that strongly influence and shape learning (Kinney, Rosier, & Harger, 2003). Generally speaking, it can be said that interactionist studies contribute to the growing amount of information pertaining to classroom and school climate or culture by examining student-student, student-teacher, teacher-teacher, or teacher-parent interactions. Ultimately this culture affects student learning and performance, and in order to be effective educators it is prudent to have a basic understanding of the culture that exists in their classrooms (Fraser, 1994; Kinney et al., 2003). By subscribing to the tenets of symbolic interactionism, educators understand that “whatever was gained [in the classroom] will be changed considerably as [students] interact now with new people” (Charon, 1998, p. 230).

As will be seen in the following section, studies which examine the experiences specific to pre-service and student teachers have implications for teacher education programs. Understanding how pre-service and even new in-service teachers develop their beliefs and practices based on their courses and experiences in the classroom can shape what activities and experiences teacher education programs expose them to before getting out in the field (Abell & Roth, 1992, 1994; McGinnis & Pearsall, 1998; Southerland & Gess-Newsome, 1999).

An additional area of growing interest is in the “culture” of science and scientific research that can be traced back to the 70’s (Latour & Woolgar, 1979). While not explicitly interactionist in nature, Latour’s work sought to understand the culture of science and scientific knowledge. This understanding came about by observing the interactions of practicing research scientists in a laboratory setting. Understanding the difference in culture between the classroom laboratory in which educators train future practitioners and the culture of practitioners has great implications for science education (Seymour, Hunter, Laursen, & Deantoni, 2004).

**Published Examples of Symbolic Interaction Studies in Science Education**

While published studies using symbolic interactionism in mathematics education are plentiful (Cobb, Stephan, McClain, & Gravemeijer, 2001; Radford, 2003; Trouche, 2003; Yackel, Cobb, & Wood, 1998) — including several books on the subject (Cobb & Bauersfeld, 1995; Wood, Wood, Nelson, & Warfield, 2001) — studies in science education are less so. A comprehensive literature search in this case was difficult due to the fact that science education studies using symbolic interactionism can be published in social science, educational psychology, or cultural study journals as well as traditional science education journals (see Table 1). I searched eight common science/chemistry
education journals,¹ and additionally performed keyword searches within the journal *Symbolic Interaction* and several databases including ERIC, PsycINFO, and Google Scholar to generate a varied sample of science education studies conducted using this framework. Rather than trying to “fit” research studies into a certain framework where none was reported, references included in this review explicitly stated that symbolic interactionism was used as a framework. Studies in science education that used this framework generally focused on one of three topics: 1) pre-service teacher preparation, 2) in-service teacher practices, and 3) student perspectives and experiences in science.

**Table 1: Summary of Literature using SI Framework**

<table>
<thead>
<tr>
<th>Authors</th>
<th>Research Questions or Purpose of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abell &amp; Roth, 1992</td>
<td>What beliefs about elementary school science education does a science enthusiast student teacher possess? How does her teaching reflect and influence these beliefs? How do the constraints she perceives to her teaching interact with these practices and beliefs?</td>
</tr>
<tr>
<td>Abell &amp; Roth, 1994</td>
<td>How does a student teacher, who is enthusiastic about teaching science in the elementary school, cope with conflicts between her beliefs about science teaching and learning and the constraints she perceives to her teaching?</td>
</tr>
<tr>
<td>Del Carlo &amp; Bodner, 2004</td>
<td>What are chemistry students’ perceptions of academic dishonesty in a laboratory based class? and What distinction, if any, do these students make between academic dishonesty in the classroom laboratory and scientific misconduct that may occur in a research laboratory?</td>
</tr>
<tr>
<td>Dillon, O’Brien, Moje, &amp; Stewart, 1994</td>
<td>How were literacy events shaped by the teachers’ philosophies about teaching science content and teaching students? How was literacy (reading, writing, and oral language) structured by the teachers and manifested in science lessons?</td>
</tr>
<tr>
<td>Gohn, 2004</td>
<td>How do leadership teams develop a team culture within the milieu of school and community and how do these teams function in building teacher leadership and extending science education reform, addresses complex social phenomena?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Title</th>
<th>Abstract</th>
</tr>
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<tbody>
<tr>
<td>Helms, 1998</td>
<td>What is the nature of secondary science teachers’ sense of personal and professional identity with respect to their subject matter?</td>
<td></td>
</tr>
<tr>
<td>Hyde &amp; Gess-Newsome, 1999</td>
<td>What characterized the experience of the women who stayed in science and graduated successfully? What type of interactions and events impacted their decision to persist? What types of relationships were meaningful to their experiences, and did those associations help them to persist in their academic pursuits? What was the nature of their context? Did the university’s special programs for female MES students make a difference in female persistence?</td>
<td></td>
</tr>
<tr>
<td>McGinnis &amp; Pearsall, 1998</td>
<td>The purpose was to gain insight into the effect of the gender difference between a male professor and his female teacher candidates on the outcomes of an elementary science methods course.</td>
<td></td>
</tr>
<tr>
<td>McGinnis et al., 2004</td>
<td>As they proceed through their induction years, how do beginning specialist teachers of mathematics and science who graduate from an inquiry-based, standards-guided innovative undergraduate teacher preparation: (a) enact their roles as teachers? and (b) think about what they do when teaching science and mathematics to upper elementary/middle-level students? And secondly, what affordances/constraints impact the introduction of new practices (reform-based) by beginning specialist teachers of mathematics and science who graduate from inquiry based, standards-guided, innovative undergraduate teacher preparation?</td>
<td></td>
</tr>
<tr>
<td>Simmons et al., 1999</td>
<td>What are the perceptions, beliefs, and classroom performances of beginning secondary science and mathematics teachers as related to their beliefs and philosophies of teaching and their content pedagogical skills?</td>
<td></td>
</tr>
<tr>
<td>Smardon, 2004</td>
<td>This study seeks to elaborate the importance of group membership and group identity in constructing a science culture in the classroom.</td>
<td></td>
</tr>
<tr>
<td>Southerland &amp; Gess-Newsome, 1999</td>
<td>Purpose is to detail pre-service teachers' understandings of teaching, learning, and knowledge and describe how these pedagogical understandings influenced their approach to inclusive science teaching.</td>
<td></td>
</tr>
</tbody>
</table>
Van Sickle & Spector, 1996  
What is happening in science classrooms with teachers who are perceived to be caring?

Zeidler, Walker, Ackett, & Simmons, 2002  
In what ways are students views of the nature of science reflected in their reactions to socio-scientific issues when confronted with information that challenges their initial beliefs?

Studies in pre-service teacher education that used symbolic interactionism as their theoretical framework examined either the student teaching experience (Abell & Roth, 1992; Abell & Roth, 1994) or events within the methods course (McGinnis & Pearsall, 1998; Southerland & Gess-Newsome, 1999). Abell and Roth reported the results of a study of the beliefs a student teacher held pertaining to elementary science teaching, how those beliefs shaped her actions (1992), and how she coped with perceived limitations in her science teaching (1994). Another study (Southerland & Gess-Newsome, 1999) examined pre-service elementary teachers' epistemological and pedagogical beliefs and sought to understand how these beliefs influenced a pre-service teacher's planned approach to teaching diverse populations of students. All three studies focused on future teachers' understandings and knowledge and how those manifested themselves as behaviors in the classroom.

The fourth study in this category involved a methods course (McGinnis & Pearsall, 1998). This study of pre-service elementary teachers was more exploratory in nature and examined how a male instructor for a predominantly female student population affected the outcomes of the course. The report is told from two different perspectives: that of the male instructor and that of the female co-researcher in an effort to illustrate the difference in the gender-imposed lenses.

Most of the published accounts of in-service teachers that utilize a symbolic interactionist framework focus, not surprisingly, on the continuity (or discontinuity) between teachers' understandings of science content, pedagogy, and pedagogical content and their actual classroom practices (Dillon et al., 1994; Helms, 1998; McGinnis, Parker, & Graeber, 2004; Simmons et al., 1999; Van Sickle & Spector, 1996). However, each report takes a slightly different slant. Simmons et al. (1999), for example, limited their study to teachers in their first three years of teaching and specifically examined how teacher beliefs, practices, and their incongruencies evolved over the three years. Similarly, McGinnis et al. (2004) examined teachers in their first two years of practice with regards to their understandings and implementation of inquiry-based teaching methodologies in elementary/middle-level science and mathematics classrooms.

Other studies were less concerned with what happens in the beginning years of teaching and instead focused on specific characteristics of teaching. Van Sickle & Spector (1996), for example, studied the behaviors and classroom culture established by middle and secondary science teachers who were perceived by students and colleagues as being “caring.” Helms (1998) related middle-level and secondary science teachers perceived level of content knowledge to their sense of “professional” self. This
sense of self dictates teachers’ teaching behaviors in their classrooms. In the last of the fours studies in this category, Dillon et. al. (1994) looked at how science teachers with additional experience in — and consequently established philosophies about — literacy, incorporate teaching strategies in science to accommodate those philosophies.

Unlike the studies of in-service teachers previously listed, which focus directly on specific classroom practices, Gohn (2004) looked at how teachers come together to implement curricular reform. Instead of focusing on the behaviors of teachers within their classrooms, this study examined how teachers interact with one another in the groups established to create and disseminate professional development plans for district-wide curricular reform (Gohn, 2004).

Other studies have examined the students’ perspective (Del Carlo & Bodner, 2004; Hyde & Gess-Newsome, 1999; Smardon, 2004; Zeidler et al., 2002). All of these report on some aspect of “culture” from the student’s point of view including the culture of the classroom (Del Carlo & Bodner, 2004; Smardon, 2004), science education school-wide (Hyde & Gess-Newsome, 1999), or science in general (Del Carlo & Bodner, 2004; Zeidler et al., 2002). Smardon (2004) used symbolic interactionism as a starting point for the development of a new socio-cultural model of how urban students negotiate cultural codes between the “street” and a chemistry classroom. Hyde & Gess-Newsome (1999) examined the experiences and culture established by female science, math, and engineering majors on their college campus which encouraged them to persist in their majors. Zeidler et.al. (2002) focused on how students perceived the established culture of science to deal with socio-scientific dilemmas such as animal testing.

The study by Del Carlo & Bodner (2004) fits into two of the above categories since it deals with students’ perceptions of academic dishonesty within chemistry. Specifically, it addresses the perceived culture within a chemistry classroom laboratory and compares that to the perceived culture of scientific research in an effort to understand student behaviors and decisions in both contexts. This study is described in detail in the following section.

A Detailed Example of a Symbolic Interactionistic Study

As a student interested in chemistry from my first experience with it in high school, I noticed over the years that my attitude toward the collection and treatment of data has evolved. Early in my education, I clearly made the distinction between data collected in a classroom laboratory for a grade and the data I collected as part of a research project. The former had a clear “right” answer, which data could be altered to reflect, whereas the latter illustrated whatever phenomenon was under study and consequently could not be fudged. While the current literature is filled with studies on cheating, plagiarism, and various other forms of academic dishonesty, most of this literature focuses on tests, papers and homework assignments (see, for example: Derting, 1997; Lord & Chido, 1995; Maramark & Barth Maline, 1993; McCabe, 1997; Singhal, 1982). Relatively few studies have explored students’ attitudes toward dishonest behavior in the unique
Symbolic interactionism was the best framework for this study because it not only examined the actual behaviors of students in a classroom laboratory but also uncovered the meanings these behaviors hold for students. My focus was on the ethics or ethical philosophies, “objects” in symbolic interactionist terms that students possess and develop through their interactions with other students, research advisors, professors, or teaching assistants in the laboratory setting. How students act in the environment is determined by the meanings that these symbols, or ethical philosophies, have for them. These actions and interactions within the laboratory environment play an important part in the evolution of meanings for the individuals involved in the interaction. The laboratory is itself a social environment in which these contextualized actions take place and, therefore, possesses some social meaning for those individuals participating in that environment.

The use of symbolic interactionism as a theoretical framework for this research implied that students’ actions could be used to understand what academic dishonesty means for them and how that meaning evolved through their interactions in a laboratory setting. More specifically, this study aimed at answering the following guiding research questions:

- What meaning does academic dishonesty have for students in a classroom laboratory?
- What changes in meaning occur when the lab environment is research oriented instead of academic?
- How do these meanings evolve with continued interactions throughout the students’ academic careers?

Over the course of one semester, I observed and took detailed field notes in four different college level chemistry lab classes for chemistry majors — 100-level general chemistry, 200-level inorganic, 300-level analytical, and 400-level instrumental analysis. I was not involved as an instructor in any of these classes. I noted behaviors, actions, interactions, and events students participated in during the course of their lab period. Having a background in chemistry I functioned as a participant-observer, moving about the laboratory, interacting with the students, participating in their conversations, as well as answering questions for the students about myself, the study, or topics in chemistry.

After students were comfortable with my presence in the lab, I solicited for volunteers to participate in either an individual or focus group interview. Eight individual and 9 group interviews were conducted involving close to 100 students. Interviews were used to ascertain the meanings held by the students of events that took place in the classroom laboratory. Individual interviews allowed me as a researcher to ask probing questions regarding meaning, while the focus group interviews, in addition to allowing for meaning
exploration, allowed the social aspect of interaction to remain present despite the fact that the interview did not take place in the laboratory setting. It was also during the interviews that questions about students’ research experiences were explored. Even though research laboratories were not part of the observations, the interviews allowed me to examine how the context of environment affected students’ meanings.

As data collection progressed, notes and interviews were transcribed into electronic form for further analysis and helped shape future observations and interview questions. After reading and re-reading transcripts, common themes regarding student attitudes, behaviors and perceptions of science emerged. These themes became the meanings students held behind the observed classroom laboratory behaviors and led to two main assertions (Del Carlo & Bodner, 2004):

- Students believe that the classroom lab is fundamentally different from a research or industrial lab.
- This difference is so significant that it carries over into students’ perceptions of dishonesty in these two environments.

Students felt that the purpose or meaning behind the classroom laboratory was to ascertain some predetermined “right” answer. The classroom laboratory may also be used to illustrate a certain concept or technique, but was primarily seen as a hurdle to overcome especially given the restrictive time schedule of a 3-hour lab period and equipment or technical difficulties that were not perceived to be the students’ “fault.” While actual data fudging was rare, data “sharing” between lab groups was common and, in one case, after making the students perform the laboratory exercise, the professor noted that it never yielded data “good enough” for analysis and provided the class with a separate set to use in their lab reports.

The students in this study, at all levels from general chemistry through the capstone course in analytical chemistry, believed that the industrial- or research-laboratory setting fostered a fundamentally different environment when compared with the classroom laboratory. While there still might be a “right” answer it was certainly not predetermined; and, consequently, data fudging, copying, or any kind of manipulation held much greater ramifications in the long run.

Interestingly, students began to hold a similar meaning about the “real” lab within their classroom laboratory when they performed one of two independent projects assigned for the class. In both cases, the outcome of the project was unknown and students expressed a sense of ownership over their project. Consequently, these assignments held a different meaning for the students and their behavior toward them was different than the other exercises assigned. Students failed to see the advantage in copying or

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2 The 200-level inorganic class assigned a 20-unknown qualitative analysis project and the 400-level instrumental analysis class required students to devise their own unique question and method of analysis using techniques and instruments studied over the course of the semester.
fudging their data in their projects. This implies that by using project-oriented or inquiry-based experiments, the meaning of the chemistry classroom laboratory and subsequently, academic dishonesty can be changed, and dishonest behavior lessened.

Since students as early as their freshman year believed there was a difference between the classroom and a “real” laboratory setting, these results also provide support for encouraging students to participate in research earlier, rather than later, in their academic careers. This is a movement in science education gaining in popularity and support as more research is done on the benefits of participating in undergraduate research (Seymour et al., 2004).

Conclusion

This chapter outlined the principles of symbolic interactionism including its assumptions about human behavior, interaction, construction of “self,” and perception of reality. Each principle is intricately connected to the other and are what give symbolic interactionism its strength as a framework.

The main focus in symbolic interactionism is on understanding the process of the construction of meaning (or reality) through examination of behavior. Consequently, it is most often used as a framework in chemistry/science educational research when a broad understanding of “culture” is needed. This culture represents the “reality” which has been constructed by the members of that culture. How the members act is a reflection of their understanding of reality and also contributes to further development of that culture.

As illustrated in the section on published examples, this culture can be understood through the eyes of one member (as in a case study) or several as in studies that examined the meanings held by several members of the population. However, because it relies on the direct interaction among its participants, symbolic interactionism is probably not an appropriate framework to study complex or multi-level social systems. Most universities, for example, function on many levels; student, untenured professor, tenured professor, department head, dean, provost, president. With the exception of exceedingly small institutions, it is rare for a president to have continued interactions with the students on campus from which these students define their world to shape their behavior in a classroom. Symbolic interactionism would not be appropriate for such a study.

Conclusions made from research using symbolic interactionism do not offer simple implications. While it may help us to understand a situation, it does not immediately offer solutions to “fixing” perceived problems. In the case of the students who fudge their classroom laboratory data, this culture of acceptance stems from deeply ingrained attitudes and perceptions about how the world works — both inside and outside of the classroom. Eliciting a change in this behavior, implies changing an entire established culture and the meanings behind the undesirable behavior. Unlike behaviorism and the
classic example of Pavlov’s dog, changing the meaning behind a behavior goes well beyond simply rewarding the desired behavior.

Symbolic interactionism also would not be an appropriate framework to study learning or cognition alone. As stated in its name, interaction is a crucial part of this framework. Involved in the analysis must be observations of behavior and interaction as well as an examination of the cognitive processes involved in that interaction. For example, determining what students learn in a typical general chemistry class would not be framed by symbolic interactionism if a simple pre-/post-test experimental design were used. However, examination of what the students experience, how they behave and interact with one another and the professor before, during and after completion of the course, and using that information to complement the test scores, would be better suited to the symbolic interactionistic framework.

Finally, since symbolic interactionism focuses on a constructed reality, rather than an objective one, the conclusions reached, are not generalizable across populations (or even individuals). While we might be able to say that there is one definition of the world that exists among chemistry majors at State U., the definition among chemistry majors at Small College, may be very different. For example, the results of the study presented above originated at a large research-based institution where most classroom laboratories utilized cookbook-style experiments and are taught by graduate teaching assistants. The meanings of academic dishonesty are based on these (and other) social structures specific to the institution and the people within it. It is not difficult to imagine that the laboratory culture and the culture of academic dishonesty would be significantly different at a small college. Even if several other variables are the same (i.e. cookbook labs and student teaching assistants), the interactions between members of each population are different, making the meanings for the first population not applicable to the second. Symbolic interactionism, an exploratory framework, is used to gain a better understanding of the population at hand, which in turn can give us only a preliminary understanding of other populations we may be interested in studying.

**Schools of Thought: Chicago, Iowa, Indiana and Beyond**

In response to the various criticisms of symbolic interactionism, several different “schools of thought” arose from Mead’s original tenets of sociology. Blumer, who has predominantly been the focus of this chapter, represents Mead’s Chicago School of thought; however Manford Kuhn and Carl Couch are credited for developing the “Old” and “New” Iowa Schools respectively, and Sheldon Stryker is known as the creator of the Indiana School (Herman-Kinney & Verschaeve, 2003). While a complete description of each school is beyond the scope of this chapter, a brief discussion highlighting the differences, versatility, and evolutionary nature of this framework is warranted.

Unlike Blumer, who took an interpretivist approach to symbolic interactionism, Kuhn was more positivistic in his method. Because positivism emphasizes a static and empirical version of reality, Kuhn’s focus was less on the relativistic and changing nature of reality, and instead emphasized the empirical testing of hypotheses and
making general statements regarding human behavior by quantifying “the self” (Herman-Kinney & Verschaeve, 2003; Meltzer et al., 1975). Consequently, the specific methodological approaches vary greatly between the two schools with Kuhn and the Iowa school relying mainly on quantitative measures, or semi-qualitative techniques such as scripted interviews (Meltzer et al., 1975). According to Herman-Kinney and Verschaeve (2003), “Kuhn’s mission was to find social life that was controllable, predictable, stable and ordered” (p. 223).

The “New” Iowa school is attributed to the efforts of Couch who carried on Kuhn’s procedures after his death in 1963. Additionally, Couch expanded his procedures to outside the social experimental laboratory with the use of audiovisual technology and shifted his focus toward studying the finer details of the processes of interaction (Katovich, Miller, & Stewart, 2002). In comparison, the Chicago school historically focused on the symbolic meaning of interaction.

Sheldon Stryker and the Indiana School also sought out regular patterns of social interaction, but expanded their work on complex social systems into models of the mind in artificial intelligence (Herman-Kinney & Verschaeve, 2003). Due to the complicated nature of the systems under study, the Indiana School also tends toward quantitative measures, and has led to the development of several mathematical models of social systems. The Indiana school is the most recent twist on symbolic interactionism, and illustrates the fact that it is a constantly evolving framework.

The last two approaches are commonly referred to as “branches” of symbolic interactionism. The first, Garfinkel’s Ethnomethodology, is often associated with conversation analysis, and is described in detail in Chapter 10. The second, is Erving Goffman’s Dramaturgical Genre which focuses on the dramatic nature of interaction. (Charon, 1998; Herman-Kinney & Verschaeve, 2003; Meltzer et al., 1975). For Goffman, people function as actors in their reality and “put on a ‘show’” in an effort to control the impressions they give off to others (Meltzer et al., 1975, p. 68). The meanings which are constructed by an individual are based on these impressions and consequently shape the actions of the other “actors.” It is through these interactions that “social actors also attempt to manage others’ impressions of the groups establishments, and organizations they represent” and control their social situations (Charon, 1998, p. 194). These examples further illustrate the dynamic nature of symbolic interactionism and its many applications.

With the exception of ethnomethodology, which is considered a separate theoretical framework, it might seem at first that it would be difficult to make distinctions in the research literature as to which “school of thought” of symbolic interaction is being used. Once one recognizes that the methodologies are the most distinguishing characteristics of the different schools — Iowa and Indiana, quantitative and Chicago, qualitative — differentiation becomes a bit easier. I did not find studies in science education using the dramaturgical genre, but as long as the “sage on the stage” model of teaching is used, it is easy to see the potential research directions that can use this particular branch of symbolic interactionism.
Chapter 3: Symbolic Interactionism

References


Models and Modeling: A Theory of Learning

Mike Briggs
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Biography

Mike Briggs is an assistant professor of Chemistry at Indiana University of Pennsylvania. He traveled a circuitous path to this position. As a teenager, he pondered the question of why people think and act the way they do. As a platoon leader in Vietnam, he carefully observed how soldiers handled fear on the battlefield. He considered how they rationalize the risk of death and acted according to their views. Later Mike took up flying and became a certified flight instructor. Again, he observed how flight students handle their fear of heights, the risk of crashing, and the development of flight skills. He found that students were developing mental models of aircraft performance that were at variance with accepted physical laws. These naïve mental models affected the developing flight skills and determined student success in the course. In industry, as manager of technical departments in the rubber industry he observed that many machine operators had developed great skill at producing quality products, without any technical training, by constructing mental models of the structure and processes of their machines. Often the mental models were flawed … but worked! These observations lead to a growing desire to understand how people, students in particular, constructed their knowledge. At the end of the millennium, Mike went to Purdue University to study with George Bodner and found the answer to the question he pondered as a teenager.

Introduction

The Models and Modeling paradigm, as developed by Lesh, Hoover, Hole, Kelly, and Post (2000) and Case, Okamoto, Stephanson, and Bleiker (1996), is a powerful research tool at several levels. As a theoretical framework, it opens a window on the mental activities of participants. As a methodological framework, it provides a method — thought-revealing activities — of inducing people to verbalize what they are thinking about while working on a task or problem. As an analytical framework, it provides a basis for building a deeper understanding of mental activities. In this chapter, I will focus on the characteristics of Models and Modeling that allow it to be used as a theoretical perspective for research in chemistry and science education.
The focus of the Models and Modeling theoretical framework is the construction of knowledge. It is therefore useful in answering questions of the kind, “What are the mental structures and processes students must possess for learning chemistry?” Models and Modeling can be viewed as building on the constructivist theory described in Chapter 2. Because the Models and Modeling framework tries to provide an understanding of the mechanism by which knowledge construction occurs, Lesh and Doerr (2003) based the title of their most recent book on this framework: *Beyond Constructivism*.

The specific implementation of the Models and Modeling perspective discussed in this chapter was developed by Lesh et al. (2000) over a period of 20 years. In an independent research program, Case et al. (1996) developed a similar mental model of learning by studying young children. The Models and Modeling theoretical perspective also grew out of the principles of Action Research (Doerr & Tinto, 2000) as a method to “… simultaneously study and generate knowledge about the very practice that it seeks to change” (p. 408). Moschkovich and Brenner (2000) viewed the paradigm as a coherent research activity in which “… theory and methods are intricately related, mutually constructive, and informing of each other” (p. 459). In order to obtain data on the actual thought processes that learners used to traverse a solution path through a problem, the Models and Modeling paradigm uses thought-revealing or model-elicitng activities (Lesh et al., 2000), which are described below.

**Antecedents of the Models and Modeling Paradigm**

Before the reader can fully understand the Models and Modeling framework, it is important to recognize how the term *model* has been used in science education in recent years. Bodner, Gardner and Briggs (2005) summarized some of the attempts that have been made to describe the characteristics of a model within the context of science education as follows:

- A model is a representation of an idea, object, event, process, or system, which concentrates attention on certain aspects of the system — thus facilitating scientific inquiry.

- Mental models represent significant aspects of our physical and social world, and we manipulate elements of these models when we think, plan, and try to explain events in that world.

- A model relates to a target system or phenomenon with which we have a common experience or set of experiences.

- Models are mental entities that people construct with which they reason; all of our knowledge of the world therefore depends on our ability to construct models of it.
Scientific models are conceptual systems mapped onto a specific pattern in the structure/behavior of a physical system within certain limits of reliability. (p.68)

The origins of the concept of mental models trace back at least 2500 years, to Plato’s allegory of prisoners in a cave who obtain all of their information about the world from shadows cast on the wall of the cave (Plato, 1952). In this allegory, Plato alludes to the construction of mental models as representations of real world objects. The prisoners’ activities are similar to our own activities when we muse about chairs we saw the day before. We do not carry chairs around in our heads but rather mental models of chairs, which we use in our thinking about chairs.

A modern view of the concept of mental models was proposed by Johnson-Laird:

We seem to perceive the world directly, not a representation of it. Yet this phenomenology is illusory: what we perceive depends on both what is in the world and what is in our heads—on what evolution has “wired” into our nervous systems and what we know as a result of experience. The limits of our models are the limits of our world. (Johnson–Laird, 1989, p. 471)

The Constituents of the Models and Modeling Framework

One of the outcomes of a study of middle-school students’ use of mathematics to solve problems was the recognition of the five constituents of a mental model (Lesh et al., 2000). The first constituent is the referents of the model, the semiotic symbols used to represent the object. Referents can be either physical or mental objects, such as an equation, the number one, the sign used to represent addition, an atom or compound, a chair or a puff of air, or even emotions and intentions. Referents also include the symbols used to refer to the object such as names, written symbols, or graphic representations. The referents are the “elements” from which mental models are constructed.

The second constituent of a mental model is the relationships between or among referents. One relationship might be physical location. Another might be cause and effect. A third relationship might be host and symbiont. A fourth relationship might be as multiplier to multiplicand. As illustrated by these examples there are many other relationships that mental models can represent.

The third constituent is a set of rules or syntax. The rules dictate the relationship that referents must have in order for the relationship between them to have meaning. In mathematics, for example, $2 + 3 = 5$ has meaning but $+2 = 35$ does not. In origami, one must make the folds in a specific order to obtain the desired outcome.

The fourth constituent is results. This constituent permits one to derive new knowledge from experience and mental activity. Results might be the answer to a mathematical equation, the products of a chemical reaction, or the genetic instantiation of prodigy.
The first four constituents are static in nature. The fifth constituent – *operation*, which acts on referents using relations and rules to produce results – is considered a dynamic constituent of a mental model. Examples of an operation might be the mental rotation of a molecule, mentally calculating the point of impact of an object shot into the air, balancing on a balance bar, and harmonizing with another singer. We cannot offer direct explanations for these activities. For this reason, it seems that the operation constituent of a mental model is knowledge located in an unheeded area of the mind. This use of the word unheeded follows from, “… we know more than we can tell” (Polanyi, 1983, p. 5). This is tacit knowledge that we possess but which we can not express directly.

As an example of the five constituents of a mental model, consider the mental rotation of the three-dimensional structure of an organic molecule. The referents are the atoms, bonds, colors, sizes, lengths, positions, angles, orientation, sequence, charges, properties, energy, and the molecule. Relations are left or right of a referent, above or below a referent, in front of or behind a referent, and the number of bonded neighbors. Other relations are angle with respect to another referent; position order in the chain or branch; and singly or doubly bonded. Some rules/syntax of rotation might be conservation of position, conservation of number of atoms, conservation of sequence, and conservation of atom identify. The operation is rotation. The results might be a mirror reflection of a molecule; a representation of the back side of the molecule; or a different orientation in space.

**A Second Conceptual Basis for the Models and Modeling Perspective**

The work of Case et al. (1996) provides another basis for a Models and Modeling framework. The objective of Case’s work was the elaboration of the mental structures and processes that accounted for cognitive maturation of children. Case argued that mental models can be either local or global. Local mental models are constructed as needed and discarded after use, to be reconstructed if needed later; global models are maintained for a relatively longer time. One uses global models in situations that require benefit of experience while local models are usually invoked in situations that are algorithmic in nature (Briggs, 2004). Many circumstances require the cooperative use of both kinds of mental models such as braking to a stop after determining how far away is the other vehicle.

Whereas Lesh’s “mental model” is composed of cognitive elements and operations that are distributed over heeded local and global cognitive sub-models, Case’s approach allows us to deal with unheeded central conceptual structures and a central executive structure conceived of as controlling mental processes and decision-making. The two types of structures interact to produce new knowledge and facilitate the use of existing knowledge.
Chapter 4: Models and Modeling

Theoretical Framework

A useful theoretical framework places its assumptions in view for practitioners (Crotty, 1998). Models and modeling has a set of assumptions that gives it a unique perspective on research activities. The ontological assumptions are that a real world exists outside of one’s mind and one can know about that world by using the senses to gather information. Another assumption is that participants can articulate and think about their heeded thoughts and that both participants and researchers can infer, from the heeded thoughts, artifacts, and actions, a participant’s unheeded thoughts. Kant (1952) argued that one can never know a thing in itself, that is, one can never know the true nature of something because one always views the thing through the filters of senses and experience. For example, if a participant says, “I think this looks like a mirror image of the molecule.” and draws a correct artifact, one can infer that the participant has a working mental model of the reflection of light between an object and its mirror image. For this reason the researcher has to be aware of her or his assumptions and make them available for evaluation by the readers of the reported research. This allows the readers to determine if the conclusions of the research project are warranted.

In the realm of epistemology, Models and Modeling assumes that “knowledge is constructed in the mind of the learner” (Bodner, 1986, p. 873). If people have mental models then they must have constructed them from sensual and experiential information (Halloun, 1996). Another implication is relativity, or the possibility of constructing various mental models for the same concept (Starver, 1998), which explains the existence of preconceptions, misconceptions, and alternative conceptions, which exist side by side with domain-acceptable mental models.

One set of research questions is particularly amenable to the Models and Modeling paradigm. In qualitative research, one can take several perspectives. In a first-order perspective one might ask, “What is the world like?” A second-order perspective asks, "What is your experience of the world?” A third-order perspective asks, "What is your conceptualization of your experience of the world?” It is this third-order perspective and question for which both Models and Modeling and phenomenography (see Chapter 8) are particularly suited.

Thought-Revealing or Model-Eliciting Activities

The Models and Modeling paradigm makes extensive use of thought-revealing or model-eliciting activities (Lesh et al., 2000). This technique consists of creating carefully designed cognitive environments in which a participant must solve a problem by constructing a mental model of the problem, the solution path, and an outcome or result. A list of questions has been generated that a researcher might ask when designing a thought-revealing activity (Briggs, 2002, adopted from Lesh et al., 2000):
Does the task put participants in a situation where they recognize the need to develop a mental model? To assure that the thought (model) eliciting activity puts the participant into this type of situation the researcher must pilot the task design and determine if the data stream will produce acceptable answers to the research questions. The piloting of the task will also contribute to confidence in the answers to the following questions.

- Is the problem fruitful, intelligible, and plausible?
- Does the problem statement strongly suggest appropriate criteria for assessing the usefulness of alternative solutions?
- Will the participants know when they are finished with the problem?
- Does the thought-revealing activity require participants to reveal explicitly how they are thinking about the situation by revealing the solution path they took?
- Does the problem provide a way of thinking that is shareable, transportable, easily modifiable, and reusable?
- Does the solution provide a useful prototype, metaphor or tool for interpreting other situations?

Other questions that should be considered in the design of a thought-revealing activity would include the following:

- Have instructions been made clear and do they solicit a clear outcome or result?
- Are all of the constraints of the problem explained clearly?
- Have confounding effects been considered? Have the identified confounding effects been eliminated or randomized throughout the research project.

Figure 1 is a representation of one molecule used in a thought-revealing activity by participants in a research project focused on mental molecular rotation.
Figure 1. One of the drawings used as a thought-revealing activity of mental molecular rotation.

During the design of the molecule to be used in this thought-revealing activity, careful attention was paid to eliminating as many confounding principles as possible. For example, the molecule was placed with its long axis along the horizontal midline of the page. This was done to eliminate problems with visualization of the molecule that might be confounded with the ability to rotate the molecule from the starting position, shown in the figure to the required terminal position. Failure to visualize the molecule properly and transform the printed image into a mental image would preclude proper mental rotation of the molecule. For example, to assure that participants could transform the printed image into a mental image of the molecule, the coordinate system in the figure was aligned with the vertical and horizontal axis. Clues about perspective were incorporated into the figure to aid visualization and the production of a correct mental representation of the molecule. I wanted to avoid the situation in which a participant failed to rotate the molecule correctly because of a problem with their ability to recognize the spatial orientation of atoms in the molecule. In the figure used in the research project, the atoms were color-coded in standard chemistry colors to help participants keep track of the atoms as they were rotated. The molecule is composed of nine atoms to keep the cognitive load within the range of all of the participants. My research has shown that novice rotators try to keep track of each atom in a molecule as they rotate it. To ensure that participants could mentally rotate the molecule successfully I kept the total number of atoms to 30 or less. Each of these criteria was implemented to assure that the participants could recognize the need to rotate the molecule in some way and could talk about it while accomplishing the task.

Only after piloting the thought-revealing activity was I able to answer the list of questions mentioned above. The design of the task proved to be successful in that every participant in the mental molecular rotation project was able to see the need to represent the molecule mentally and rotate it to the required terminal position. The participants developed specific solutions to the tasks and were able to talk about their strategies, barriers, and techniques used to achieve the required terminal position of the
molecules. The most important question seemed to be, “Does the thought-revealing activity require participants to explicitly reveal the solution path they took?” The participants did reveal their thoughts and this aspect of the task was vital to obtaining a fruitful, intelligible, and useful stream of data. The questions in the list assured that the thought-revealing activity design provided a successful data collection phase for the research project.

The Models and Modeling paradigm also requires a technique for capturing the conceptualizations of the participant. These conceptualizations are usually verbal in nature but can also encompass artifacts, computer key-strokes, and body gestures. For these kinds of data streams one might use video, field notes, and audio recordings.

A fruitful technique for assuring a useful data stream of participant conceptualizations is the think–aloud Protocol (Simon & Ericsson, 1993). This protocol is an interviewing technique in which the researcher introduces the thought-revealing activity and instructs the participant to talk continuously, during the activity, about the problem, the strategies for reaching a result, the solution path, any barriers to reaching a result, and the nature of the result. In addition, the researcher instructs the participant to talk aloud about ideas and concepts, definitions, and observations about the problem and the desired result. The researcher then transcribes the captured data stream for analysis.

The goal of analysis of data is the creation of new knowledge. Using the text and artifacts as data, the researcher can analyze for construction of models. One method of analysis that is congruent with the models and modeling paradigm is grounded theory (Strauss & Corbin, 1998). In this technique, participant conceptualizations identified in the text as codes are analyzed by, “... differentiation, abstraction, reduction, and comparison of meaning” (Svensson, 1997, p. 171). The codes from the data and artifacts are compared and contrasted in order to elucidate explicit components of the participants’ conceptualizations. The goal of the process is to “understand in a limited number of qualitatively different ways...” (Walsh et al., 1993, p. 1134) the participants’ constructed mental models. The researcher can then use the identified components of the participants’ conceptualizations to construct a representation of the participant’s mental model.

**Examples of Research Using Thought-Revealing/Model-Eliciting Activities**

Most of the examples of research studies using a mental models paradigm come from Math Education. Lesh et al. (2000) described research studies using three different thought-revealing activities: The Sears Catalog Problem, The Softball Problem, and The Million Dollar Problem. As a graduate student at Purdue University, I worked on a research project analyzing another thought-revealing activity, The Summer Jobs Program. Lesh and his graduate students have developed and used more than 20 thought-revealing activities that were implemented in research projects using the models and modeling theoretical framework.
One example of the use of the Models and Modeling framework in chemistry can be found in my work (Briggs, 2004). The primary research question for this study was “What are the structure and processes required in the mind of a participant to mentally rotate molecules?” The experimental design was a cross-case study of participants who were learning to mentally rotate molecules. Nine molecules were chosen as rotational tasks in the study. The molecules were printed as two-dimensional representations of the three-dimensional structures of these organic compounds. The task molecules were graded in difficulty by changing the number of atoms, the amount of branching, and the identity of the atoms. The tasks consisted of asking the participants to rotate the molecules along various axes and in combinations of axes.

Participants were drawn from two semesters of an organic chemistry course taught at Purdue University. Participants were invited to join the research study and were not given any compensation. Each student that applied for entry into the study was given the Purdue Visualization of Rotations Test (Bodner & Guay, 1997) because visualization is an important prerequisite for mental modeling, as has been addressed by Briggs and Bodner (2005). Five volunteers demonstrated sufficient ability to mentally rotate objects to participate in the study.

Each participant was interviewed three times over a 15-week period (one semester). Each interview took about 50 minutes and produced a ten-page transcript, on average. Each interview consisted of two tasks; each task asked for rotation of one of the molecules.

Twelve transcripts were obtained for analysis. Two interviews were not recorded due to equipment malfunctions, and one participant could not perform the requested rotation of a difficult molecule. The transcripts were treated individually, as a participant set, and as a study set (all participants, and all transcripts). In the following analysis, the set of transcripts from the study are summarized. During multiple passes through the transcripts, 140 codes were assigned to conceptualizations by the participants. During the analysis 34 unique codes were obtained by differentiation, abstraction, reduction, and comparison. The subjects (conceptualizations) of participants’ mental actions that had the same referent were grouped, and the name of the code was modified to indicate the nature of the referent. Participants are labeled R, C, O, and J. The three most frequently occurring codes are listed with the frequency (in parentheses), a definition, and a vignette from the transcripts.

*Mental tool* (79)

A constructed model used to visualize a referent.

A model used to operate on a referent.

O: OK, that’s about as good as my brain is going to get it. One thing I noticed that I found myself doing at the end was for a lot of these hydrogens and a couple of the carbons that I was working on, on
the carbon chain, was thinking about the whole right side and actually gripping that oxygen bond, as if it were a stick figure, and then just feeling out, as I rotated, where that other atom was going to come. You see what I am saying?

I: Yes.
O: It would be almost as if I were turning the whole molecule physically in my mind. I was just sort of … and I would grip that other one [atom] in my other hand and it would just have to follow.  
(This model was labeled the “crank—shaft model”.)

**Modeling** (151)

Mental activity required to produce a representation.

The model contains cognitive elements, operands, and operations which reduce the complexity or increase the comprehensibility of the referent.

J: (Constructs a model of a reflection in a mirror.) … this is also kind of like a mirror reflection of what you are going to see on the other side … .
C: (Also constructs the mirror model.) I would imagine just flipping it over, based on a mirror.  
(This mental model was labeled the "mirror model").

**Representation** (175)

A change of structure from one medium to another.
Re-presentation of a referent in a new medium: such as a molecule drawn on paper or a physical molecular model or a mental image of a paper image.

The physical or mental model of a referent that can be transported from one place to another without moving the referent.

O: I’m finding that I’m using the triangle bonds which show coming out at me more [the symbols in the drawing] from my … I guess the way you show a bond going into the page. … mine are not very artistic so it’s a little difficult to see ….  
R: Then this carbon (carbon number one in the task statement) has three hydrogens attached. And those will be in a tetrahedral shape so I can just draw them in (on the drawn artifact).  
(This code was assigned to relations and any methods of indicating the relation in a transformation from mental image to paper drawing.)

The objective of the code analysis was to unfold the referents, relations, results, rules/syntax, and operations which composed a mental model of mental molecular rotation. The outcome was a mental model of the way participants learned to mentally
rotate molecular models. These results are consistent with our belief that the Models and Modeling paradigm can be used as an explanatory metaphor for learning.

**Implications of Using a Models and Modeling Theoretical Framework**

As noted previously, the Models and Modeling framework is useful for answering questions such as: “What are the mental structures and processes that allow ...?” that are not amenable to quantitative research methods. Individuals who have struggled with computer software often conclude that “ease of use” and “power” seem to be mutually exclusive characteristics. In some ways, qualitative researchers experience the same phenomenon; their methodology is powerful but it is also labor intensive. The design phase of a research project must carefully consider the research questions and match them with the theoretical framework that is the most coherent and powerful. For the Models and Modeling paradigm to be successful, the thought-revealing activities that serve as its foundation must be carefully designed to produce clear conceptualizations. The participants should be chosen from a population that is currently learning the subject of the research project because as Minsky (1986), has said, “An idea will seem self-evident — once you’ve forgotten learning it!” (p. 128).

Because the Models and Modeling paradigm seeks to know how participants construct their mental models, the most effective time to interview them is during the process of model construction. The interview process must give the participant time to think, and iterative interviews are required to capture the construction process over time. The data stream must be captured and transformed into a text for analysis. The analysis requires multiple passes through the text searching for concepts that form the constituents of a mental model. The mental model must be assembled and then confirmed. Only after one performs each of these steps in the research can the mental model be obtained.

Despite the labor-intensive nature of this theoretical framework, it is useful for the class of research questions dealing with learning and knowledge construction. The use of this framework opens a window of research into knowledge, behavior, emotions, intentions, and opinions, but it may not be able to address questions of the structure and functions of the brain. Questions in chemical education that seek to illuminate how students learn and how instructors and teachers can facilitate learning are in the domain of models and modeling. For example, when we understand students’ learning processes, we are in a better position to teach students. As we discover the constituents of domain-specific mental models, we can facilitate students’ learning by showing them the mental materials, the referents, relations, rules/syntax, results, and operations that they can use to build mental models. Chemists have abundant theoretical and methodological frameworks for seeking the answer to questions such as which substituent is more effective in increasing the enantiomeric yield in an organic synthesis, Models and Modeling can provide answers to questions that deal with how a learner conceptualizes a substituent, the structure and properties of a molecule, and its reactions.

The models and modeling theoretical framework provides an explanatory metaphor of learning. It seems to be the best available description of the way students construct
knowledge and can provide an evolutionary advance in our the knowledge of the thought processes of our students, which gives us a deeper understanding of mental activity and structure that is useful in teaching and learning. Results obtained from use of the Models and Modeling framework are compatible with many educational methods such as process-oriented guided inquiry learning (POGIL), discovery learning, inquiry learning, distance learning, and other models of instruction and learning. The framework can also inform instruction from lesson planning to curriculum design.

A theoretical framework is only as useful as its ability to explain a phenomenon and to predict future phenomena. The models and modeling theoretical framework has shown that it is capable of explaining the mental structure and processes required to rotate mentally a molecule. One last task is to show that the Models and Modeling paradigm can also predict the success or failure to rotate mentally a molecule and explain why such a prediction might be trustworthy. The process of transforming a representation, the dynamic operation, gives the paradigm the ability to predict outcomes of molecular rotation. If a participant has difficulty transforming a physical representation of a molecule into a mental representation of the molecule then no processing can take place and no result is possible. In this case, the participant must work on obtaining the static constituents of a mental model and using them to build a representation of the molecule.

If the participant can transform a physical model into a mental image but cannot operate on it properly, then a physical artifact might be drawn but would be incorrect. Another possibility is that the transformed, mentally rotated, molecule might be correct but the participant may not be able to draw the artifact due to lack of drawing ability. In this case a crude artifact might be produced that is essentially correct. Inspection of the artifact can determine which is the case.

If a participant can transform a physical artifact into a mental image and operate on the mental image correctly and then can produce a correctly transformed, that is, rotated artifact, then one can say the participant has a complete and working mental model of mental molecular rotation. In each case presented the instructor can determine the state of the mental model and facilitate the construction of the missing or immature constituents.

References


Pedagogical Content Knowledge

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Biography

Matthew Miller is an Assistant Professor of Chemistry & Biochemistry at South Dakota State University, Brookings. He studied chemistry at the University of South Dakota, receiving a bachelor’s degree in chemistry education in 1985. Later that year, he accepted a teaching position at Southwestern Wisconsin Community Schools in Hazel Green where he taught AP chemistry, introductory chemistry, physics, and physical science. In addition, he found time for coaching football, basketball, softball, and forensics (prose and poetry reading, play acting, group interpretive reading, oratory, etc.). Nine years later he enrolled in graduate school at Purdue University to study analytical chemistry and chemical education, completing a degree in those fields in 1998 and 2001, respectively. His dissertation study, under the direction of Mary Nakhleh, involved case studies of pre-service teachers and their struggle to construct pedagogical content knowledge while enrolled in the physical science methods course. In 2001, he accepted the faculty position at South Dakota State University where he continues to pursue his research interest in chemical education, specifically secondary science education. He currently teaches an introductory honors/majors chemistry course and the secondary education physical science methods course.

Introduction

Pedagogical content knowledge (PCK) was first described by Lee Shulman as a form of knowledge which connects a “teacher’s cognitive understanding of subject matter content and the relationships between such understanding and the instruction teachers provide for students” (Shulman, 1986a, p. 25). Although not considered among the traditional frameworks for research in education, PCK offers a new perspective on research within the area of teacher education. As described by Patton (1990):

The social and behavioral sciences have evolved into disciplines by focusing over time on different core questions. Those differences in focus have implications for the kinds of questions a particular researcher will ask and the scholarly tradition within which a specific study is placed. (p. 66)
PCK has provided researchers interested in studying teacher expertise with “... a new analytical frame for organizing and collecting data on teacher cognition” (Gess-Newsome, 1999a, p. 10). PCK allows researchers to focus on specific questions regarding teachers’ knowledge and on appropriate methodology for answering those questions. PCK, therefore, can be considered a useful theoretical framework for qualitative research.

**History of Pedagogical Content Knowledge**

During the final decades of the 20th century, educators and politicians were engaged in an intense debate on science education in the United States. Many reports were issued describing the status of American schools, including reports from the National Commission on Excellence in Education (1983a, 1983b); the Carnegie Forum on Education and the Economy, Task Force on Teaching as a Profession (1986); the Holmes Group (1986); and the Southern Regional Education Board (1985). Each report specifically pointed toward the competency of teacher education programs as a potential reason for poor results in science education. Of particular concern was the limited amount of time spent on content knowledge during teacher preparation programs. The creation of standardized exams to assess teachers' content and pedagogical knowledge, mandated through the No Child Left Behind Act (2002), has tried to address these issues. However, some argue that creating standardized exams to assess teacher content and pedagogical knowledge does not measure the most important form of teacher knowledge. This type of knowledge, PCK, is a category of knowledge specifically constructed by teachers, yet distinctly different for each specific content area.

The initial model of PCK was developed and supported by studies related to a research project entitled “Knowledge Growth in a Profession” (Shulman, 1987; Wilson, Shulman, & Richert, 1987; Shulman, 1986b). Findings from this work labeled PCK as the specific teacher knowledge that allowed a teacher to transform content knowledge into a more conceptually understandable version for students. As explained by Shulman (1987), PCK results from the blending of content knowledge with pedagogical methods. Through this combination of knowledge, teachers gain a perspective that enhances their abilities to present specific topics in a specific subject area. Later it was proposed that teachers construct PCK not only by combining content and pedagogy, but also by combining these two knowledge categories with curricular, student, and contextual knowledge. The various forms or categories of teacher knowledge are summarized in Table 1.

**Table 1. Categories of Teacher Knowledge.**

<table>
<thead>
<tr>
<th>Knowledge Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedagogical</td>
<td>Encompasses the general knowledge, beliefs, and skills about methods for teaching (Grossman, 1990).</td>
</tr>
<tr>
<td><strong>Content</strong></td>
<td>The facts, concepts, principles, and procedures taught about a respective subject (Gess-Newsome, 1999b).</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Curricular</strong></td>
<td>Understanding how particular concepts fit into the grade level at which it is taught (Grossman, 1990).</td>
</tr>
<tr>
<td><strong>Student</strong></td>
<td>The prior knowledge of students and how students will most likely enhance or change that knowledge (Grossman, 1990).</td>
</tr>
<tr>
<td><strong>Contextual</strong></td>
<td>Specific knowledge that is unique to the learning setting (Grossman, 1990).</td>
</tr>
<tr>
<td><strong>PCK</strong></td>
<td>An amalgam of content and pedagogy unique to a subject matter teacher. The blending of content and pedagogy into an understanding that allows the teacher to more thoroughly understand how to present a topic (Shulman, 1987).</td>
</tr>
</tbody>
</table>

Continued research in the area of teacher knowledge suggested that the acquisition of PCK was essential for teachers to provide proper instruction and improve conceptual learning by students (Gudmundsdottir & Shulman, 1987). Case studies showed that differences between novice- and expert-teachers’ level of PCK resulted in differences in the quality of student learning. Additionally, PCK allowed teachers to conceptualize their own specific content knowledge and transform it into a form understandable to students (Gudmundsdottir, 1991). Effective teaching appeared to be linked to the quality of teachers’ PCK.

The acquisition of PCK by teachers was considered critical because teachers were responsible for making concepts meaningful to students (Grossman, 1990). According to Grossman, this acquisition of PCK could result from a variety of experiences during the overall career of a teacher. PCK construction might occur during apprenticeship of observation activities (student teaching/internships), disciplinary background instruction (content courses), experiential learning (in the classroom), or professional coursework (education courses).

A slightly different view of PCK was developed by Cochran, DeRuiter, and King (1993). These researchers believed that the word knowledge in PCK was too static for the constructivist perspective. PCK should be thought of as a versatile form of knowledge which required continual change to meet the needs of students. Shulman’s view of PCK inferred a stagnant production of knowledge that, once constructed, did not change. To establish the point that PCK was a continually changing construction of knowledge, these researchers replaced the word knowledge in PCK with knowing because PCK required active involvement of this knowledge in a continually changing classroom environment. Stengel (1997) provided support for this alternative view. According to Stengel, the concept of PCK is less effective if teachers forget that knowledge is constructed through active learning. If teachers become satisfied with their current knowledge and stagnant with respect to continuing education, their teaching knowledge
will become less effective. PCK must be thought of as an ongoing, ever-changing entity that is only maintained through continuous activity.

This changeable nature of PCK makes it difficult to pinpoint specific constructs of this category of knowledge. Teachers, as learners, construct their own knowledge, resulting in many individual examples of PCK. Additionally, because of the numerous categories of knowledge that may be integrated into PCK, differences in PCK constructs between instructors will likely exist. Finally, as described by Stengel (1997), PCK results from active learning, allowing PCK to change to fit the needs of individual instructors.

Assumptions of Pedagogical Content Knowledge

PCK as a Category of Knowledge

Several assumptions are made when considering pedagogical content knowledge as a category of knowledge. First, it is assumed that teachers become experts in a specific subject area through construction of specific knowledge that informs them of superior teaching methods for that subject, ultimately assuming that a particular method of teaching is more effective toward teaching a specific topic. Second, researchers assume instruments can be devised to identify and measure PCK. Third, it is assumed that PCK can be shared with other science educators for use in their classrooms. Finally, it is assumed that articulations by teachers about beliefs and knowledge mirror teacher practice in the classroom. In this section, I will examine the validity of these assumptions.

Before exploring these assumptions, however, it may be helpful to provide several examples of teacher PCK. One example of PCK is taken from a study by Coll and Treagust (2002). In this work, student explanations of covalent bonding were elicited. The data showed that students at all levels, secondary through graduate students, rely on relatively simplistic mental models to explain covalent bonding. A comparison of curricula across these levels showed that a number of bonding models were used by instructors to teach covalent bonding, yet students continued to use the octet rule as a basis for explanation rather than using more robust models. The authors therefore suggested that teachers carefully analyze their curricula and utilize models that will provide students with information they will most likely use to explain concepts. At the secondary level, it would be most beneficial to focus on the principles of the octet rule because students at this level generally fail to utilize the more complex theories in their explanations, even when these models are presented by instructors. At the undergraduate and graduate levels, valence bond, molecular orbital, and ligand field theories should be introduced to increase the complexity of student understanding of covalent bonding. This is an example of PCK because content knowledge, pedagogy, and curricular knowledge are integrated into a concept about teaching covalent bonding.

The work of Frykholm and Glasson (2005) provides another example of PCK because it shows the integration of pedagogical knowledge with content knowledge across several
content areas, specifically biology and mathematics. A student teacher monitored during the study stated:

I presented a way that the students could predict how many incubation periods it would take for every student in the room to get infected. I thought this would be a good way for students to see how scientists use mathematical models to predict the spread of disease. (Frykholm & Glasson, 2005, p. 136)

From these two examples, we can observe the nature of PCK. Concepts from different categories of knowledge are combined to create a teaching concept that more effectively promotes student learning.

PCK has been identified as teacher knowledge that empowers teachers to help students construct appropriate content knowledge. Yet, our first assumption is that identifying PCK will yield knowledge about how to teach specific concepts to all instructors. For example, in drawing the conclusion in the PCK example presented by Coll and Treagust (2002), we assume using the octet rule exclusively in the secondary level represents the best approach for teaching secondary students. But if PCK is a personal transformation of knowledge into a form that best enables students to learn, then PCK will have different configurations for individual instructors, and generalizations such as those from the example above may not work best for all instructors.

A second assumption is that identifying and measuring teachers’ PCK can be accomplished using instruments designed for such purposes. The methodology currently used to measure PCK generally requires teacher articulation of personal beliefs about teaching during multiple experiences. For example, in a study by Miller (2001), changes in pre-service teacher PCK were monitored through using concept maps, interviews, journaling, and other classroom writing activities. The concept maps were used to identify changes in content pedagogical knowledge during a physical science methods course while the interview, journaling, and assorted classroom writing were used to elucidate reasons for changes in content and pedagogical knowledge. PCK was identified by analyzing the statements of pre-service teachers as they discussed changes made on concept maps. In a study by Van Driel and Verloop (2002), semi-structured interviews identified teacher knowledge with respect to models and modeling in science. Information from the interviews was used to construct questions for a Likert-type survey designed to reveal perceptions regarding teaching activities, student knowledge, and modeling. Yet, due to the nebulous nature of PCK, using multiple methods to identify PCK may not successfully accomplish the goal of identifying and measuring PCK. For this reason, no specific measures are available for identifying or quantifying PCK.

A third assumption regarding PCK as a category of knowledge is the ability to share PCK between educators. Instructors construct their own personal PCK, but the ability to embrace examples of PCK from others through continuing education opportunities may not be a practical process. The personal nature of PCK construction would suggest that PCK constructed by one instructor may not be designed for use by another.
Finally, do teachers’ beliefs and knowledge actually influence classroom practice? It is assumed that what the teacher believes and knows about teaching automatically becomes utilized in the classroom. Yet, many teachers quote constructivist ideas but fail to support those ideas with constructivist methods. Therefore, the assumption that teacher articulations of beliefs and knowledge represent actual teacher practice is questionable.

**PCK as a Theoretical Framework**

The use of PCK as a theoretical framework is based on a series of assumptions:

- PCK represents a category of teacher knowledge that is the essence of an expert teacher.
- PCK provides a framework that can be used to describe the origin of this critical teacher knowledge, i.e., that PCK represents an epistemological approach to constructing teaching knowledge.
- PCK is a constructivist process and therefore a continually changing body of knowledge.

It is now a widely accepted belief that PCK represents the essential knowledge needed for a novice teacher to mature into an expert. Shulman’s (1987) vision of teacher knowledge as an “amalgam” of knowledge has focused many teacher education programs on creating new activities that engage pre-service teachers. This same vision also provides a focus for educational research. Unfortunately, PCK remains a nebulous category of knowledge that is difficult to isolate and study.

PCK provides researchers with a starting point for collecting and analyzing data regarding teacher knowledge. It embodies an epistemological approach to understanding teacher knowledge because it articulates the central components of that knowledge, laying a pathway to find improved methods for teacher preparation. Through continuing PCK research, researchers may soon outline methods teachers may use to construct important teaching concepts.

Finally, as a constructivist endeavor, PCK is a continuously changing unit. Researchers must be aware of the sinuous nature of PCK, being careful not to influence teacher knowledge during data collection methods. The ever-changing nature of PCK challenges the researcher to consider longitudinal methods to determine the impact of experience on PCK.

**Methodologies/Analysis of Research on PCK**

The use of PCK in research and the methods of data collection and analysis that result will be separated into two components: research on PCK and research using PCK as a theoretical framework. The basic difference between these distinctions is the first
involves trying to identify or measure PCK while the second utilizes the assumption that PCK exists to examine other aspects of teaching science.

Research on PCK

Many studies have been conducted to identify aspects of PCK. A few examples of PCK studies are shown in Table 2. Current research on PCK involves the use of methodologies in one of three classifications: 1) convergent and inferential techniques; 2) visualization techniques; and 3) multi-method evaluation (Baxter & Lederman, 1999). These techniques have been used to identify PCK constructs, how these constructs were constructed by teachers, and how these constructs influence student learning in the classroom. In the following sections, each of these classifications will be discussed using examples and criticisms to illustrate differences between them.

Table 2. Examples of PCK Studies in Chemistry/Science Education

<table>
<thead>
<tr>
<th>References</th>
<th>Research Questions/Purposes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basista &amp; Mathews, 2002</td>
<td>How do integrated science and mathematics professional development programs enhance teachers’ content and pedagogical knowledge?</td>
</tr>
<tr>
<td>Carpenter, Fennema, &amp; Franke, 1996</td>
<td>How does understanding students’ thinking connect teachers’ PCK to subject matter, curriculum, and pedagogy?</td>
</tr>
<tr>
<td>Clermont, Krajcik, &amp; Borko, 1993</td>
<td>How do intensive chemical demonstration workshops impact novice teacher PCK?</td>
</tr>
<tr>
<td>De Jong, Ahtee, Goodwin, Hatzinikita, &amp; Koulaidis, 1999</td>
<td>What PCK do pre-service science teachers have regarding the teaching of combustion?</td>
</tr>
<tr>
<td>Fernandez-Balboa &amp; Stiehl, 1995</td>
<td>How do professors transcend their status from “subject matter knowers” to “subject matter teachers”?</td>
</tr>
<tr>
<td>Frederik, Van Der Valk, Leite, &amp; Thoren, 1999</td>
<td>What conceptual difficulties about temperature and heat do pre-service teachers have and what difficulties do they expect their students to have?</td>
</tr>
<tr>
<td>Frykholm &amp; Glasson, 2005</td>
<td>What are pre-service science and mathematics teachers’ perceptions of their content and PCK with respect to connecting science and mathematics instruction?</td>
</tr>
<tr>
<td>Grayson, 2004</td>
<td>How does concept substitution enable teachers’ to identify student difficulties?</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Question</td>
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<td>---------------------------------</td>
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<tr>
<td>Halim &amp; Meerah, 2002</td>
<td>What is science trainee teachers’ awareness of pupils’ likely misconceptions and how do these teachers suggest explaining scientific ideas to pupils?</td>
</tr>
<tr>
<td>Irving, Dickson, &amp; Keyser, 1999</td>
<td>How do professional development courses enhance secondary teachers’ content and pedagogical knowledge?</td>
</tr>
<tr>
<td>Lowery, 2002</td>
<td>How do pre-service teachers construct PCK of elementary mathematics and science and what is the extent of that knowledge construction?</td>
</tr>
<tr>
<td>Major &amp; Palmer, 2002</td>
<td>To what extent does college faculty think about student learning?</td>
</tr>
<tr>
<td>Margerum-Leys &amp; Marx, 2004</td>
<td>How is knowledge of educational technology acquired, employed, and shared by the participants?</td>
</tr>
<tr>
<td>Penso, 2002</td>
<td>How and to what extent does a teaching practice in schools contribute to the acquisition and growth of PCK?</td>
</tr>
<tr>
<td>Sweeney, 2003</td>
<td>What are the articulated personal practice theories of a beginning high school chemistry teacher?</td>
</tr>
<tr>
<td>Thiele &amp; Tregust, 1994</td>
<td>Why did teachers choose to use analogies in chemistry and what variations between teachers existed?</td>
</tr>
<tr>
<td>Tregust &amp; Harrison, 2000</td>
<td>What is the role of explanations in science instruction?</td>
</tr>
<tr>
<td>Twiselton, 2000</td>
<td>What are the knowledge constructions of student teachers and what types of knowledge do they see as important in their teaching?</td>
</tr>
<tr>
<td>Van Der Valk &amp; Broekman, 1999</td>
<td>How does lesson preparation demonstrate PCK?</td>
</tr>
<tr>
<td>Van Driel &amp; Verloop, 2002</td>
<td>What is experienced science teachers’ knowledge of teaching and learning models in science?</td>
</tr>
<tr>
<td>Veal, 2004</td>
<td>What is the relationship between chemistry teachers’ beliefs in teaching and PCK?</td>
</tr>
<tr>
<td>Viiri, 2003</td>
<td>How well do teachers’ know their students’ conceptions of moments of force?</td>
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</table>
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Convergent and Inferential Techniques

Convergent and inferential methods involve the use of pre-determined verbal descriptions of teacher knowledge categorized as PCK. These descriptions are organized in the form of Likert-scale surveys or pre-/post-assessment, multiple-choice/short-answer tasks to assess teacher recognition of pre-described PCK. Data are analyzed to assess the level of awareness teachers have with respect to pre-described knowledge. Comparisons between teachers exhibiting or not exhibiting PCK can then be made to assess the importance of acquired PCK on student learning.

Examples of the use of convergent and inferential methods can be used to further explain this methodology. Viiri (2003) used a short-answer questionnaire to assess student knowledge of moments of force. The questionnaire was constructed from prior research regarding difficult concepts for students studying moments of force (Rowlands, Graham, & Berry, 1998). Experienced teachers were given the same questions and asked to predict their students’ answers and provide reasons these answers would be chosen by their students. The students’ answers and teachers’ predictions were compared to assess experienced teachers’ awareness of student difficulties with moments of force. Additionally, teachers were shown student questionnaires and their reactions to students’ answers were observed, providing further evidence of teacher awareness. This study provides an example of identifying PCK because two categories of knowledge — content and student — are being analyzed with respect to what experienced teachers know about how their students will answer specific content questions.

Halim & Meerah (2002) utilized previously-written short-answer questions involving basic concepts in physics, for which there are known misconceptions, to survey pre-service teachers’ PCK. Pre-service teachers were asked to explain the physics concepts as if they were going to address an audience consisting of secondary students. The explanations were written and submitted to the researchers. Since the physics concepts chosen for the survey were known to involve student misconceptions, responses from pre-service teachers provided evidence of trainee teachers’ awareness of these misconceptions. The degree of teacher awareness provided information as to pre-service teacher knowledge of student misconceptions. Therefore, references to known misconceptions were counted as evidence of pre-service teacher PCK because this represents integrating teacher’s knowledge of what students perceive with their specific content knowledge.

A final example of convergent/inferential methods is a study by Basista & Mathews (2002). These researchers used pre- and post-testing to assess content knowledge changes resulting from participation in a workshop. Assessments of teacher knowledge were statistically analyzed to identify changes in teacher content knowledge. Additionally, pre-workshop, post-workshop, and post-teaching Likert-scale/short answer questionnaires were used to determine the impact of the workshop on teacher pedagogy, opinions, and confidence regarding the content knowledge following their participation in the workshop. Statistical analyses of teacher responses were used to
identify connections between the impact of the teacher workshop on content knowledge and change in teacher pedagogical approaches toward teaching the content. In this example, the analysis provided information about how changes in content knowledge influence pedagogical decisions, therefore an example of teacher PCK.

**Criticism of Convergent and Inferential Methods.** Convergent and inferential methods have been criticized for several reasons. First, multiple-choice and short-answer exams designed to measure teacher knowledge assume the existence of a correct answer which is inconsistent with the concept of PCK. It is difficult to justify the “correct” PCK because the correct method of teaching specific content may be based on personal intuition. Therefore, the ability to measure teacher PCK using specific knowledge-based methodology such as multiple-choice or short-answer instruments may be inhibited by an inability to identify the many perspectives that may exist regarding how science concepts are taught (Baxter & Lederman, 1999).

Another criticism of convergent and inferential methods relates to the criterion-related validity of multiple-choice or short-answer exams for teachers. The problem with multiple-choice questions is that they may not be legitimate measure of the specific skill being analyzed by the researcher, thereby resulting in faulty information about teacher knowledge and, in this case, PCK. Questions exist as to the ability of these exams to effectively measure specific skills for teachers (Haertel, 1991). Considering the difficulty in establishing specific examples of PCK, writing questions that meet validity standards would be difficult.

Finally, standardized statements may not accurately depict the perceptions of a teacher regarding personal views about teaching (Kagan, 1990). The construction of these statements requires the transformation of teacher articulations into homogeneous constructs for such exams. The generalization of personal views of teaching makes it difficult to construct examination questions which explicitly match the views of all teachers.

**Visualization Techniques**

Visualization techniques are often used to analyze teacher knowledge, including PCK. Techniques such as drawing concept maps, using vignettes, and constructing analogies are examples of methods that provide illustrations of teacher perspectives. The use of visualization techniques by PCK researchers provides a physical representation of teacher knowledge. These physical representations can then be monitored for changes which may result when teacher knowledge is challenged during various activities and workshops.

Novak and Gowin (1984) have argued that concept maps provide visual representations of an individual’s knowledge. The use of tools such as concept maps allows researchers to create concrete representations of knowledge which can be monitored over time, yielding longitudinal assessments of knowledge changes. Changes in physical representations are assumed to provide evidence of teacher knowledge change.
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Miller (2001) used concept mapping to analyze the construction of pre-service teacher PCK during a science methods course. Teachers were asked to construct a concept map containing terms important to one specific unit in a chemistry course that was the focus of numerous teaching activities throughout the science methods course. The teachers’ concept map was reviewed periodically throughout the next year while the pre-service teacher was enrolled in a second science methods course (in the fall) and in a student teaching practicum (in the spring). Changes in the structure of the concept map were related to changes in the personal knowledge of that student. The researcher analyzed the data to connect these changes in knowledge with activities that may have influenced the changes.

In addition to the concept maps on specific content knowledge, pre-service teachers were also asked to draw concept maps of teaching pedagogy and of student difficulties related to the specific unit. These concept maps represented the teachers’ knowledge of pedagogy and students with respect to the chemistry unit. Changes made to these maps were also connected to activities which may have influenced these changes. Overall, the concept-mapping exercises allowed the researcher to monitor the changes made in pre-service teacher knowledge as a result of experiences during the year in question (Miller, 2001).

The construction of PCK by teachers has also been assessed by using vignettes as visualization techniques. Vignettes are short, descriptive stories specifically written to describe specific activities. Veal (2004) used carefully designed vignettes containing pedagogical issues (classroom management, student learning, teaching styles), inaccurate science content, and questionable teaching methods to provoke conflict in the teachers’ knowledge. A microgenetic method was utilized by the researcher in which participants in the study were exposed to the same stimulus at various times during the study. In this case, teachers were asked to read a vignette and respond to a set of questions at different times during a secondary science curriculum course and during student teaching field experiences. Over the course of a year, the teachers had multiple experiences with the same vignette, allowing the researcher to monitor cognitive conflicts through interview responses, observations, and coursework documentation.

Analogies are another example of visualization techniques that have been used to monitor PCK construction by teachers. Thiele and Treagust (1994) were interested in analyzing how teachers use analogies when teaching content in chemistry, specifically energy, reaction rates, and equilibrium. The researchers observed actual classroom use of analogies, audio-taped their use, and then carefully analyzed each analogy to identify the purpose for the use of the analogy. The analogies provided the researcher with an illustration of the teacher’s knowledge structure regarding the specific content. Analysis of the analogies included categorizing the analogies as to why they were, what evidence of spontaneity existed for their use, and how similar analogies vary across teachers. On the basis of additional data that included observation notes, student work, and teacher materials, assertions were made as to why the analogies were used by teachers. A picture of teacher PCK was then constructed from these assertions.
Card-sort tasks represent another visualization technique used to assess teacher PCK. Gess-Newsome & Lederman (1993) used card-sorts and concept maps to allow teachers to organize their knowledge about teaching their primary content area. Participants were asked "What topics make up your primary teaching content area?" and then asked to use these topics to diagram the content area. Participants were allowed to diagram using a method of personal preference, and card-sort methods were an example of a chosen format. Participants were asked to create the card-sort diagram four times throughout one year. Changes in the structure of the diagram, along with interview data, provided documentation of knowledge changes. Data were analyzed to observe noticeable patterns among all participants.

**Criticism of Visualization Techniques.** Several criticisms can be offered regarding the use of visualization techniques to analyze PCK. First, to what extent can visualization techniques be expected to mirror the structure of knowledge within an individual's mind? The use of concept mapping to assess PCK, for example, assumes that the map constructed by an individual represents the knowledge of that individual with respect to the corresponding content knowledge. Is this technique reliable at representing all that an individual knows with respect to the content knowledge being assessed? Additionally, the use of this visualization tool may also stimulate knowledge growth of the content being studied, so careful analysis of the degree to which this occurs should also be considered (Baxter & Lederman, 1999). In the future, a study might be done that involved careful training of participants with respect to the visualization tool followed by analysis of the degree to which an individual is able to completely diagram their knowledge of a specific subject.

Kagan (1990) voiced criticism concerning the length of time knowledge changes monitored by visualization techniques persist. The techniques discussed in the prior section — concept mapping, vignettes, analogies, and card sorts — typically represent changes in knowledge that occur during the assessment period. Unfortunately, changes in teacher knowledge can be short-lived if not reinforced when teachers return to the classroom, so the visualization techniques might only monitor short-term changes. Additional research is needed to study how long these changes last in the real world of teaching and to develop visualization techniques that might provide assessment of knowledge change over a longer period of time.

A final criticism of visualization representations is that they are ambiguous in nature. Several individuals may construct similar visualizations, yet these visualizations may represent entirely different knowledge constructs (Phillips, 1983). Researchers may be able to address this issue by standardizing representations made while using visualization techniques. However, training participants to use specific representations to describe similar concepts, although helpful in the assessment process, will likely impact the participants' knowledge structure, changing it as the visualization technique is being used to assess that knowledge. In doing so, this assessment technique would now be acting as an intervention causing changes knowledge. This would diminish the effectiveness of the visualization technique as a method of analyzing PCK.
Multi-method Analysis

The most frequently used method of data collection and analysis for PCK research involves collecting multiple sources of data. In addition to visualization and convergent-/inferential methods, interview responses, observations, reflections, and course materials are often analyzed by researchers to establish perspectives on teachers' knowledge structure. Due to the ambiguity discussed regarding visualization methods and the questionable validity of using standardized assessments to identify PCK, triangulation of data sources is useful to validate research conclusions. Examples of the use of multiple methods in PCK studies will be provided in this section.

Large group discussions, small group collaborations, observation notes, written responses to classroom questions, journal entries, group presentations, unit plans, and lesson plans were data sources for a study by Frykholm and Glasson (2005) in which they analyzed the perceptions of pre-service teachers regarding content and PCK construction. Data analysis involved an iterative coding process of each type of data using a core set of themes. Following the coding process, an analysis was conducted to determine any relationships that existed across codes. The multiple layers of data provided opportunities for researchers to identify duplications in participant statements, thereby establishing the validity of the data.

In another example of multiple methods, Van Driel and Verloop (2002) used semi-structured interviews to identify teacher knowledge with respect to models and modeling in science. Information from the interviews was used to construct a Likert-type questionnaire. The interviews provided categories for which specific questionnaire items were constructed. The items were designed to ask teachers about teaching activities and student knowledge with respect to models. The questionnaire was taken by participants in the study at the beginning of an in-service workshop. The teachers' responses to these questionnaires were then analyzed to assess their knowledge of models.

A final example of the use of multiple methods involves using lesson plans, questionnaires, and interviews to identify characteristics of pre-service teachers’ views regarding the teaching of combustion (De Jong et al., 1999). All participants were asked to construct a lesson plan for the first teaching opportunity of combustion in their classroom. Following the planning of their lesson, participants completed an open-ended questionnaire about their expectations of student preconceptions of combustion and why they chose the teaching approach described in the lesson. Finally, pre-service teachers participated in an interview in which they were verbally prompted to explain their lesson, the difficulties they expected students to encounter, and why the particular pedagogical approach was chosen. The analysis of each data set was conducted to categorize responses in pre-determined categories.

Criticism of Multi-method Analysis. The use of multiple methods of data collection to assess teacher PCK can be questioned because of the variety of opportunities provided for teachers to reflect on the construct of particular concern. Each added layer of data
collection provides additional opportunities for the participant to consider what they know about a topic and change that viewpoint. Although additional data sources provide opportunities for triangulation, they also provide opportunities for reflection and knowledge change. Multi-method analysis will likely have an increasingly larger impact on changing knowledge with each added dimension to the project, thereby potentially biasing the findings of the study.

**Using PCK as a Theoretical Framework in Research**

Studies using PCK as a theoretical framework are not as numerous as those seeking to characterize examples of PCK. Several examples are shown in Table 3. A select few will be discussed further in this section.

**Table 3. Examples of research studies using PCK as a theoretical framework.**

<table>
<thead>
<tr>
<th>References</th>
<th>Nature of the Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fottland, 2004</td>
<td>Pre-service teachers need to draw on experiences to connect theory; therefore, narrative of other teachers provide PCK learning opportunities.</td>
</tr>
<tr>
<td>Garcia, 2004</td>
<td>Teacher knowledge known as “desirable content knowledge” (Porlán &amp; Rivero, 1998) consists of a network of metadisciplinary, disciplinary, and experience-based knowledge.</td>
</tr>
<tr>
<td>Halai, N. &amp; Hodson, D. 2004</td>
<td>Teachers construct appropriate learning experience for students by drawing on a wide array of knowledge also referred to as “personal practical knowledge” (Connelly &amp; Clandinin, 1985).</td>
</tr>
<tr>
<td>Hipkins &amp; Barker, 2005</td>
<td>PCK is a form of teacher knowledge which connects complex structures, including knowledge of the nature of science: “NOS PCK” (Abd-El-Khalick &amp; Lederman, 2000).</td>
</tr>
<tr>
<td>Hogan, Rabinowitz, &amp; Craven III, 2003</td>
<td>PCK is useful in analyzing the complex interaction between teachers’ understandings of content and pedagogy and the influence this has on classroom instruction.</td>
</tr>
<tr>
<td>Johnson, 2006</td>
<td>Teachers face three dimensions and barriers — technical, political, and cultural — while engaging in standards-based instructional practices.</td>
</tr>
<tr>
<td>Kreber, 2004</td>
<td>Teachers engage in three types of reflection — content, process, and premise — across three domains of knowledge — instructional, pedagogical, and curricular.</td>
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</tbody>
</table>
Kreber (2004) utilized PCK as a theoretical framework in a study to analyze the degree and type of reflection higher education instructors devote to teaching. The work was based on the belief that reflection on teaching occurred in nine dimensions. These dimensions resulted from instructors’ reflecting on content, process, and premise while considering three domains of knowledge: instructional, pedagogical, and curricular. This nine-dimensional view established the methodology as the researcher conducted an interview in which questioning was intentionally designed to elicit responses in each of these dimensions.

The concept of “desirable content knowledge or DCK,” as initially reported by Porlán & Rivero (1998), was the basic framework of a study by Garcia (2004) to analyze the results of a specific educational strategy in Spain designed to convey a mode of teaching described as a “teacher investigator” to novice teachers. The goal was to engage teachers in activities promoting the teacher as a guide to student learning. This framework specifically identified three categories of knowledge teachers must integrate to construct desirable content knowledge: metadisciplinary, disciplinary, and experience-based knowledge. The methods used in this study included interviews and the collection of course documents to produce a case study for each participant. These methods were a direct implication of the DCK theoretical framework as in-depth data were needed to extract information about teacher knowledge constructed during the educational strategy.

In the final example, Hogan et al. (2003) utilize PCK as a theoretical framework in a meta-analysis study of novice and expert teachers to establish teacher representations of certain aspects of a classroom. In this study, PCK was viewed from a cognitive science perspective as an outline for identifying the basic processes of teacher problem solving. One outcome of the study showed that a major methodology used included three main components: curriculum planning, instruction, and the perception and reflection classroom activities. A general theme appears to be the need for reflective data collection methods to draw out teacher perceptions and identify the basic processes to teacher knowledge construction.

**Conclusion**

PCK is a complex form of teacher knowledge needed by teachers to convey their understanding of specific content knowledge using multiple methods that enhance student understanding and achievement. Much of the research involving PCK has been conducted to identify and characterize PCK, and the teacher education community continues to call for studies to devise methods for measuring PCK. However, PCK represents much more than a category of teacher knowledge; it also provides a starting point for research involving teacher education. As a theoretical framework, PCK provides a process for organizing this important research. The inclusion of PCK in this book on theoretical frameworks is an important step towards increasing its use in this role.
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References


Chapter 5: Pedagogical Content Knowledge


Part

II

HERMENEUTIC FRAMEWORKS
Hermeneutics and the Meaning of Understanding

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Biography

Joseph W. Shane is an Assistant Professor of Chemistry and Science Education at Shippensburg University, one of fourteen state-owned liberal arts schools in Pennsylvania. In addition to teaching general chemistry to both majors and non-majors, he teaches the methods classes for secondary science teacher candidates and serves as their supervisor during student teaching. He received both his Ph.D. in Science Education and M.S. in Chemistry from Purdue University and his B.S. in Chemistry from the University of Delaware. During the eight-year interim between graduate degrees, he taught chemistry at Noblesville High School in Noblesville, Indiana. He feels quite fortunate to have an academic position that allows him to work in both chemistry and science pedagogy. Even though his teaching load is quite heavy, Joe still finds time to continue his research into how teachers implement educational policies in their classrooms.

Introduction and Key Assumptions

As readers will find as they proceed through the various theoretical frameworks described in this book, the “researcher-as-instrument” metaphor drives all phases of qualitative studies. The types of questions that researchers ask, the participants they solicit, the data they collect, and the manner in which they analyze data and communicate results are each affected by their underlying assumptions about what constitutes knowledge and how they conceptualize their roles in the research process. Each theoretical framework uses a unique set of concepts to clarify such assumptions. It is therefore essential to analyze and verbalize, at least to one’s self, the theoretical orientations a researcher brings to a given study. This will increase the significance of the findings by guiding and delimiting the research process and help connect the results of the study to related research.

From the perspective of the theoretical framework known as hermeneutics — the art of understanding — the researcher acts as the voice of the participants by establishing the context of their actions and by communicating both overt and tacit findings in a clear, fair, and comprehensive manner (Gadamer, 2000; Patton, 2002). Although its origins lie
in the interpretation of sacred texts, hermeneutics is commonly used in qualitative research to describe how individuals and groups construct meaning within a given context (Patton, 2002). Some key assumptions of hermeneutics include the following (Gadamer, 1976, 1996, 2000; Patton, 2002):

- Understanding can only occur within specific, historical contexts.
- Understanding is a mediated or dialogic event between the individual doing the interpretation and the object or phenomenon being interpreted.
- Language, both written and oral, is the medium through which understanding occurs.
- Researchers’ personal biases, perceptions, and transformations of understanding are documented and reported throughout the research process.

In this chapter, I briefly outline the history of an intellectual rift that occurred in Western philosophy which led to the development of a particular brand of hermeneutics, philosophical hermeneutics, in the twentieth century. Building on this foundation, I will then outline how hermeneutics can serve as a theoretical orientation in qualitative research and discuss several applications from the chemistry and science education literature and from my own work in science teacher education (Shane, 2005).

Hermeneutics through the Works of Hans-Georg Gadamer

To gain insight into the history and tenets of philosophical hermeneutics, I have chosen three works by Hans-Georg Gadamer, a mid-twentieth century German philosopher from the University of Marburg: *Reason in the Age of Science* (Gadamer, 1996), *Philosophical Hermeneutics* (Gadamer, 1976), and *Truth and Method* (Gadamer, 2000). This is not intended to be a comprehensive treatment of Gadamer’s ideas, but rather an extraction and interpretation of certain concepts necessary to build a sufficient case for the application of hermeneutics to qualitative research. Other interpretations of Gadamer’s ideas can be found in Halliday (2002), Garrison (1996), Stewart (1983), and Brooks (1982), as well as in Moss and Schutz’s (2001) comparison of Gadamer’s philosophical hermeneutics to the discourse ethics of Habermas (1996), a contemporary of Gadamer who is often cited in the critical theory literature.

Gadamer (1996) argued that the original philosophy (*prima philosophia*) of the ancient Greeks did not distinguish between knowledge of the physical, human, and supernatural worlds. Fundamental questions about the nature of existence and how to live permeated all areas. For ancient Greece, and for the millennia that followed, Western philosophy encompassed all domains of epistemology, ethics, aesthetics, and ontology. It is also worth noting the etymology of *hermeneutics* at this point; Hermes was the liaison between Olympus and human society in Greek mythology and, thus, served as a voice for both groups.
The onset of the seventeenth-century European Enlightenment, with its emphasis on rationality and universal scientific methods, fundamentally altered how Western society viewed philosophy. Gadamer (1996) claimed that an intellectual rift developed as science broke away from and eventually overtook philosophy as the dominant framework for human knowledge. Science, therefore, subsumed philosophy rather than remaining as a subset of philosophy as it had been in the Greek tradition. Gadamer attributed this rift to the Enlightenment notion that fundamental substances and principles existed outside of human experience and beyond human interpretation. Kant’s doctrine of *Ding an sich*, or things which exist “in-and-of themselves,” is perhaps the most famous, single statement of Enlightenment thought. Gadamer (1996) referred to Kant’s statement as “the doctrine of substance as the true being” (p. 156).

The ostensibly simple notion of the existence of a reality that was independent of human experience and interpretation had serious ramifications for philosophy and society. Science gave rise to precise methods which were used to study and characterize a detached reality or to reproduce the so-called original or supposedly universal meaning of historical documents and artifacts. Science, however, quickly grew beyond mere methods of knowing. From Gadamer’s (1996) perspective, science became knowledge itself and concurrently and consciously sought to remove the dimensions of human experience and interpretation from the search for knowledge. Therein lay the problem for Gadamer.

The idea of describing realities or reproducing original meanings devoid of contemporary, human interpretations was fundamentally flawed from Gadamer’s viewpoint, and he derided any attempts to “extinguish the individual” from understanding (Gadamer, 1976). To reconcile science and philosophy in modern society, Gadamer (1976, 2000) argued for a more philosophical, Grecian approach to generating understanding by integrating the perspective of the interpreter with the object or phenomenon being interpreted; what we might call a subjective approach. He asserted that our personal prejudices, biases, or prior knowledge are the bases upon which all interpretations are made (Gadamer, 1976):

> Prejudices are not necessarily unjustified and erroneous so that they inevitably distort the truth. In fact, the historicity of our existence entails that prejudices, in the literal sense of the word, constitute the initial directedness of our whole ability to experience. (p. 9)

Thus, instead of attempting to eliminate human bias, Gadamer embraced the idea of the subjective observer as inevitable, necessary, and advantageous. To understand a text, for example, one must actively produce meaning by mediating between one’s current situation and interpretations of the past. Understanding and meaning are derived from active *production* and *synthesis* of the past with the present rather than detached reproduction of historical events. In *Truth and Method*, Gadamer (2000) referred to this synthesis as “historically affected consciousness” or a “fusion of horizons.”
The idea of understanding as an event mediated between the interpreter and that which is interpreted is the core of the dialogic or dialectic nature of knowledge (Gadamer, 2000). Mediated understandings are not restricted to interpretations of texts; they also extend to interpretations of works of art and to everyday conversations between people. Thus, Gadamer (1976, 2000) described hermeneutics in a comprehensive sense in an attempt to reassert the primacy of philosophy in Western thought.

Gadamer (1976, 2000) extended his arguments for philosophical hermeneutics by integrating language, which he suggested was the basis for all human understanding, into his scheme. As with most contemporary scientific endeavors, linguistics had been decomposed into a collection of methods. Language had become a thing or an object to be studied. Thus, syntax, grammar, and vocabulary were developed as tools or methods for understanding language (Gadamer, 1976). Gadamer (1976) defined language as not simply the means, but rather “the real medium of our being” and, consequently, language and understanding were inseparable, complementary concepts.

When we establish the fundamentally dialogic nature of understanding, Gadamer argued, philosophy can be reaffirmed above science as the central, inclusive framework for human inquiry. Science tends to avoid dialogic or mediated meanings of events. From Gadamer’s perspective, science was appropriately and narrowly viewed as a collection of methods or a specific way of knowing rather than knowledge itself. Gadamer’s philosophical hermeneutics, however, asserts that every conversation, every reading of a text, and every viewing of a work of art is an event of understanding facilitated by language. As we will see, his historical analysis of the tenuous relationship between science and philosophy forms a powerful basis for understanding hermeneutics as a theoretical framework in qualitative research.

Hermeneutics Applied to Qualitative Research in Science and Chemistry Education

Patton (2002) listed four key principles of hermeneutic inquiry in his well-known text: (a) Understanding a human act or product, and hence all learning, is like interpreting a text, (b) all interpretation occurs within a tradition, (c) interpretation involves opening oneself to a text (or its analog) and questioning it, and (d) texts are interpreted from the perspective of the researcher’s present situation. Patton (2002) also commented on using hermeneutics to generate meaning from qualitative data: “Hermeneutics focuses on interpreting something of interest, traditionally a text or a work of art, but in the larger context of qualitative inquiry, it has also come to include interpreting interviews and observed actions” (p. 497).

The overlap between Patton’s (2002) account of hermeneutics in qualitative research and Gadamer’s (1976, 1996, 2000) philosophical hermeneutics should be sufficiently clear. In the research literature, we see hermeneutics applied on both theoretical and practical levels. Bodner and MacIissac (1995) and Geelan and Taylor (2001), for example, presented theoretical arguments for why hermeneutic paradigms are powerful alternatives to traditional, empirical-analytic models in educational research, which often
overlook or cannot account for the context and complexity of educative environments and, consequently, tend not to affect positive change. Hermeneutics, by its nature, is appropriate for context-sensitive, educational inquiries. Analogous arguments were presented by Eger (1992, 1993a, 1993b) and Ginev (1995) in their discussion of the connections between hermeneutics and the philosophy of science.

Hermeneutics is often put into practice as a data analysis tool in qualitative research. A general approach, called the hermeneutic cycle or spiral (Bodner, 2004), is used to facilitate understanding and to generate holistic meaning from specific components embedded within qualitative data. In this approach to qualitative research, the researcher repeatedly cycles through the data, related research, and previous interpretations to derive greater understanding. The hermeneutic circle begins to close when the specific parts of the data can be interpreted within a greater whole. Gadamer (2000) provided similar descriptions of the hermeneutic circle, which were consistent with his notions of dialogic understanding, historically affected consciousness, and fusion of horizons.

The hermeneutic cycle has been reported as a general analysis procedure in the context of beliefs-based, science education research (Tobin & LaMaster, 1995; Tobin & McRobbie, 1997). These studies compared a high-school chemistry teacher’s beliefs about the nature of science (NOS) to those of his students (Tobin & McRobbie, 1997) and clarified the difficulties that an inexperienced secondary science teacher had with teaching lessons that were consistent with her personal beliefs about science (Tobin & LaMaster, 1995). Dagher and Cossman (1992) also invoked principles of hermeneutic analysis in their inquiry into the types of scientific explanations that middle-school science teachers used in their classrooms. Obed (1998) and Atwater (1998) described similar procedures in their comparison of students’ and teachers’ interpretations of scientific literacy.

The aforementioned research often cited the hermeneutic cycle as an interpretive, language-mediated process founded upon the researchers’ a priori assumptions, literature reviews, interviews, observations, and frequent meetings with the participants and fellow researchers. Such general procedures are common in the research literature and they are consistent with the philosophical underpinnings of hermeneutics. Novice researchers seeking specific guidance, however, might be easily frustrated by these general and often vague data collection and analysis procedures. In the next section, I lend a degree of specificity to our discussion by describing how I used hermeneutics to inform several aspects my own work in science teacher education (Shane, 2005).

Hermeneutics and Teachers’ Beliefs about Standards-Based Reforms

The guiding research question in this inquiry was, “What are high school science teachers’ beliefs about the intended and actual impacts of standards-based reforms?” This work built upon literature precedents in chemistry and science education with respect to teachers’ beliefs about teaching and learning (Abd-El-Khalick, Bell, & Lederman, 1998; Brickhouse, 1989, 1990; Brickhouse & Bodner, 1992; Bryan, 2003;
Lederman, 1999; Southerland, Gess-Newsome, & Johnston, 2003), educational standards and reforms (Cronin-Jones, 1991; Spillane & Callahan, 2000; Tobin & LaMaster, 1995; Tobin & McRobbie, 1997), as well as my previous experiences as a high-school science teacher in Indiana.

Over the course of two years, I conducted two rounds of on-site, focus group interviews (Morgan, 1993; Patton, 2002; Stewart & Shamdasani, 1990) with 23 high-school science teachers from rural, urban, and suburban districts in Indiana. Each focus group had between three and five participants and lasted anywhere from 45 minutes to two hours. During the initial sessions, four open-ended prompts or questions guided the discussion: (a) Describe your experiences with working with standards, (b) what impacts have these experiences with standards had on your work?, (c) what do you believe standards are intended to do?, and (d) what changes would you recommend to the existing standards?

After collecting these initial data, I realized that the discussions expanded beyond the implications of standards to include aspects of the teachers’ fundamental beliefs about teaching and learning. Consequently, I returned for a second round of interviews guided by three questions: (a) What words do you use to describe your role as a science teacher?, (b) what are your goals for science teaching?, and (c) what is the relationship between your roles, goals, and your work with standards? Throughout the research process, I identified five ways in which hermeneutics influenced my work.

First, focus group interviews epitomize hermeneutic phenomena. It was not surprising that the 23 teachers exhibited significant differences in their experiences with standards, beliefs about standards, and beliefs about teaching and learning. The researcher’s goal in a focus group is not to generate consensus in the sense of complete agreement, but rather to guide and moderate the discussion so that the participants build upon one another’s often diverging and contradictory responses en route to constructing mutual understanding and novel ideas. The focus group literature refers to this as a synergistic or cueing effect (Morgan, 1993; Patton, 2002; Stewart & Shamdasani, 1990). Citing Gadamer’s philosophical hermeneutics, Moss and Schutz (2001) referred to this as creating dissensus to account for a diverse range of beliefs and actions. Hermeneutics, therefore, guided my roles as moderator and dissensus builder during data collection.

Second, like all research projects, literature precedents helped to establish the significance of the guiding questions and eventual findings as well as enhanced the credibility of the data collection and analysis procedures. In this work with teachers’ beliefs about standards, it was necessary to integrate several resources with the interview data in order to place the teachers’ responses into an appropriate historical context. Educational standards, like many policies, often vary between states and school districts. Thus, I traced the history of Indiana’s Academic Standards for Science (Indiana Department of Education, 2003), which are based upon the American Association for the Advancement of Science’s (AAAS) Benchmarks for Science Literacy (AAAS, 1993). I also placed Indiana’s science standards within more general frameworks of educational standards (Anderson & Helms, 2001; Collins, 1998; Ravitch,
Chapter 6: Hermeneutics

1995, 2000) and educational policy (Adams & Krockover, 1998; Coombs, 1994). Since educational policies such as standards are enacted through legislative bodies, I included Indiana’s standards-and-accountability legislation – Public Law 221 – in the analysis (Indiana Department of Education, 2003). Finally, I gathered documentation as to how each school and district implemented Indiana’s science standards on a local, classroom level. Integration, or fusion, of these data sources was necessary to provide a context for, or to historicize (Goodson, 1997) the interview data. Gadamer’s hermeneutics continued to guide my research by suggesting additional sources of relevant data.

Third, with respect to data analysis, my general procedures did not significantly differ from the previously cited research (Bodner, 2004; Tobin & LaMaster, 1995; Tobin & McRobbie, 1997). My hermeneutic cycle was circumscribed around the aforementioned interview data and contextually relevant documents. I transcribed the interview data, read through these data and additional sources multiple times over two years, maintained several research notebooks, and generated summary sheets or overview grids (Knodel, 1993) for each teacher based on the interview topics. I also had several researchers from my institution audit the final analysis to enhance the credibility of the findings. As Moss (1994) argued, the central goal of a hermeneutic inquiry is “to construct a coherent interpretation of the collected performances, continually revising initial interpretations until they account for all of the available evidence” (p. 5). To this end, I generated frameworks to comprehensively account for all of our data sources, rather than selecting or extracting specific assertions or a singular essence. I ultimately represented the results of the analysis in a narrative, or storied, form (Polkinghorne, 1988, 1995) which is the subject of Chapter 13 of this book.

Fourth, hermeneutics, like critical theory described in Chapter 14 is often used as a theoretical backdrop for studies in which the researcher provides a voice for those who cannot speak for themselves. In my work, there was a clear power differential between those responsible for authoring and enforcing Indiana’s science standards — legislators and other governmental organizations — and those responsible for enacting standards on a local level — teachers and local administrators. I played a valuable role by providing a non-threatening mechanism for clearly and comprehensively communicating teachers’ experiences with and beliefs about the educational standards with which they were working on a daily basis. It is unlikely that teachers, administrators, and policymakers would have sufficient time and resources to perform such a study on their own. Educational researchers, therefore, have the opportunity and responsibility to serve in a liaison role, which is vital in our current, policy-driven environment (Anderson & Helms, 2001; Collins, 2004; Cuban, 1999; Fenstermacher, 2002).

Fifth and finally, since I am a former Indiana high school science teacher, it was important that I be honest with both myself and the subjects of my study about my personal experiences with and beliefs about standards. I wrote a brief autobiographical statement at the beginning of the analysis and, throughout the research process, compared my perspectives and biases to those of the participating teachers. I was particularly vigilant in noting instances where the teachers’ perspectives diverged from
my own, thereby transforming my personal understanding. By fusing my biases with the focus group interviews and additional data sources, I generated the narrative to communicate my understandings of how 23 high school science teachers interpreted and implemented Indiana’s science standards.

**Delimitations, Criticisms, and Recommendations**

As the various chapter authors will demonstrate throughout this book, a theoretical framework or orientation drives all aspects of a qualitative research project. One difficult task, especially for novice educational researchers, is to select a theory or combine theories so that they resonate with the guiding research questions, data-collection methods, analysis procedures, and presentation of findings. During the initial phases of my work, for example, my colleagues and I quickly narrowed the list of theories to a few possibilities – hermeneutics, critical theory, phenomenology, and ethnography — before ultimately selecting hermeneutics. Critical theory (Chapter 14) tends to presuppose circumstances where individuals are unjustly oppressed. Although this might have applied to some teachers, we did not believe that critical theory would adequately represent all of the participants. We were also uncertain as to whether we could determine a singular essence of the teachers’ experiences with and beliefs about standards as suggested by phenomenology (Chapter 8). Ethnographic inquiries (Chapter 10) in educational research tend to include descriptions of classrooms, schools, and surrounding communities in order to place the research questions into a cultural context. Our research was simply narrower in focus.

While we could have fit one or more of these theories to the guiding research question, none seemed to match as well as hermeneutics. Our choice, however, was not free from criticism. Many of the arguments against hermeneutics are the same as those used against qualitative work in general — subjectivity, lack of generalizability, no rigid criteria for validity and reliability, etc. — and I will not attempt a comprehensive defense here. Simply stated, some of the basic tenets of Gadamer’s (1976, 1996, 2000) philosophical hermeneutics can be simultaneously viewed as either strengths or shortcomings, depending on the critics’ theoretical foundations. It is the researcher’s duty to argue for an appropriate theoretical orientation while acknowledging its limitations.

Lack of guidance in data analysis and representation procedures is one problematic feature of hermeneutics in qualitative research. This is not surprising, however, since proponents of the hermeneutic cycle, including Gadamer (2000), do not advocate standard or universal analysis procedures:

> The circle, then, is not formal in nature. It is neither subjective nor objective, but describes understanding as the interplay of the movement of tradition and the movement of the interpreter. (p. 293)

Specific and prescribed analysis procedures are antithetical to philosophical hermeneutics. At some point in the inquiry, however, researchers must develop and
report specific procedures to analyze their data and communicate their results. This is where I chose to invoke a complementary theory, narrative analysis, which is the subject of Chapter 13. By coupling hermeneutics with narrative, I formed a more comprehensive theoretical foundation for the inquiry into teachers’ beliefs about standards-based reforms.

If you are considering hermeneutics as a possible theoretical orientation, consider the following checklist of questions that should help to guide your decision:

- Is it appropriate to describe your role as a voice for the research participants?
- Is your goal to understand and communicate the participants’ beliefs and actions in a comprehensive sense?
- Is it necessary to understand the historical context around your research question?
- Is it essential to incorporate your personal perspectives and biases into the analysis?

In addition to these guidelines, I recommend that you consider hermeneutics if your research questions include broad constructs such as beliefs, perceptions, or experiences. Such inquiries often lend themselves to historically- and contextually-grounded data collection procedures where the roles of the researcher are to understand the various data sources and to communicate this understanding in a fair and comprehensive manner. This is what it means to be a voice in the hermeneutic tradition.

For inquiries of a more cognitive nature where the emphasis is on problem solving, conceptual development, and mental representation, I recommend against using hermeneutics. Constructivism (Chapter 2), situated cognition (Chapter 11), and modeling (Chapter 4) are likely to be more appropriate theoretical frameworks here.

And, finally, hermeneutics can easily be used in conjunction with other orientations. If the aforementioned inquiry into teachers’ beliefs about standards, for example, expands to include classroom observations, hermeneutics may be insufficient. Ethnology (Chapter 10) or pedagogical content knowledge (Chapter 5) might need to be invoked to capture teachers’ actual instructional practices as a complement to their beliefs about educational policies designed to influence their practice. If the focus shifts to having teachers reflect upon and improve their practice within the context of policy, tenets of action research (Chapter 9) would need to be included. Such blending of theoretical frameworks is common in qualitative work and the reader is encouraged to consider this option as the various chapters of this book are reviewed and research questions are refined.
References


Phenomenology

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Biography

Kirsten Casey is an Assistant Professor of Chemistry at Anne Arundel Community College. She decided to become a chemistry professor at the ripe old age of 11, never imagining that the journey would take her from coast to coast and everywhere in between. After leaving her home in Greenbelt, Maryland, she spent her undergraduate years at the University of California San Diego as a chemistry student, tutor, and teaching assistant—all the while filled with a nagging suspicion that there had to be a better way to teach chemistry. She was thrilled to spend her graduate years as a chemical education student at Purdue University finding the ideas, people, and theories to bring to life what she intuitively knew. Her journey next led her back home to Maryland and Anne Arundel Community College, where she was awarded the Rookie Professor of the Year award.

Introduction

Phenomenology is a philosophical research tradition that has been influenced by the work of many philosophers including Husserl, Schutz, and Merleau-Ponty (Polkinghorne, 1983; van Manen, 1990). In practice, “phenomenology” is a broad term; it can refer to a general research tradition of human science (often contrasted to empiricism or positivism) or to a theoretical perspective with associated methodologies. As a theoretical perspective, phenomenology can be subdivided into categories such as hermeneutic phenomenology, social phenomenology, existential phenomenology, transcendental phenomenology, and others (Creswell, 1998; Polkinghorne, 1983). The differences in the various strands of phenomenology are a result of the differences in the philosophical traditions from which they emerged.

As this chapter is designed to provide an overview of phenomenology, I am not going to focus on distinguishing one type of phenomenology from another. Rather, I will describe the characteristics that are general to all phenomenological research, and focus on what a phenomenological study looks like. I will conclude the chapter with an analysis of a specific example of phenomenological research in chemistry education and a discussion of when and how this framework can be used appropriately to understand issues in chemical education.
Aims and Assumptions of Phenomenological Research

Phenomenology focuses on human experience as the object of research (Marton, 1996; van Manen, 1990). There are many ways to explore human experience, and many traditions have this as a starting point, including case study, Action Research, and symbolic interactionism, to name a few. What separates phenomenology from many of these other traditions is that it seeks to understand the meaning of a chosen human experience by describing the lived experience (the phenomenon) of the participants (van Manen, 1990). A phenomenological researcher interested in the phenomenon of studying, for example, would ask the question “what is the meaning of studying?” rather than questions related to what constitutes effective studying or what attitudes students hold about studying. The goal of such a study would be to provide a description of an essential concept or phenomenon, such as studying or completing classroom laboratory experiments, that answers the research question.

A phenomenological study begins when a researcher gathers data from participants about their own experiences of a phenomenon. "Phenomenologically oriented researchers seek to understand human behavior from the 'insider’s' perspective" (Fetterman, 1988, p. 18). Phenomenologists assume that human experience is inherently subjective; van Manen (1990) makes reference to the “multiple and different lifeworlds that belong to different human existences and realities” (p. 101) and speaks of gathering the “subjective experience of our so called subjects or informants” (p. 62). Fetterman (1988) refers to the “subjective realities of human perception” (p. 18).

Phenomenology is founded in the assumption that the way to understand the meaning of a phenomenon is through description (van Manen, 1990, p. 11). Therefore, a phenomenologist takes the data regarding the participants’ subjective experiences and creates a description of these experiences. Inductive analysis strategies are then used to interpret the descriptions and reduce the data to central themes. These themes are a reduction of the data that captures the main points: van Manen describes themes as “a simplification … a form of capturing the phenomenon…[that] give shape to the shapeless” (1990, p. 87). Polkinghorne (1983) argues that themes represent essential structures of human experience, which serve as the “organizing principles [used for] making sense of experience” (pp. 204-205) and which allow us to distinguish one experience from another.

From the collection of themes, phenomenologists then seek to reduce the experiences to a single common meaning, termed the essence of the experience (Creswell, 1998; van Manen, 1990). Marton (1996) states, phenomenology seeks to develop a “single theory of experience”. Van Manen (1990) describes this essence as “the very nature of the phenomenon … that which makes a ‘something’ what it is — and without which it could not be what it is” (p. 10). This focus on a single common meaning of an experience clearly separates phenomenology from the similar sounding framework of phenomenography described in Chapter 8, which focuses on understanding differences in the meaning of experiences.
It is important to note that the meaning, or essence, of the experience comes from the descriptions of the experience, rather than from what the participant thinks the experience means (Volkmann & Anderson, 1998). Phenomenologists do not seek participants’ interpretations of experience, rather they seek full descriptions of the experience from which the essence emerges. Polkinghorne (1983) expressed this as follows, “it is the lifting out and in the examination of the experience that it acquires meaning” (p. 208).

Within the phenomenological framework, both the structures (themes) and the essence of an experience are considered to represent a broad truth about the phenomenon being studied, a truth that is generalizable beyond the scope of the participants. Polkinghorne (1983) states “the goal of the method is to produce descriptions which lead to general, if not universal, intersubjective agreement” (p. 213). Van Manen (1990) argues that phenomenological knowledge claims represent universal truths about the phenomenon and states that the essence of an experience addresses “the question of what something is ‘really’ like” (p. 42). Sexton-Hesse (1983) characterizes phenomenology as the search for the “objective sphere of human existence … [that can] only be discerned by tracing its foundations in the subjective sphere, human consciousness itself” (p. 8).

The ultimate use for the description of the essence varies depending on the particular tradition of phenomenology with which a researcher identifies. For those traditions more closely linked to the goals of philosophy, the purpose of the research is to understand our own experiences — to gain knowledge about what it means to be a human – because such research allows us “to become more fully who we are” (van Manen, 1990, p. 12). For other phenomenologists, the purpose of research is less self-centered but still focused on describing an essence of the experience. For these researchers, the goal is to produce a description that allows the reader to better understand what it is like to experience a particular phenomenon (Creswell, 1998).

In conclusion, phenomenology is a framework that seeks to understand the meaning of human experience. This is accomplished by describing the subjective experiences of participants (and the researcher) with a chosen phenomenon. These descriptions are then analyzed to find the essential themes that shape that experience. From these themes, a single universal essence emerges that describes the meaning of the experience. This essence may be used to evoke the meaning of the experience for the readers or simply for the researcher themselves.

**Methods of Phenomenology**

At the surface, phenomenological methods are similar to other interpretive research methods; phenomenological researchers use open-ended interviews, inductive data analysis techniques, and member checking to verify analysis. However, it is important to remember that phenomenology is not a method for simply describing or interpreting experience; rather, phenomenology seeks to answer the question “what do lived experiences of a phenomenon tell us about the essence of the particular phenomenon?”
This has important implications that shape the methodology used in a phenomenological study.

One of the unique features of phenomenological methodology is the role that the researcher plays in the research. Although all interpretive methodologies recognize that the researcher and research are intertwined, the central role that the researchers’ own experiences have in phenomenological studies is characteristic. Since the goal of phenomenological studies is to describe a universal essence of a phenomenon, it is important that the essence also reflects the researchers' experiences with the phenomenon. Van Manen (1990) explains that a researcher's experiences “are immediately accessible ... in a way that no one else’s are” (p. 54). The deep role that the researcher’s experiences play in a phenomenological study is often reflected by the use of personal pronouns such as “I” or “we” in phenomenological descriptions (van Manen, 1990). There is not one consistent way in which the researchers involve themselves in the study. The manner in which the researcher’s experiences are incorporated in the study vary from study to study, and there are even stages of a study when the researcher may consciously “bracket [or set aside] his or her own preconceived ideas about the phenomenon to understand the voices of the informants” (Creswell, 1998, p. 54). However, in all phenomenological studies, the researcher's experiences with the phenomenon are incorporated into the research.

The initial stages of phenomenological study involve selecting a research question and choosing a philosophical basis for understanding the phenomenon. Creswell (1998) describes this stage by stating that “the researcher needs to understand the philosophical perspective behind the approach, especially the concept of studying how people experience the phenomenon” (p. 54). There are many forms that the philosophical basis for understanding the phenomenon can take, depending on the nature of the chosen phenomenon. Commonly, researchers adopt frameworks or theories that have been used to study the phenomenon before. These frameworks serve as starting places that give the researcher practical tools to explore the undefined territory of the meaning of human experience. They are reference points used to guide the creation of the questions used for interviews, the selection of research participants, and the schemes used for data analysis. Typically, discussions of the frameworks are included as part of the literature review for the study, along with a narrative that explains the researcher’s choice of frameworks.

The major source of data in a phenomenological study is interviews with participants, although journals and other artifacts may be analyzed, as appropriate. Phenomenological interviews tend to be lengthy and centered around a few questions that the researcher explores in great depth. During an interview, the researcher attempts to fully record the participants’ thoughts, actions, feelings, and experiences regarding the phenomenon in question (Polkinghorne, 1983). This is the stage where interviewers will bracket their own experiences because the goal is to try to understand the experience from the participants’ point of view. Bracketing requires researchers to set aside “all preconceived experiences” (Creswell, 1998, p.235) which means they must not assume immediate understanding of the participant’s responses that seem
obvious. As a result, interviews are cyclical and lengthy, with the researcher returning again and again to participants’ responses, asking for clarification or more explanation of the participants meaning.

Following an interview, the researcher will transcribe the interviews and then analyze the data. Creswell (1998) describes the steps of the analysis process:

> The protocols are divided into statements, or horizontalization. Then, the units are transformed into clusters of meanings … [based on the philosophical frameworks used to guide the study] … Finally, these transformations are tied together to make a general description of the experience, the textural description of what was experienced and the structural description of how it was experienced. (p.55)

With this description in hand, the researcher will return to a participant and ask questions designed to understand how the participant views the description. (A technique known as “member checking”, see Chapter 2). The researcher will explore how the participant’s experiences do, or do not, validate the initial ideas. This process will continue through several interviews, until the researcher is satisfied that a full and complete explanation of the experience has been reached. A phenomenological study concludes with the researcher’s collecting all the descriptions generated from each participant (frequently including his/her own) and writing a description that captures the essence of the experience.

In summary, there are several aspects of methodology that are characteristic of a phenomenological study. In a phenomenological study, the researcher’s experiences with the phenomenon are an integral part of the study and are typically made explicit. A phenomenological study contains a discussion of explicit philosophical frameworks that help guide the study and which are chosen based on the phenomenon in question. Phenomenology relies on multiple interviews with participants to fully explore the phenomenon and shape the data analysis. A phenomenological study concludes with a description of the essence of the experience, which explains a fundamental truth about the meaning of the phenomenon for the benefit of the researcher or the wider audience.

**Published Examples of Phenomenological Studies in Science Education**

As a research tradition, phenomenology has been used in many fields, including psychology, sociology, and health care (Rieman, 1986). It is a tradition that is included in the majority of manuals that survey qualitative research traditions, many of which focus on methodologies for education research (Cohen, Manion, & Morrison, 2000; Cottrell, 2005; Creswell, 1998; Denzin & Lincoln, 1998). However, to a large extent, it is a tradition that many have written about, but few in science education have applied. To date, there have only been a handful of papers written by science educators that have used a phenomenological approach, and most of this work has been done in physics education (Roth & Bowen, 1999, 2000; Roth, McRobbie, Lucas, & Boutonné, 1997; Volkmann & Zgagacz, 2004).
There are legitimate reasons why this approach has not been used extensively, which I will address later; for now I’d like to discuss an example of a phenomenological study in chemistry education to illustrate how and why a researcher might use this approach. In a paper published in *Science Education*, Mark Volkmann and Maria Anderson use a phenomenological approach to answer the question “What is the nature of creating a professional identity of a science teacher?” (Volkmann & Anderson, 1998). In this section I will demonstrate how this study puts into practice each of the methodological characteristics described previously.

This study clearly demonstrates the phenomenological approach to intertwining the researcher and the research. The two authors are also the two participants; the source for the data on the lived experience of science teachers is their own experiences as first year chemistry teachers. Each of their backgrounds in this regard is described in the study. In addition, their self-interest in conducting the research is explicitly explained in the paper based on their study. Volkmann wanted to use the results of the study to understand his own experiences, and Anderson wanted to understand her experiences so she could help future teachers be better prepared than she had been. Further, throughout the study the authors refer to themselves by first names and use personal pronouns such as “we” and “our.”

Volkmann and Anderson chose four different theories in teacher education research (stage of teaching, dilemmas of teaching, teaching metaphors, and professional identity) and the philosophically-based performance theory to help them define and describe the experiences. Each of these frameworks is briefly defined and described as it relates to the study; they write, “in what follows we provide an overview of these areas and show how they provide a basis for our work” (Volkmann & Anderson, 1998, p. 294).

The cyclical nature of the data collection (along with the intertwined nature of the researcher and research) are illustrated in the following description of how the study was designed:

Maria unknowingly began the research process when she wrote her first-year teaching journal (1988-1989). Mark entered the cycle by responding to an invitation from Maria to read her journal (1994). This reading caused Mark to recall events within his own first year of chemistry teaching (1969-1970). Our analysis was influenced by both sets of first year experiences and by current experiences and interactions. During fall 1995, we met once per week over the course of a semester to discuss Maria’s journal. We tape recorded those sessions and transcribed the tapes. These transcriptions provided a record of the emerging themes, as well as unrecorded details of events Maria described in her journal. (Volkmann & Anderson, 1998, p. 298)

Based on the analysis and the frameworks chosen to guide the study, the authors chose to describe the themes of the research in the form of three dilemmas. The three dilemmas were chosen because they frequently appeared in the journal and because they remained unresolved throughout Anderson’s first year of teaching. Along with each
dilemma, the authors provide a metaphor that Anderson used to help her balance the
tensions created by the dilemma.

In their discussion, the authors relate dilemmas and metaphors such as these back to
the research on teacher education and describe how the various theories of teacher
education failed to capture Anderson’s experiences. The authors conclude that previous
research has failed to address the essence of the experience, which consisted of “a
struggle to create a professional identity that was consistent with personal identity
through the [use of] metaphoric resolution of … teaching dilemmas” (Volkmann &
Anderson, 1998, p. 307). They suggest that teacher education programs need to
recognize that the major challenge in becoming a teacher is the struggle to create a
professional identity that is consistent with the personal identity and that mentors focus
on helping teachers find their own metaphors for resolving the conflicts.

Conclusion

It is not surprising that little research in chemistry education has been done using
phenomenology. One of the most obvious reasons for this is that phenomenological
research is inherently difficult. Creswell (1998) describes phenomenological research as
challenging because:

- The researcher requires a solid grounding in the philosophical precepts of
  phenomenology.
- The participants in the study need to be carefully chosen to be individuals who
  have experienced the phenomenon.
- Bracketing personal experiences by the researcher may be difficult.
- The researcher needs to decide how and in what way his or her personal
  experiences will be introduced into the study. (p. 55)

However, beyond the difficulty factor, I believe there are several other reasons why
chemistry educators have not widely used this framework. First, chemistry education
research has often focused on understanding differences between students instead of
looking for commonalities among them. This makes sense; we all observe differences in
student performance in our classrooms every day. The vast majority of our research is
designed to help us close the gap and improve the performance of weaker students.
Phenomenology cannot be used to help in this endeavor, although phenomenography
(see Chapter 8) can.

Second, most chemistry educators’ research questions have not centered on
understanding lived experiences. Instead we have focused on asking questions about
the cognitive domain (misconceptions research or spatial ability, for example), or the
affective domain (what are students’ attitudes about scientists, for example). We want to
know everything we can about how students learn chemistry — how they conceptualize
it, explain it, and represent it. We have historically been interested in the students’ experiences with learning chemistry in hopes of understanding how we can shape these experiences to improve learning; rather than asking “What can our students experiences tell us about the meaning of learning chemistry?”

Third, much of the research in chemistry education is by necessity and design very context dependent. We are a discipline composed of established sub-disciplines — organic, inorganic, physical, and biochemistry for example. Though we share common ideas about the structure and nature of matter, we tend to believe that each specialty requires different skills from our students and, therefore, ask specific research questions. We are not interested in asking about learning chemistry in general, but rather we want to know about learning organic chemistry, or inorganic chemistry, and so on. In addition, chemistry is taught in many different settings and situations, and we are aware that what works in one setting may not work in another (large class versus small class for example), so we present research findings that are context dependent and less generalizable that phenomenology would require.

Fourth, the relationship between researcher and research required by phenomenology is very problematic. Most of us have reached our current positions based on our past successes with chemistry, and yet we conduct research designed to help those who struggle in ways that many chemistry instructor never did. In addition, we have built our careers by carefully delineating “us” (the teachers) from “them” (the students). We are aware that our experience of the classroom is very different from our students’ experiences (what we say is not what they hear). When conducting our research, we do not often consider our own experience to be relevant.

Given all this, I think there is room for phenomenology in chemical education research. Finding a suitable area of research requires finding a part of our curriculum that we value primarily for the experience it provides students, so that investigating the meaning of this experience is useful. It also requires finding a part of our curriculum for which we are interested in understanding the common impact of the experience on all our students, and one for which models or theories exist that could be used to help shape a phenomenological study. In addition, we need a question that would allow us to incorporate our own experiences.

One possibility that would yield useful results, would be phenomenological studies of the laboratory components of our courses. In an article discussing laboratory reform, Hilosky, Sutman, and Schmuckler (1998) comment that “overall reform in the teaching of beginning college-level chemistry continues to be a primary concern for the chemistry community” (p. 100). Reform efforts have been mounted, but change has been slow; and today, many of our students still labor using the same cookbook labs that have been used for generations.

A phenomenological approach to the laboratory experience seems appropriate for several reasons. More than any other part of our curriculum, the laboratory is designed to create an experience for the students; yet “there is a lack of studies that sharply focus
on what students are actually doing in science laboratories” (Roth et al., 1997, p. 107). The laboratory is a long-established part of our curriculum, yet there are multiple, and sometimes conflicting, reasons given for why it is necessary: it helps build technical skills, it helps students conceptual understanding, it helps students connect the material learned in lectures, it helps students think like a scientist. Perhaps if we could understand the meaning of the students’ lived laboratory experiences, we would be able to clarify what purpose the laboratory currently serves. Further, the laboratory is an experience we share with our students, both as former students and as instructors, so the blending of our experiences with our students’ seems relevant. Finally, this seems an appropriate topic to look for the commonalities instead of differences. A phenomenological study of the laboratory experience that gives voice to the meaning of the students’ (and the researchers’) experience might be a push that helps reform take hold.

References


Phenomenography

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Biography

MaryKay Orgill is an Assistant Professor of Chemistry at the University of Nevada, Las Vegas. Her education has been eclectic and her professional life somewhat schizophrenic so far. She studied chemistry at Brigham Young University to prove that a girl could “do chemistry” and do it well. She was surprised to find during her undergraduate studies that she actually liked chemistry — and loved teaching it. Not willing to be tied to only one kind of learning or working, she enrolled in graduate school at Purdue University to study both biochemistry and chemical education, completing a degree in each of those fields. She continued to pursue both interests as a first-year faculty member with a joint appointment in biochemistry and science education at the University of Missouri-Columbia. During that year, she took on the extra challenge (and incredible learning experience) of teaching a high school chemistry class. In 2004, she moved to her home state of Nevada to take a position at UNLV, where her research focuses on undergraduate chemistry and biochemistry education and where she enjoys working with undergraduate chemistry students and teachers in the local school district. In 2006, students at UNLV named her their favorite chemistry professor.

Introduction

Phenomenography is an empirical research tradition that was designed to answer questions about thinking and learning, especially in the context of educational research (Marton, 1986). It is concerned with the relationships that people have with the world around them. The word “phenomenography” has Greek etymological roots. It is derived from the words “phainonmenon” (appearance) and “graphein” (description). Thus, “phenomenography” is a “description of appearances” (Hasssel-gren & Beach, 1997).

Aims of Phenomenographic Research

Marton (1981) suggests that there are two ways to approach questions about learning: (1) to orient ourselves toward the world and make statements about it and its reality, or (2) to orient ourselves towards people’s ideas or experiences of the world. In other words, we can either choose to study a given phenomenon (a first-order approach), or we can choose to study how people experience a given phenomenon (a second-order approach). Phenomenography is the latter kind of approach. Its aim is to define the
different ways in which people experience, interpret, understand, perceive or conceptualize a certain phenomenon or aspect of reality.

Different people will not experience a given phenomenon in the same way; there will be a variety of ways in which different people experience or understand that phenomenon. Phenomenographers seek to identify the multiple conceptions, or meanings, that a particular group of people have for a particular phenomenon. The focus of a phenomenographic study is not on providing rich descriptions of individual experiences. Rather, it is on describing the variation in experiences of a certain phenomenon across the group (Dall’Alba et al., 1993; Trigwell, 2000; Walsh et al., 1993). As such, detailed descriptions of the individuals in the group are not typically included in phenomenographic studies.

Because the focus of a phenomenographic study is on the conceptions that a particular group of people have for a given phenomenon, the conceptions of the researcher for that phenomenon are not usually a focus of such a study. Instead, the researcher attempts, as much as possible, to act as a "neutral foil" for the ideas expressed by the participants of the study. "As phenomenography is empirical research, the researcher (interviewer) is not studying his or her own awareness and reflection, but that of the subjects" (Marton, 1994, p. 4427).

Marton (1981, 1994) has argued that there are a limited number of qualitatively different ways in which different people experience a certain phenomenon. From this theoretical stance, it is irrelevant if those conceptions are considered “correct” or “incorrect” by current standards. The aim is simply to elucidate the different possible conceptions that people have for a given phenomenon.

The main results of phenomenographic research are “categories of description” of the various conceptions of a phenomenon. Phenomenographic research is more than simply reporting these different conceptions, however. It involves identifying the conceptions and looking for their underlying meanings and the relationships between them (Entwistle, 1997). Marton (1981) makes the following statement about this additional goal of phenomenography:

Still, we are able to point not only to conceptions — making up its constituents — but also to relations between certain conceptions of one aspect of the world and certain conceptions of another aspect. What we have in mind is certainly not merely a listing of one conception after another. Some aspects are certainly more basic than others and different (and more or less fundamental) layers of the perceived world can be revealed. (p. 190)

Marton (1994) also states that the qualitatively different ways of experiencing phenomena or concepts are representative of different capabilities for dealing with those phenomena or concepts. Some ways of dealing with phenomena or concepts are more productive than others. Thus, the conceptions, or “ways of experiencing,” and their corresponding descriptive categories can not only be related, but also be hierarchically
arranged. The ordered and related set of categories of description is called the “outcome space” of the concept being studied.

**Assumptions of Phenomenography**

Unlike other theoretical research perspectives, phenomenography does not make any assumptions about the nature of reality. Phenomenographers do not claim that their research results represent “truth.” They do claim, however, that their results are useful. Svensson (1997) makes the following point about the phenomenographic position on the nature of reality:

> Phenomenography does not [...] have an articulate metaphysical foundation. The question may be raised if it has implicit metaphysical assumptions. Individual researchers doing phenomenographic research may make such assumptions but they certainly vary between the researchers. It is possible to have any and all of the metaphysical positions within the main categories of materialism and idealism and do phenomenographic research. The tradition is not based on any of these metaphysical beliefs and it is open in this respect. (p. 165)

Although phenomenography makes no assumption about the nature of reality, it does make assumptions about the nature of conceptions. The primary assumption is that conceptions are the product of an interaction between humans and their experiences with their external world. Specifically, conceptions result from a human being’s thinking about his or her external world. The variations in the conceptions of a particular phenomenon are the focus of a phenomenographic study. An assumption that is extremely important to phenomenographic research is that a person’s conceptions are accessible in different forms of actions, but particularly through language (Svensson, 1997).

**Methods of Phenomenography**

Phenomenographic studies strive to discover the different ways in which people understand or experience certain phenomena. Although many possible sources of information can reveal a person’s understanding or conception of a particular phenomenon, the method of discovery is usually an open, deep interview (Booth, 1997). “Open” indicates that there is no definite structure to the interview. While researchers may have a list of questions or concerns that they wish to address during the interview, they are also prepared to follow any unexpected lines of reasoning that the interviewee might address as some of these departures may lead to fruitful new reflections that could not have been anticipated by the researcher. “Deep” indicates that the interview will follow a certain line of questioning until it is exhausted: until the participant has nothing else to say and until the researcher and participant have reached some kind of common understanding about the topics of discussion.

The aim of an interview is to have the participant reflect on his or her experiences and then relate those experiences to the interviewer in such a way that the two come to a
Chapter 8: Phenomenography

mutual understanding about the meanings of the experiences (or of the account of the experiences).

The experiences and understandings are jointly constituted by interviewer and interviewee. These experiences and understandings are neither there prior to the interview, ready to be “read off,” nor are they only situational social constructions. They are aspects of the subject’s awareness that change from being unreflected to being reflected. (Marton, 1994, p. 4427)

Because the aim of phenomenographic research is to identify the variation of experiences within a group, samples are chosen to maximize the possible variation (Trigwell, 2000). Data collection continues until no new ways of experiencing a phenomenon are revealed through additional interviews. In other words, data collection often continues until “saturation” is reached (Lister, Box, Morrison, Tenenberg, & Westbrook, 2004).

A variety of interviewing styles can be used in order to identify a group’s experiences of a phenomenon, including semi-structured interviews (for example, see Orgill & Bodner, 2004), interviews about instances (for examples, see Ebenezer & Fraser, 2001; Carlsson, 2002; and Brass, Gunstone, & Fensham, 2003), and interviews involving problem-solving (for example, see Bhattacharyya & Bodner, 2005). Interviews can also be combined with other data collection methods. For example, Guisasola, Almudi, and Zubimendi (2004) examined first-year university students’ conceptions of magnetic field theory. They initially provided large groups of students with a questionnaire, which they followed with individual interviews with a smaller number of students. Liu, Ebenezer, and Fraser (2002) gathered pre-interview data about engineering students’ conceptions of energy through paragraph writing.

**Data Analysis**

During data analysis, the researcher will identify qualitatively distinct categories that describe the ways in which different people experience a different concept. Phenomenographers believe that a limited number of categories are possible for each concept under study and that these categories can be discovered by immersion in the data, which, in most cases, are transcripts of the interviews (Booth, 1997).

The researcher examines the transcripts of several participants’ interviews, looking both for similarities and differences among them. In this process, the researcher develops initial categories that describe different experiences of the given phenomenon. The goal is not to identify the ways in which an individual experiences the phenomenon, but to capture the diversity of ways a group experiences the phenomenon. It is entirely possible that an individual will identify with more than one category of description (Lister et al., 2004). The categories of description become the “outcome space” of the study. If the interview has covered multiple topics or multiple aspects of a given phenomenon, the researcher will attempt to develop an “outcome space” for each topic. The only ground rules for category development are internal consistency and parsimony, or
finding an “outcome space” that includes the minimum number of categories which explain all the variations in the data.

With these initial categories in mind, the researcher reexamines the interview transcripts to determine if the categories are sufficiently descriptive and indicative of the data. This second review of the data results in modification, addition, or deletion of the category descriptions. This process of modification and data review continues until the modified categories seem to be consistent with the interview data. Marton (1986) says that “definitions for categories are tested against the data, adjusted, retested, and adjusted again. There is, however, a decreasing rate of change, and eventually the whole system of meanings is stabilized” (p. 43).

Once a stable “outcome space” has been defined, the researcher attempts to develop “…as deep an understanding as possible of what has been said, or rather, what has been meant” (Marton, 1994, p. 4428). To do this, the researcher needs to consider not only specific categories of description, but also how the individual categories relate to each other and how one person’s conceptions compare across different topics. The research report includes a description of each of the ways of experiencing a phenomenon and how those ways of experiencing are related to each other.

**Criticisms of Phenomenography**

One of the criticisms of phenomenography is its tendency to equate participants’ experiences with their accounts of those experiences, as Marton (1994) evidences by stating that conceptions, the focus of phenomenographic studies, are “ways of experiencing.” Saljo (1997) reports that, at times, there appears to be a discrepancy between what researchers observe of a participant’s experience with a particular phenomenon and how the participant describes his experience with the phenomenon. Richardson (1999) claims that phenomenographers do not skeptically examine the effects of the interview environment or of socially accepted linguistic practices on what is reported by the students.

In order to avoid equating experiences with accounts of experiences, Saljo (1997) suggests that phenomenographers refer to studying people’s different “accounting practices” of phenomena, which are public and accessible to study, instead of referring to studying people’s “experiences.” Researchers must keep in mind, however, that such accounting practices may be socially and environmentally influenced (ie. the student might say what he thinks the interviewer wants to hear, etc.).

It may be true that people’s accounts of their experiences with a particular phenomenon are not equivalent to the ways in which they experience the phenomenon. However, the only way researchers can begin to understand the ways in which people experience a given phenomenon is to ask each person to describe his or her experience. Researchers can make observations of what people experience, but those observations will not tell them how people experience a given particular phenomenon. This is especially true if researchers accept the idea that conceptions, or ways of experiencing,
are products of an interaction between the person and the phenomenon he experiences. Phenomenographic results may not be “truth,” in that they may never accurately describe “ways of experiencing,” but they may be useful. So, then, it may not matter if accounts are equivalent to experience.

One of Webb's (1997) main critiques of researchers using phenomenography is their assumption that they can be “neutral foils” while analyzing research data. It is more reasonable to assume that researchers have had certain experiences and hold certain theoretical beliefs that will influence their data analysis and categorization. Webb calls for researchers to make their backgrounds and beliefs explicit, not because having these backgrounds and beliefs is “bad,” but rather because the readers and users of phenomenographic research need to be informed about all variables that have potentially affected the study results. Such self-examination may lead to additional insights into the data and, to some extent, a more critical examination of how the researcher's own beliefs have affected the research and the results of this research.

Other researchers have questioned the reliability and repeatability of phenomenographic studies. On issues of reliability, Marton (1986) says that it is possible that two different researchers would discover different categories of description while working on the same data individually. However, once the categories have been found, they must be described in such a way that all researchers can understand and use them. Marton compares this process to botanists that discover a new plant species on an island. If the new species does not appear to fit into already existing category, a botanist must develop a new category of classification for it, and it is highly probable that a separate botanist would develop a qualitatively different category for that new species. However, once the botanist has developed and described a category, the category is now accessible and available for classifying plants that any botanist finds. Indeed, once the category is developed and described, it becomes useful to others who use the results of the study.

**Potential Educational Benefits of Phenomenographic Research**

There are certain benefits to using the results of phenomenographic research in educational research. At all levels of instruction, students are generally encouraged to develop conceptual understandings (Entwistle, 1997), and it is often the goal of teachers to help their students develop conceptions that are consistent with those held by recognized experts in various fields. However, students often have multiple different conceptions for a phenomenon that are not necessarily consistent with the conceptions held by experts. Marton (1986) claims that “a careful account of the different ways people think about phenomena may help uncover conditions that facilitate the transition from one way of thinking to a qualitatively ‘better’ perception of reality” (p. 33). Thus, phenomenographic information about the different conceptions that students hold for a particular phenomenon may be useful to teachers who are developing ways of helping their students experience or understand a phenomenon from a given perspective (Bowden & Marton, 1998).
Additionally, it has often been documented that students’ views and beliefs are affected by those held by their teachers. Phenomenographic methods can be used to examine teachers’ conceptions of a particular topic or teaching method. If those conceptions are incorrect according to accepted scientific and educational principles, they can be remedied for the benefit of the students. Even if the conceptions are correct, there may be key differences between the teachers’ conceptions and those of their students. Knowing these differences may allow teachers to design instruction that will bridge the gap between the teachers’ knowledge and understanding and that of the students (Stromdahl, Tullberg, & Lybeck, 1994; Tullberg, 1998; Tullberg, Stromdahl, & Lybeck, 1994).

Another possible benefit of phenomenographic research is that participating students may become conscious of contradictions in their own reasoning and become more open to alternative ideas as they reflect on their perceptions and understandings of their world experiences (Marton, 1986).

Published Examples of Phenomenographic Studies

I have examined eight chemistry education and science education journals for research studies that used phenomenography as a major theoretical framework during the years from 1990 to 2005 (Chemistry Education: Research and Practice, International Journal of Science Education, Journal of Chemical Education, Journal of Research in Science Teaching, Research in Science Education, Science Education, Science & Education, The Chemical Educator). Table 1 contains a list of the references of the articles and their main research questions or purposes. While this list is certainly not exhaustive of the chemistry/science education research that uses phenomenography as a theoretical framework, it does provide a sample of the types of studies that can be done phenomenographically.

Table 1. Examples of Phenomenographic Studies in Chemistry/Science Education

<table>
<thead>
<tr>
<th>Reference</th>
<th>Research Questions/Purposes</th>
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<tbody>
<tr>
<td>Aguirre &amp; Haggerty, 1995</td>
<td>What are pre-service teachers' conceptions of learning?</td>
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<tr>
<td>Bhattacharyya &amp; Bodner, 2005</td>
<td>What are the different ways graduate students propose organic mechanisms?</td>
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<td>Boddy, Watson, &amp; Aubusson, 2003</td>
<td>What conceptions do elementary students develop about a particular concept when their teachers use the 5E model of teaching?</td>
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<tr>
<td>Brass et al., 2003</td>
<td>What are university professors' and high school physics teachers' conceptions of &quot;quality learning&quot;?</td>
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<tr>
<td>Author(s)</td>
<td>Research Question</td>
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<tr>
<td>Carlsson, 2002</td>
<td>What are students' ways of thinking about photosynthesis?</td>
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<tr>
<td>Case, Gunstone, &amp; Lewis, 2001</td>
<td>What kinds of metacognitive knowledge and awareness do chemical engineering students develop as a result of participating in an innovative course?</td>
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<tr>
<td>Dall'Alba et al., 1993</td>
<td>What are students' conceptions of &quot;acceleration&quot;?</td>
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<tr>
<td>Ebenezer &amp; Erickson, 1996</td>
<td>What are students' conceptions of &quot;solubility&quot;?</td>
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<tr>
<td>Ebenezer &amp; Fraser, 2001</td>
<td>What are first year chemical engineering students' conceptions of the energy changes taking place in dissolution?</td>
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<tr>
<td>Ellis, 2004</td>
<td>What are university students' approaches to learning science through writing?</td>
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<tr>
<td>France &amp; Davies, 2001</td>
<td>What are elementary teachers' strategies for teaching about values issues in technological problem solving?</td>
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<tr>
<td>Guisasola et al., 2004</td>
<td>What are university engineering students' and high school physical science students' conceptions of magnetic fields?</td>
</tr>
<tr>
<td>Hazel, Prosser, &amp; Trigwell, 2002</td>
<td>What are biology students' learning orchestrations? (How do they manage their learning activities in response to task or course demands?)</td>
</tr>
<tr>
<td>Ingerman &amp; Booth, 2003</td>
<td>What are the ways that physicists expound on their research? How do university physics students approach an advanced physics problem?</td>
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<tr>
<td>Johnston et al., 1998</td>
<td>How do quantum mechanics students conceptualize the mental models involved in the wave-particle paradox? How do students organize their thinking about abstract concepts like uncertainty and indeterminacy?</td>
</tr>
<tr>
<td>Kesidou &amp; Duit, 1993</td>
<td>What are students' conceptions of the 2nd law of thermodynamics (energy, irreversibility, heat transfer and temperature)?</td>
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<tr>
<td>Author(s) and Year</td>
<td>Research Question</td>
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<tr>
<td>Linder et al., 1997</td>
<td>What are the different ways in which physics tutors' metalearning abilities develop as a result of participating in a reflective practicum?</td>
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<td>Lister et al., 2004</td>
<td>What are the variations in understanding that computer scientists have of the purpose of teaching data structures?</td>
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<tr>
<td>Liu et al., 2002</td>
<td>What are university students' conceptions of energy (in general and related to the solution process of ionic compounds)?</td>
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<tr>
<td>Lybeck et al., 1988</td>
<td>How do students decide which samples contain 1 mole of substances?</td>
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<tr>
<td>Marton, Fensham, &amp; Chaiklin, 1994</td>
<td>What are Nobel prize winners' conceptions of scientific intuition?</td>
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<tr>
<td>Orgill, 2003</td>
<td>What are biochemistry students' conceptions of the analogies used in their classes?</td>
</tr>
<tr>
<td>Orgill &amp; Bodner, 2004</td>
<td>What are the circumstances under which students find biochemistry analogies useful? How do biochemistry students believe analogies should be presented to be useful?</td>
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<tr>
<td>Selley, 1996</td>
<td>What are children's conceptions of light and vision?</td>
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<tr>
<td>Sharma et al., 2004</td>
<td>What are university physics students' understandings of gravity in an orbiting space ship?</td>
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<tr>
<td>Stromdahl et al., 1994</td>
<td>What are chemistry teachers' conceptions of the &quot;mole&quot;?</td>
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<tr>
<td>Tao, 2002</td>
<td>Of which aspects are students focally aware as they read science stories designed to foster nature of science understanding?</td>
</tr>
<tr>
<td>Tsai, 2004</td>
<td>What are high school students' conceptions of learning science?</td>
</tr>
<tr>
<td>Tullberg et al., 1994</td>
<td>What are students' conceptions of &quot;1 mole&quot;?; What are educators' conceptions of how they teach 'the mole'?</td>
</tr>
</tbody>
</table>
What are biology teachers' conceptions of fairness in implementing school-based assessments?

The majority of the articles in Table 1 focused on identifying students' ideas about a particular scientific concept. For example, Lybeck, Marton, Stromdahl, and Tullburg (1988) examined students' ideas about the “mole” concept in chemistry. Walsh et al. (1993) studied students' ideas about the concept of "relative speed." Carlsson (2002) looked at students' ways of thinking about photosynthesis. Other articles focused on students' problem-solving strategies. Bhattacharyya and Bodner (2005), for example, focused on students' approaches to solving organic synthesis problems. Still other articles focused on more general aspects of science learning (see Brass et al., 2003; Ellis, 2004; Koballa, Graber, Coleman, & Kemp, 2000) and science teaching (see France & Davies, 2001; Orgill & Bodner, 2004) or on identifying the results of students' participation in an innovative class or program (see Linder, Leonard-McIntyre, Marshall, & Nchodu, 1997). Finally, some studies examined content experts' views about science and scientific processes (see Ingerman & Booth, 2003; Marton, Fensham & Chaiklin, 1994). It is clear that phenomenography can be used to answer many different types of questions related to science teaching and learning.

Phenomenographic studies can be done in combination with other studies and research questions. Johnston, Crawford, and Fletcher (1998) continued their examination of students' ideas about uncertainty and indeterminacy by determining which ideas were consistent with accepted scientific principles. Ellis (2004) determined which of university students' approaches to learning science through writing were most effective for learning. Dall'Alba et al. (1993) compared student conceptions of “acceleration” with their textbooks' explanations of that concept. Sharma et al. (2004) compared the ideas of two different groups of students about the concept of gravity in an orbiting space ship. Orgill and Bodner (Orgill, 2003; Orgill & Bodner, 2004) compared biochemistry students' views of the analogies used in their classes with the views of their instructors, identifying some key differences in the ways the students and their instructors were using that teaching/learning tool. Selley (1996) identified how children’s conceptions of light and vision change with age and educational experience. Koballa et al. (2000) compared pre-service teachers' conceptions of chemistry learning with their conceptions of chemistry teaching. Each of these studies demonstrates that phenomenography can lay the foundation for many different kinds of future research.

A Detailed Example of a Phenomenographic Study

I once attended a general chemistry class in which an analogy was used. It was clear to me that the students did not understand the analogy. The experience made me wonder what I should do to use analogies effectively in the biochemistry classes I taught. I began by searching the literature for relevant information. While I found a lot of information about analogies in general and about how children and young students interact with analogies, I found no information about how biochemistry students interact with analogies and very little information about how college science students use
analogies to learn or how college science instructors use analogies to teach. I decided that I would need to do my own research to inform my practice.

I chose to use phenomenography as the theoretical framework in my study for several reasons. First, I was primarily interested in the experiences that instructors and students have with analogies in biochemistry classes. I was not interested in my own experiences, but those of other people. Using phenomenography as a guiding framework, my own experiences were not directly examined. Second, my experiences as both a student and as an instructor of biochemical concepts led me to believe that different people have different ways of experiencing and understanding analogies. Phenomenography allowed me to identify and describe the multiple ways that students and teachers experience biochemical analogies. Third, I was interested in letting my participants define their own experiences with analogies, and the open, deep interviews that are generally associated with phenomenographic research allowed them to do just that. Finally, I would be able to use the “outcome spaces” of my study in order to develop an understanding of how students’ experiences with biochemical analogies relate to those of their instructors.

I developed a semi-structured interview guide that would allow me to explore biochemistry students’ and instructors’ conceptions of the analogies used in their classes. I was particularly interested in what they thought analogies were, when and why the analogies were useful in learning biochemistry, how students used the analogies to learn and how instructors used the analogies to teach. I designed questions that would allow my participants to comment on these issues from several different perspectives. I have included examples of these questions from the student interview guide below.

- I’m interested in the use of analogies as a teaching technique. An example of an analogy is “an atom is like a bookcase.” The word “analogy” has different meanings to different people. Can you describe for me, in your own words, what an analogy is to you?

- Do you remember hearing any analogies in your biochemistry class? Can you describe them for me?

- Do you use analogies to study? How? Do they help you when the time comes to take exams? If so, how?

- Do you like it when teachers use analogies? Why?

- What do you think are the advantages and disadvantages of using analogies?

- Why do you think teachers use analogies to teach?
I began the study by looking for participants. The goal of phenomenography is to identify the range of variation of experiences. I needed a wide range of student and instructor participants that would allow me to discover that variation. I requested student volunteers from several biochemistry-related classes, ranging from a freshman biochemistry class to graduate-level biochemistry courses. I also asked biochemistry instructors of different level classes and from different types of colleges/universities to participate in my study. I interviewed each of the participants, using the questions I had designed as a guide. I spent a good portion of each interview asking my participants to clarify their responses. I continued to ask clarifying questions of each participant until I felt that I understood how they were defining their experiences with analogies. After interviewing approximately 25-30 students, I began to notice that I was not hearing any new conceptions of biochemistry analogies during the interviews. I had reached saturation and began transcribing the interviews and looking for patterns in the data.

I read through the transcripts several times, making notes about the different ways that students (and instructors) defined what analogies are, how they use analogies, and when analogies are useful. Their descriptions became my outcome spaces. For example, I was able to identify the ways that students use analogies to learn in their biochemistry classes and the ways that instructors use analogies to teach in their biochemistry classes. When I compared the two, I found that there were some key differences in how and why the two groups were using analogies, which differences may have kept the analogies from being used as effectively as they could have been (see Orgill, 2003; Orgill & Bodner, 2004).

Conclusion

According to a constructivist point of view (see Chapter 2), learning and understanding is created in the mind of the learner through interaction with the world around him/her. Because one's constructed knowledge must fit a perception of reality, a group of individuals experiencing the same phenomenon will come to similar, but not identical conclusions. For example, we will all look at a ripe banana (not plantain) and say that it is yellow. However, our individual conceptualizations of yellow must be different according to constructivism. Thus, one of the powers of phenomenography can be to determine what those, sometimes subtle, differences are.

Phenomenography focuses on identifying variation in peoples' experiences of a topic. In chemistry/science education, phenomenography is most often employed to explore the variation in students' conceptions of a certain scientific topic. That variation can then be used to inform instruction that addresses students' current understanding. If you are interested in determining what is similar about how a group of people experience a phenomenon instead of the variety of ways they experience a phenomenon, phenomenology (see Chapter 7) would be a more appropriate framework than phenomenography.

Because phenomenography studies people's perceptions of their experiences and because perceptions are not necessarily consistent with observed reality, phenome-
graphy cannot report on the reality of a situation. For example, while students may perceive that they cannot solve buffer problems because they haven't seen enough examples of those types of problems, it is possible that through observing the students solve or talk about problems, the observer would be able to identify additional aspects of buffer problems that, in reality, impede students from solving the problems. While the second type of information (the "real" impediments to learning) is useful, it is not elucidated by phenomenography. Thus, phenomenography may not be able to elucidate the factors that contribute to a certain outcome — only the participants' perceptions of which factors contribute to a certain outcome.

Phenomenography can be extremely useful for determining what aspects of a phenomenon should be examined further. Sometimes you can go to the literature for that background information. If, however, no such research background exists, you do not know what features of an experience to focus on until you have performed some sort of exploratory research. Phenomenography seems ideal for performing that exploratory research. For example, Des Traynor (personal communication, September, 21, 2005), a computer science education researcher, describes his experience with phenomenography in the following way:

I think it highlights what is worth studying further. For example I recently concluded a study involving interviewing 24 students who had just finished first year computer science, and what I found through phenomenography was that the skill they thought most relevant for their success was their ability to learn foreign languages. Whilst this note itself could have been found through plain old paper studies with a "What skills are most important question", what I got was much more than that. It turns out that there are 2 schools of students, one of which rely almost entirely on their mathematical prowess when approaching C.S. The other group claim that Java is just an extremely restrictive form of a language, and they can get used to speaking in any language so for them, learning to program was learning the language itself.

Phenomenography seems well-suited for establishing a broad, but not deep, research base in a previously unexplored area or for future research. Because the focus of phenomenography is on describing the variation in the ways the members of the group experience a phenomenon and not on the individuals or the phenomenon itself, phenomenographic studies do not describe the richness of individual experiences or even the detailed characteristics of individuals in the group. If you want to describe the richness of one person’s experience with a phenomenon or the contextual influences on individual’s experiences with a phenomenon, phenomenography is not an appropriate framework.

The size of the population available for study may determine whether phenomenography is an appropriate framework for the study. Should the sample size be very small (one person, a handful of people), phenomenography may not be an appropriate framework. How can you reach saturation in identifying categories of description if you are only interviewing 2 people? In this situation, case study should be
combined with another theoretical framework (see, for example, Chapter 14 about critical theory). Additionally, phenomenography does not seem useful for determining which way of experiencing a phenomenon is most common. Typically, there are not enough participants in a phenomenographic study to make a generalization like this. A statistical analysis of a larger group — possibly accompanied by qualitative data — seems most appropriate here.

Although phenomenography is strictly a qualitative research framework, phenomenographic studies can be used to inform and design larger quantitative studies. Assume you want to study a group that is so big that it can only be covered by a quantitative instrument. In order to create the instrument, you must first know what responses to include as possibilities for the individual items on the instrument. A smaller, phenomenographic study can be carried out with the aim of identifying responses that can be included on the instrument for the larger study (see, for example, the work of Hutchinson, Follman, Sumpter, & Bodner, 2006).

There are questions that phenomenography cannot answer. Phenomenography, by itself, does not seem useful for answering questions of "is this way of experiencing better than another way of experiencing?" or "does teaching method A or teaching method B result in better test scores/conceptual understanding?" In phenomenography, different categories of description are identified; however, there is little judgment about the quality or "goodness" of the different categories of description. The goal is simply to identify the categories of description and the relations between those categories of description. Assigning quality to the categories means that they must be compared to an outside standard. Although this comparison goes beyond the bounds of phenomenography, it does seem like a natural extension of a phenomenographic study.

An After-thought: “New” Phenomenography

This chapter has focused on the describing classical phenomenography, as it was developed by Marton (1981, 1986, 1994). However, in recent years, a “new” phenomenography has been developed that focuses on the ontological concerns of describing “what is a way of experiencing?” Both classical and new phenomenography focus on the key concept of “variation.” In the new phenomenography, it is assumed that there are critical aspects of a given phenomenon that learners must simultaneously be aware of and focus on in order to experience that phenomenon in a particular way. Discernment of a critical aspect of a phenomenon results from experiencing variation in dimensions that correspond to that aspect (Marton & Booth, 1997; Pang & Marton, 2002; Pang, 2002). For example, if a critical aspect of the concept of “ripe banana” is the yellow color of the banana, learners must experience variation in the dimension of color to discern “yellowness” as a critical aspect of the concept “banana.”

One of the main ideas of new phenomenography is that if teachers understand which aspects of experiencing a given phenomenon are critical for students’ developing correct understandings of that phenomenon, they can develop experiences that allow students to examine variation along the dimensions of those critical aspects. Ideally,
experience of variation in critical dimensions will allow students to discern critical aspects of the phenomenon and, ultimately, develop correct understandings of the phenomenon (Pang & Marton, 2002). It is essential to identify the aspects of a phenomenon that are critical for students’ understandings because teachers’ critical aspects may be different from those of their students.

In this “new” phenomenography, researchers often assume a more direct role in data collection than in classical phenomenography. In order to determine which aspects of variation are available in the classroom, researchers record and analyze classroom discourse (Rovio-Johannson, 1999; Runesson, 1999). Runesson (1999), for example, identified the aspects that can be varied when teaching fractional numbers and percentages through the analysis of classroom transcripts.

Often, features of classical phenomenography are combined with features of new phenomenography. For example, Pang (2002) used classical phenomenography to determine the variation in secondary students’ understandings of the concept of sales tax. He then used new phenomenography to identify the critical features that yielded a good understanding of the concept of sales tax. Pang (2002) found that “when simultaneous variation in critical aspects was afforded, twice as many students reached a good understanding as did students in other classes where there was not simultaneous variation in the critical aspects of the object of learning” (p. 17).

There were no examples of chemistry/science education research in the journals I examined that used new phenomenography as a guiding framework. This is certainly an area in which future research can and should be done, particularly since such research can yield practical results that can inform instruction.

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References


Action Research as a Framework for Science Education Research

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Biography

William Hunter is an Associate Professor of Chemistry and Curriculum & Instruction at Illinois State University in Normal, Illinois. He is also Associate Director of the Center for Mathematics, Science, and Technology. He was born in England, grew up in Canada, and moved to the United States in 1994. He has a B.Sc. in Chemistry from Mount Allison University in Sackville, New Brunswick; a B.Ed. in Science and Social Studies and an M.A. in Curriculum Studies from Dalhousie University in Halifax, Nova Scotia; and a Ph.D. in Chemistry (Education) from Purdue University in Indiana. His research centers on translating learning theory into practice in chemistry teacher education, testing model programs for in-service teachers using data analysis to guide pedagogical change, and developing programs to encourage students from under-represented groups to consider science-based careers.

Introduction

The term Action Research appears in many sources. There are scholarly journals dedicated to the results of Action Research such as Educational Action Research and Action Research International. There are also many books that can help both the novice and expert through a project, such as The Action Research Planner, 3rd Ed. (Kemmis & McTaggart, 1988), Reflective Teaching and Learning in the Health Professions: Action Research in Professional Education (Kember, 2001), Action Research: A Guide for the Teacher Researcher (Mills, 2003), Action Research for Teachers: Traveling the Yellow Brick Road (Holly, Arhar, & Kasten, 2005), and All You Need To Know About Action Research (McNiff & Whitehead, 2006). Indeed, a recent search of Amazon.com generated a list of 600 books with the phrase “Action Research” in the title. In today’s society, perhaps the best testament to the power and appeal of this research methodology might be the result of typing “Action Research” into a web-based search engine. The last time we did this we obtain almost 6,000,000 “hits.”
This chapter, which draws heavily upon an article published in *University Chemistry Education* (Bodner, Maclsaac, & White, 1999), will provide just three parts of the Action Research story. We will begin with a brief background of the rationale for using Action Research. We will then describe studies from the chemical education or science education literature to see how action research was used to inform the research questions. We then describe, in depth, how we have used action research for one project.

**Background for Action Research**

Action Research is an approach to educational research that involves reflective intervention in an operating classroom setting. It is an outgrowth of a process that often occurs when instructors reinvent their approach to teaching a particular course based upon their perception of the efficacy of their previous experiences with the class. In a similar manner, those engaged in Action Research continually reinvent their questioning and analysis of a classroom situation to answer questions of interest about that course. The difference is that Action Research is a process designed to empower all participants in the educational process (students, instructors, administrators, and curriculum developers) with the means to improve the practices conducted within a particular educational setting. This process, the primary distinguishing feature of Action Research, is embodied in a series of self-evaluations and reflections by all participants. The need for active participation by all stakeholders means that in addition to having knowledge of ordinary instructional processes, all participants must be knowing, active members of the research process.

Action Research has its roots in the 1940’s when the social psychologist Kurt Lewin developed its current methodological characteristics (Lewin, 1946). During the 1950’s and 1960’s, Action Research was rarely practiced as researchers turned to more quantitative methods. In the 1980’s and 1990’s, however, as the positivist foundations of quantitative methods were more carefully scrutinized, Action Research became more popular, particularly through the work of Kemmis and McTaggert (Kemmis & McTaggart, 1988, 1990; McTaggart, 1991).

Kemmis and McTaggert describe Action Research as an informal, qualitative, formative, subjective, interpretive, reflective and experiential model of inquiry in which all individuals involved in a situation are knowing and contributing participants to the research study. Critical theory (see Chapter 14) as characterized by Habermas’s focus on emancipatory interest provides a foundation for understanding the methodology advocated by proponents of Action Research. Both Action Research and critical theory suggest that studies are enhanced and strengthened when all those involved are knowing and active participants (Young, 1990).

Action Research is most appropriate for participants who recognize the existence of shortcomings in their educational activities and would like to make changes in their initial stance in regard to the problem. According to Hopkins (1985), after the initial stance has been clarified, participants must formulate a plan, carry out an intervention, evaluate the outcomes and develop further strategies in an iterative fashion. Although each of these stages must occur, each stage does not necessarily need to be formally articulated. In this
sense, non-experts in research — students, teachers, and curriculum developers — can all contribute to the reform effort. Each individual brings his or her own frustrations and suggestions to the development exercise.

Winter (1989) describes six key principles which should be adhered to carefully for Action Research to be successful.

1) **Reflexive critique**

   An account of a situation — be it verbal or written in notes, transcripts or official documents — will make implicit claims to be authoritative, i.e., it implies that it is factual and true. Truth in a social setting, however, is relative to the teller. For Action Research to take place, some of the participants are likely to disagree that the current truth of a situation must be maintained. The act of research, then, may begin with testing those truth claims. The principle of reflective critique is used first to encourage people to reflect on issues and processes and make explicit the interpretations, biases, assumptions and concerns upon which judgments are made. In this way, practical accounts can give rise to theoretical considerations and subsequent theories can be challenged.

2) **Dialectical critique**

   Because social reality is consensually validated through language, the role of dialogue and therefore a dialectical critique is critical in understanding the relationships both between the phenomenon and its context, and among the individuals, the context and the phenomenon. The key elements to focus attention on are those constituent elements that are unstable, or in opposition to one another. These are the ones that are most likely to create changes. From a practical standpoint, unless quality dialogue is part of the Action Research project, and voice is given to all stakeholders, the project will soon fall apart as those disenfranchised stakeholders retreat from the project.

3) **Collaborative Resource**

   All participants in an Action Research project are co-researchers. The principle of collaborative resource expects that each person’s ideas have the potential to be equally important resources for describing the current situation and for creating categories for change. Action Research attempts to avoid *a priori* credibility from the initial status of one participant. This is not to say that all ideas are created equal, but that insights gleaned from noting the contradictions both between many viewpoints and within a single viewpoint are encouraged to be made explicit.

4) **Risk**

   The change and reformation process that occurs during Action Research potentially threatens many previously established ways of prior conduct. Fear of change can be
a significant hindrance to participants. One of the more prominent fears comes from the risk to ego stemming from open discussion of one’s interpretations, ideas, and judgments. Initiators of Action Research will use this principle to allay others’ fears and invite participation by pointing out that they, too, will be subject to the same process, and that whatever the outcome, learning will take place. Perhaps this is the most important skill in getting started with Action Research — using personal beliefs and trust to gain entry to the situation if one is an outsider, or to encourage participation when inside the situation.

5) Plural Structure

The nature of Action Research explicitly encourages a multiplicity of views, and critiques which, in turn, promote many future choices of action and interpretation. Coping with many possibilities, and dealing with many data sources and texts challenge the researchers to deal with an evolving problem and evolving and multi-faceted data-sources. Any interim results, therefore, act as a support for ongoing discussion among collaborators, rather than a final conclusion of fact.

6) Theory, Practice, Transformation

For Action Researchers, theory guides practice and practice reforms theory, in a continuous transformation. In any setting, actions are based on strongly-held assumptions, theories and hypotheses, and with every observed result, theoretical knowledge is enhanced. Theory and practice always come back to each other in a cyclic change process. The researchers are expected to make explicit the theoretical justifications for their actions, and to question the philosophical beliefs that underpin those justifications. Practical applications that follow are further analyzed in the cycle that continuously alternates emphasis between theory and practice.

By now, you should be getting the idea that Action Research involves a few key considerations and the more closely a group of Action Researchers adheres to those considerations the more likely for within-group success and for quality research to occur. The process must be open-minded, it must be inclusive, it must be open to change, and it must be active. The data considered initially and subsequently gathered must come from a variety of sources and must be shared among participants. The theories developed must be constantly scrutinized by participants for the extent to which they both answer the research questions and to which they promote a change in research questions.

Beliefs about Action Research

The use of Action Research is based on a series of assumptions that are so fundamental to this work they might be considered beliefs. First, Action Research assumes that teachers introduce changes in the curriculum or in the way they teach because they perceive weaknesses in the current situation. Essentially they have formulated a hypothesis (which may or may not be precisely defined) that a particular change will lead to a particular improvement. As a concerned educator/scientist they will wish to test or evaluate their
hypothesis. This means that a systematic evaluation should be done whenever significant changes are made in an established curriculum or in the way the curriculum is delivered. These evaluations should look behind the facade of answers to the question “do the students like it?” toward deeper questions such as “what do students learn that they were not learning before?” and “if we could provide students with a voice to express their opinions and concerns, what changes would they recommend?” Towns, Kreke and Fields (2000), for example, used Action Research to study small-group interaction in a physical chemistry course. Using field notes and questionnaires, the researchers worked with students to identify strengths and weaknesses in their instructional program. The researchers initiated this project because they believed that changing their approach might lead to better performance on the part of the students and to improved affective domain characteristics. The instructors had a hypothesis, and used several cycles of action research to involve their students in assessing the worth of the classroom experiences.

Second, Action Research is based on the assumption that any significant intervention into a practicing classroom will have an effect. (If no effect is found, this is more likely the result of poor experimental design than from a flaw in the intervention.) Instead of asking “does the intervention have an effect on the classroom environment?,” the Action Researcher is more likely to ask “what is the effect of the intervention on all participants? What changes occur to the teacher? How does the nature of the students’ experience change?” Rolnick, Zwane, Staskun, Lotz, & Green (2001), for example, used an Action Research approach to investigate how different modes of pre-laboratory preparation contribute to a fruitful laboratory experience for first-year students. In the course of their study, the researchers assumed that an effect would exist and then took steps to ensure that they could detect it. As a result of this study, they were able to conclude that the ability to prepare for the laboratory depended upon a change in students’ understanding of both conceptual and procedural components of the laboratory.

Finally, Action Researchers believe that changes in instruction seldom benefit all students equally. They believe that educational change may have both positive and negative effects; some students may benefit, others may be harmed. Action Research is therefore viewed as a cyclic process in which evaluations help us understand what aspects of the intervention are responsible for the positive effects and what facets give rise to the negative effects so that changes in the innovation can be made to maximize the positive effects and minimize the negative effects.

Action Research provides a link between theoretical discussions of what education should be and practical instances of classroom experience by requiring participants to reflect upon their circumstances and plan for the future of their education. Schön (1990) described the use of reflection to generate models from a body of previous knowledge. These models are used to re-frame a problem and experiments are then performed to bring about outcomes which are subjected to further analysis. Schön’s model of reflection-in-action, in which there is little distinction between research and practice, or between knowing and doing, is an ideal complement to the iterative and investigative nature of action research. Action Research is formative, rather than summative, in nature. Formative research helps to guide the development and implementation process in such a fashion that positive
aspects are enhanced and negative aspects are removed without the repercussions of a final report. Such research is described by Walker (1992) as (1) rooted in educational practice; (2) evaluated in terms of pragmatic, contextually-appropriate criteria such as participant utility; and (3) varied in data collection methods. According to Walker (1992):

Formative researchers use such methods as reviewing research, consulting experts, constructing conceptual models, measuring characteristics of the intended audience for the educational program, and trying out prototypes in laboratories and in realistic field settings. They seek to learn about such matters as the readiness and needs of the audience, the value of the content to society and to the audience, the appeal of the planned program to the audience, the receptivity of teachers to it, and its utility and appeal for both students and teachers. Formative research is usually eclectic in its choice of techniques for eliciting data, including self-reports (in the form of diaries, interviews or questionnaires), observations, tests, and records. (p. 111)

Walker goes on to discuss the validity of this kind of activity:

... formative research draws its greatest credibility from (1) the close similarity between the intended situation in which data are collected and the situation of ultimate interest (trying out prototype materials in a classroom can be very close to using final versions in typical classrooms) and (2) the compelling face validity of the data collected (observations of classroom interaction, test scores, and so on). (p. 111)

Communication with Participants

Another distinguishing characteristic of Action Research is the degree of empowerment given to all participants. Involvement is predicated upon the participants' knowing as much as possible about the research project, with as few as possible hidden controls given by the research leaders. In fact, many initiators of Action Research would prefer not to be known as leaders because it is vital that all participants — including the researcher, the teachers and the students — negotiate meaning during the project and contribute to the selection of subsequent strategies. In an ideal Action Research project, communication among all participants is welcomed and facilitated. In the simplest situation this is the teacher and students, but can (and perhaps should) include curriculum developers, administrators, and other stakeholders. Communication among all participants is of paramount importance as it is the only way that group progress can be made. Since Action Research looks at a problem from the point of view of those involved it can best be validated in unconstrained dialogue with them. Since Action Research involves unconstrained dialogue between the "researcher" (whether a teacher/researcher or an outsider) and the participants, there must be a free flow of information among them.
What Does Action Research Look Like in Practice?

Action Research has the primary intent of providing a framework for qualitative investigations by teachers and researchers in complex, working classroom situations. The essentials of action research design are considered to follow a characteristic cycle. Initially an exploratory stance is adopted, where an understanding of a problem is developed and plans are made for some form of intervention. The Action Research protocol is iterative or cyclical in nature and is intended to promote a deep understanding of a given situation, starting with conceptualizing the problem and moving through several interventions and evaluations.

Figure 1 tries to capture the iterative nature of action research along with the major steps of planning, action, observation and reflection before revising the plan. Throughout each stage and each cycle, the idea is to move closer to achieving some outcome by repeated iterations. It is possible that during any iteration the final outcome may be redefined, but the goal does determine the plan at any particular stage. The original goal provides the initial framework and protocol for the action, observation and reflection stages of the activity. Later protocols reflect changes in the goal as determined via experience during the reflections of earlier iterations of Action Research.

Figure 1. The Action Research Spiral

Criticisms of Action Research

One of the main criticisms of Action Research is that Action Research strategies focus on the action itself and the change within the setting, rather than upon the development of sound research procedures, techniques and methodologies (Gustavsen, 1993). This often leads critics into seeing Action Research projects as merely an application to solve practical educational problems — at best generating formative improvements and methodologies, rather than valid research knowledge obtained in a rigorous way. Orlikowski and Baroudi (1991) describe three possible weaknesses in Action Research that cause tensions between positivists and Action Researchers.

Lack of environmental control. This lack of control is one of the main reasons that Action Research is seen as inappropriate to test or produce strong theories. Without "solid
evidence” how can robust research models be built? In particular, any one variable might never be isolated in an Action Research study and so testing or refining causal models where the extent to which a dependent variable is influenced by a set of independent variables is likely to be unattainable.

**Local utility of the research conclusions.** While important links between variables can be unveiled in Action Research that might not result from the use of more deterministic approaches, the development of models with high external validity, i.e. that are valid outside the context of the Action Research project, can be very difficult (Berkowitz & Donnerstein, 1982). This lack of generalizability in most Action Research projects arises from the limited number of participants in in-depth, longitudinal studies.

**Personal bias.** The personal attachment of researchers with participants in Action Research projects may hinder good research by introducing and promoting personal biases throughout the process and in conclusions drawn. This is particularly true in situations involving a conflict of interests. Action Research requires that the researcher be very cognizant of his or her own biases and personal interests.

To some extent, these criticisms result from differences in beliefs about the goals of educational research. Traditional educational research has been preoccupied with philosophy and general theories; Action Research tries to find a link between theory and practice, to bring teachers and researchers together. Kock, McQueen and Scott (2000) assert that society is the victim of this dichotomy as educational research outcomes often end up forgotten on some dusty shelf without any practical application other than support for further theoretical research. Action Researchers maintain that their work contributes to theory in a much deeper and thorough fashion as the researcher has a close understanding of the educational environment. Action Research is seen as adding texture to theoretical ideas and a way of dealing with complex reality which cannot be adequately described by an oversimplified theory. In positivist research the rejection or confirmation of hypotheses is absolutely critical, while the main contribution of Action Research is to modify existing practice, and to describe the effects of the modification and in the process to reform an existing model or theory.

**Research Questions, Data Collection and Analysis in Action Research**

There is not direct relationship between the theoretical framework of Action Research and the methods used for data collection and analysis. Data collection and analysis in Action Research should be driven by the research questions being asked. That said, the collaborative nature of Action Research lends itself to interviews, group discussions, and other forms of qualitative data and analysis.

Action Research has helped answer questions that might not otherwise have been asked, such as:
• How do instructors overcome student resistance to a novel method?

• What factors ensure that groups operate effectively?

• What is the nature of the dissatisfaction that might lead an instructor to change to a problem-oriented approach?

• How can the use of explicit instruction develop intrinsic understanding?

• What factors make it difficult to change the classroom environment?

• What factors interfere with the ease with which a technique can be used by other instructors, or transported to other institutions?

• What effect does a mode of instruction have on the instructor’s attitude toward teaching?

When it comes to data analysis, Action Research practitioners often engage in inductive analysis, grounded theory analysis, or similar techniques as they look for factors and themes that emerge repeatedly from the data (Creswell, 2002; Silverman, 2004; Strauss and Corbin, 1998). Consider, for example, the process described by Brown (2004).

I used an inductive interpretation and analysis of data starting with minute details and working up into big themes. In other words, after reading all the data that had been collected, I identified the details such as issues, factors, themes, and items that came up repeatedly that emerged from the data. I will describe the process I went through as I read, absorbed, thought, sifted, and thought some more as I struggled to make sense of the adolescents’ experience.

I thoroughly read through of all the data many times to obtain a general sense of the content. Describing and developing themes was my primary objective at this point of the analysis. Next I coded the text and development of themes and/or descriptions from the common elements. By adapting Creswell’s qualitative stages to my study, I was able to unearth the big themes in a vast amount of data.

The initial stage of the data analysis required the organization of the data. After each of the six sessions, I transcribed the participant journals and read them over to ensure clarity. The session entries provided interesting information for each of the topics discussed in each session.

Next, a post-interview was conducted. When the member checks were completed and verified as correct, I read the transcripts over many times. I analyzed the individual sessions and interviews through the coding and the labeling of the text. Common themes began to emerge and take shape. During this stage of data analysis I labeled as many as 45 text segments or codes throughout the data. In successive readings I tabulated how many times each code occurred throughout the
entire data collection. In subsequent analysis, the codes were collapsed to six to seven major and minor themes through the process of eliminating repeated codes, codes that occurred only a couple of times, and finally codes that could not be categorized. Multiple perspectives were used to corroborate each theme. In other words, evidence for each theme was based on several viewpoints from different individuals. Triangulation among different data sources was also used to corroborate evidence from different individuals; in this study between the individual participants and the teacher and the method of data collection, journals, and interview transcriptions, were also used to corroborate each theme.

This process is echoed in article after article, as Action Research practitioners pull out main ideas from data generated by the participants through interactions and discussion. At each data collection stage, researchers would then turn the results of this process back to the group (member-checking) to decide if the process was producing a desirable goal.

**How Can One Determine if Action Research is Successful?**

The quantitative model of educational research, in which the performance of experimental and control sections is compared, has the advantage that we always know whether or not the hypothesis being tested was supported by the data collected in the study. The answer is given by the “objective” test of statistics. By focusing on those ideas that can be measured by statistical tests, however, we often lose the ability to measure the phenomenon in which we are interested. Or more likely in an educational setting, there are so many confounding variables that statistical tests are almost meaningless. Action Research focuses on ideas and strategies that interest the participants. This raises an important question: What characteristic of Action Research plays the role that $p$ values, $F$ values, or tables of two-tailed tests of significance play in more traditional quantitative educational research? In particular, how do we ensure that mistakes are not made in deciding which effects of an intervention are “positive?”

The answer is simple: no research methodology operates in a philosophical vacuum. Quantitative research is based on a philosophical tradition that its proponents describe as scientific and its opponents label as behaviorist and positivist (Fenstermacher, 1986). Action Research is tightly linked to critical theory and often linked most explicitly with the work of the German sociologist-philosopher Jurgen Habermas (Young, 1990). Kemmis and McTaggart (1990, as cited in Bodner et al., 1999) argue that Action Research is “... a process in which people deliberately set out to contest and reconstitute irrational, unproductive (or inefficient), unjust and/or unsatisfying (alienating) ways of interpreting and describing their world ... , ways of working ... , and ways of relating to others” (Bodner, et al., p. 34). As long as Action Research is a process done by a group, in which each member of the group is a knowing participant, and decisions or conclusions are agreed to by the group — not just the individual in charge of the course — they are likely to be the correct decisions about strategy or conclusions, be they qualitative or quantitative. When is Action Research successful? Precisely when all the stakeholders say it is.
Published Examples of Action Research Studies in Chemistry/Science Education

Most articles in the research literature on chemistry/science education that have involved Action Research have focused on facilitating professional growth on the part of teachers. Some researchers describe how they have used Action Research to help others, most often secondary or elementary science teachers, to evaluate and reform their teaching practice at their own pace. For instance, Hodson and Bencze (1998) describe how a group of teachers overcame challenges in innovation as they created more authentic science experiences for their students. Likewise, Pedretti (1996) described the experiences of six science teachers and a facilitator to explore and issues-based science, technology, and society (STS) education. In the mid-1990's, the National Science Foundation funded teacher enhancement projects in which secondary school teachers analyzed their own teaching. After taking a research methods course involving Action Research, the teachers met in groups over the course of three years to reform their teaching (Spiegel, 1995). The use of Action Research has changed the focus of teaching in many classrooms and improved teaching knowledge of the effects of instructional practices (Madsen & Gallagher, 1992; Staten, 1998).

In some cases, the “other” teachers were pre-service teachers who were learning to use Action Research as a foundational part of their teaching repertoire. Hewson et al. (1999) used Action Research to help pre-service teachers design research projects that focused on student conceptions and, thereby, develop the pre-service teachers' understanding of conceptual change. In a similar project, McGinnis and Pearsall (1998) report on the changes experienced by both teacher and students in an elementary science methods class and how this led to changes in the instructor's practice. More recently, Akerson and Reinkens (2002) report on a study which followed a pre-service teacher's attempts to design and deliver conceptual change chemistry instruction in the context of an action research project. In this study they describe the political and professional constraints encountered in making pedagogical changes.

A second major theme of Action Research is changes in pedagogy and how those changes influence student learning. Solomon, Duveen, and Scot (1992), for example, noted how they spent more than a year changing the way they used the history of science to promote British students' understanding of the nature of science. In the course of this process they provided quantitative and qualitative data as substantial evidence of specific changes away from positivist empiricism and toward a more post-modern view of the nature of science. In the late-1990's, Butler (1999) used Action Research to focus on the efficacy of problem-based learning and the development of student autonomy in a single science class. The emergence of students' critical-thinking skills, the relevance of science concepts taught, the interdisciplinary nature of the problems addressed, and the changing roles of the teacher and students were encouraged by the inclusiveness as part of the project. Lauterbach, White, Liu, Bodner, and Delgass (1999) used Action Research to study the introduction of computer simulations in a capstone chemical engineering laboratory course that focused on design. Through Action Research, they were able to modify the implementation of the computer simulations and enhance both the acceptance of these simulations by students and their subsequent learning. More recently, Chang (2005) described a set of changes in...
teaching practice from a traditional standpoint through a set of innovations to a more constructivist approach to teaching in a university physics course. Even more interesting is that this study described four years of change in the instructor’s behavior, rather than over a single semester or year. In particular, Chang noted the lack of early success in the teaching innovation that was followed by the rewarding outcomes later in the process.

Only a few articles on Action Research identify curricular changes and the effect of these changes on science learning. Willison (1999), for instance, developed the concept of scientific literacy and the nature of science through the use of metaphors to promote reflective thinking. The writing-of-recipes and the use-of-recipes metaphors were found to be advantageous in helping students to understand the common ground for otherwise divergent views on scientific literacy. Wholesale changes to the science curriculum through a focus on issues of science, technology and society (STS) were studied by Action Research teams facilitated by Hodson and others (Pedretti & Hodson, 1995; Hodson & Bencze, 1998). This process helped participating teachers formulate their own modifications within the curriculum, and helped students learn about STS issues. In a similar fashion, Waters-Adams and Nias (2003) used Action Research, not only as a way of understanding the processes of teaching, but to delve into the teachers’ own understanding of science content.

A Detailed Example of an Action Research Project

This project is part of a nationwide program funded by the National Science Foundation and is part of a larger study of teaching and learning of science and mathematics in schools being undertaken at Illinois State University. This project is an eight-year long University-School partnership project involving the departments of Biological Sciences, Chemistry, and Mathematics and more than ten school districts within driving distance from the University. The project started in 2001 and is in the sixth year of an eight-year plan, but the published reports are based upon the first four, five and sixth years of implementation (Mumba et al., 2003, 2006). The underlying goal of this project is to promote scientific and mathematical literacy in participating schools by sending undergraduate and graduate scientists and mathematicians to work with teachers and students in secondary schools. The project is following the NSF model of putting mathematics and science advanced undergraduate and graduate students in high school classrooms to help the teachers with subject matter knowledge and other resources.

Action Research was an appropriate framework for this project for two major reasons. First, no one involved in this project either locally or nationally had been part of a graduate teaching fellows project and so no one really knew how the project would proceed; and second, the project leaders believed very strongly that the teachers, fellows, and leaders involved in this project all had, and would each develop more expertise and more relevant expertise in the course of the project and hence should all be part of the project development and research process — an almost ideal Action Research setting.

In the first year of the project, fellows were matched with local teachers based upon the mutual content interests of teachers and fellows. The teachers and fellows then decided
upon novel curriculum units they would develop co-operatively. In essence, the teachers had ideas for novel units, but not the time to develop them; the fellows had the time to develop the units, but needed guidance from teachers about pedagogical style and implementation. (In the Action Research sense, this was the initial condition, which presented both a problem and opportunity for teachers, fellows, and researchers.)

Project leaders and fellows met weekly to discuss progress, the teachers and fellows met frequently (daily - weekly - biweekly), and the whole project group met once or twice a semester. At these meetings, competing agendas were negotiated and implementation strategies were discussed. Within the first five months, lessons were taught, and teachers and fellows created a few novel activities. (This was the initial intervention in the Action Research cycle) To assess the current state of the project, data were collected in the form of lesson plans, lesson observations, meeting notes, and semi-structured interviews.

At the end of the first six months, however, there was dissatisfaction with progress being made. Some teachers and fellows were very happy, others were not. Data collected indicated that some teachers expected fellows to have more well-developed teaching expertise — such as student teachers often have. Likewise, some fellows felt unprepared for secondary school student interactions. (This dissatisfaction became the impetus for a revised intervention — a second Action Research cycle.) In response, a new intervention occurred in which the whole group of fellows watched video-taped model lessons, read articles on classroom implementation, and attended lectures by school-based experts. (Within the context of the Action Research cycle, these were interventions chosen by the group to address perceived shortcoming in their preparation for working in schools.) A further round of lessons was developed and implemented over the next year in which very few of the original complaints resurfaced. The second year’s orientation program was modified to include more of the activities used in the implementation of the first year.

During the second and third year, researchers studied the content and nature of the fellows’ lesson planning and drew conclusions about the reflective attitudes of the fellows. The nature of the reflections centered on their lesson plans was found to be descriptive, critical, and dialogical (Mumba et al., 2003). It was still not clear, however, that students in schools were responding to these novel lessons with more thorough science or mathematics knowledge or that they were gaining insight into the nature of science as an endeavor. Since a major function of the project was to use the fellows as role-model scientists, this was disappointing to teachers and fellows alike. (This statement about the status of the project can be considered a new initial condition for Action Research, which in turn could — and did — promote a new intervention.)

At this point the groups developed new Research Questions which became the focus of four months of intervention. How consistent are the teaching fellow’s views of science, theories, and laws relate with the characteristics of science outlined in science education reforms? What changes (if any) in the teaching fellows’ understanding of science and the nature of scientific theories and laws can be promoted as a result of an intervention?
To address the questions surrounding the fellow’s perceptions of the nature of science, an explicit training program was developed based upon models used elsewhere including a pre- and post-assessment. The intervention on science, theories, and laws was provided to the participants in nine one-hour long instruction sessions spread out over one semester covering the characteristics of science outlined in science education reforms and literature namely: (1) science is a way of knowing, not the only way of knowing, (2) science is built on a set of functional assumptions such as predictability and testability, curiosity, creativity, imagination, (3) chance plays a significant role in science, (4) absolute objectivity is a goal of science but this is rarely achieved due to human natural bias and social cultural factors embedded in science, and (5) concise and persuasive communication of findings is crucial in science if one scientist's or group of scientists' interpretations of the findings are to be accepted by other members of the scientific community.

The participants were first engaged in hands-on activities and demonstrations that were designed to demonstrate and explicate the aforementioned characteristics of science. The set of inquiry activities were commensurate with those that the teaching fellows were expected to foster in K-12 classrooms. Each activity was followed by a structured discussion aimed at getting participants to reflect on the sort of new ideas they had learned, and how the new ideas differed from their initial science views. The discussions also enabled the participants to reflect on the inquiry activities they were engaged in, compare them to the activities they experienced their traditional science courses, and articulate the benefits and burdens of the new experiences.

The teaching fellows were then engaged in reading the text from science education reform documents such as Project 2061 in order that they might recognize contemporary explanations of science, theories and laws. Each participant responded to some questions. Then the responses were paraphrased and shared with the whole group during the sessions.

The participants then explored the interrelationships among the characteristics of science through activities and discussions. The goal was to help the participants understand that the characteristics of science are not discrete but interrelated.

All the activities in the intervention were conducted using one or a mixture of the following five instructional approaches: (1) concept map construction, (2) text reading, (3) experiments, (4) individual and group reflections, and (5) small and whole group discussions. The instructional approach used in a particular session was determined by the element of the nature of science to be addressed.

Data Collection Instruments and Procedure

Data were collected through a questionnaire, semi-structured interviews, and pre- and post-assessments. The questionnaire comprised five open-ended questions designed to elicit participants' understanding of science, theories, and laws. During the interviews the participants were provided with their pre-and-post-test questionnaires. They were allowed to read and asked to explain their responses. They were asked if their responses in the two surveys were the same or different. They were also asked to provide examples and
reasons to support any changes they made to their responses. This interview procedure provided the participants with an opportunity to describe the nature of their experiences, identify changes in their pre-and-post instruction responses, and elaborate on them.

Data Analysis

Data were analyzed by first coding the responses to identify recurring themes and descriptors. Theme identification was then performed by relating sub-themes through a combination of inductive and deductive thinking. Categories were then generated and representative profiles of the group were studied. The main goal was to develop a single storyline around which everything else was covered. The questions in the data sources provided the frameworks into which responses were categorized and further analysis led to a differentiation of the categories. We remained grounded in the data to allow it to speak directly, not through misinterpretation. In order to achieve this, two science education experts independently conducted the analysis using the procedure described above. Then, the two met to compare and discuss the themes and categories that emerged from the analyses. Some minor differences that emerged in the themes and categories were resolved through sustained discussions and a group analysis on the aspects that needed to be re-examined.

Conclusion

Regardless of whether it is applied to curriculum development, professional development, or planning and policy development, there is a consensus that Action Research is intrinsically collaborative. Kemmis and McTaggart (1988) argue that Action Research occurs within groups of participants who can be teachers, students, principals, parents, or other community members. What is important is a shared concern among the members of the group. There are proponents of action research whose slogan is “each teacher a researcher.” Others argue that an outsider should be included in the community being studied, who is neither the instructor nor a student, but who is actively involved with both students and their instructor(s) in the action research cycle and who does not have a vested interest in the success of the change being studied.

The key features of Action Research could be summarized as follows. Changes are made in what we teach or the way we teach it. Evaluation occurs while the changes are being made. As many sources of information are collected as possible. The participants in the Action Research cycle never presume that all students will benefit from the change and are constantly searching for ways to maximize the positive effects and minimize the negative effects of these changes. Students enrolled in the courses in which Action Research occurs are knowing, active participants in the decision-making process about changes that should be made in the next iteration in the innovation cycle.

There are many levels of Action Research conducted by and with various levels of teachers. At one end of the spectrum are studies which are well-planned, involve careful protocols, and have clear research questions and activities. Each cycle of Action Research is carefully documented, and the results are readily available in peer-reviewed journals. At
the other end are projects that are begun by teachers in their classrooms with the intention of reforming their practice or their students’ learning. These projects have a direct impact upon students’ learning, but the publication of these studies is outside any professional or personal need felt by the teacher-researcher. While, in our opinion, these are both valid forms of Action Research, both forms are not found in the research literature. If the number of articles in the research literature is compared to the number of websites for academic courses teaching, (and likely requiring Action Research projects) there are a huge number of Action Research projects that are initiated and carried out each year.

References


Ethnography and Ethnomethodology

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Biography

Gautam Bhattacharyya received his Sc.B. in Chemistry in 1992 from Brown University and his A.M. in Organic Chemistry from Harvard University in 1994 under the direction of Professor E. J. Corey. After several years as a Teaching and Research Fellow, Gautam “saw the light” and turned to chemical education at Purdue University. This change resulted in a Ph.D. degree in 2004 under the direction of George Bodner. At Purdue, Gautam explored many areas of chemical and science education and fell in love with chemical education research. Broadly defined, his primary research interests are in epistemology of professional practice and the philosophy of science. After completing two years as an Instructor at the University of Oregon, Gautam will be joining the Department of Chemistry at Clemson University as an Assistant Professor as of July 2006.

Introduction

Ethnography\(^1\) and ethnomethodology are two related, but distinct theoretical frameworks that revolve around the issue of culture. While ethnography tries to describe or define a culture, ethnomethodology seeks to understand how individuals make sense of their routine activities as members of a culture. This chapter will briefly describe each of these theoretical frameworks or perspectives, use published examples to show how each framework can be used to address research questions, and then discuss, in depth, an ethnomethodological study conducted by the author of the chapter.

Ethnography

With its roots in cultural anthropology, ethnography focuses on describing a culture or group (Fetteman, 1989). Although much of the early ethnographic research, such as

\(^1\) For the purposes of this chapter, the term “ethnography” will be used to refer to the theoretical framework, not ethnographic tools, such as observation and field study, associated with most qualitative research methods.
Mead’s *Coming of Age in Samoa* (1928) occurred within the field of anthropology, this framework has been widely used in recent years in most disciplines within the social sciences.

**Designing an Ethnographic Study**

There are several important elements or characteristics associated with ethnographic research and the choices made with regard to these elements or characteristics play a critical role in shaping the data collection process. The first of these elements is the notion of *culture*, itself. Ethnography assumes that any group of people who are together for an extended period of time will develop a culture of their own, i.e., a set of established norms and standards to which members of the group are held accountable (Patton, 1990). This definition of what constitutes a culture is purposely vague to allow for the greatest flexibility in conducting ethnographic research. It also acknowledges the fluidity of cultures with respect to issues such as composition of the group that represents the culture. The assumption of the existence of a culture is critical in ethnography because it implies that there are rational systems of conduct and behavior within a group which the researcher will be able to unveil.

The second element of ethnography is *perspective*. Classical ethnographers like Mead worked from a *holistic perspective*, which strives to develop the most complete and comprehensive description of the culture under study. This approach has inherent limitations because it asks the researcher to achieve the impossible, absorbing every aspect of the culture during the course of a qualitative study. Other perspectives include *semiotic ethnography*, which focuses the research on signs and symbols used among the members of a culture (Patton, 1990). A newer perspective is *critical ethnography*, which combines the principles of ethnography and critical theory (Chapter 14). In seeking to free individuals from the repressive aspects of their culture, critical ethnographers strive to define the constraints that a culture places on its members (Anderson, 1989).

The third major element of the ethnographic framework is the orientation toward an *emic* versus *etic* perspective. An *emic* orientation is adopted by the researcher who wishes to view the culture from the insider’s perspective, i.e., a perspective in which the researcher tries to become part of the culture under study. It is at one extreme of the participant-observer continuum (Patton, 1990). In contrast, an *etic* orientation would be adopted by a researcher who wishes to view the culture from the perspective of an outsider. Both approaches have their limitations. Research that proceeds from the emic perspective can often result in significant changes in the behavior of the group under study because of the researcher’s presence. The distance, however, required by the etic perspective may lead the researcher to reach erroneous conclusions. Because neither perspective is without problems, multiple data sources should be used so that the researcher may triangulate the data during analysis.
**Data Collection in an Ethnographic Study**

Once the target group is identified, the researcher must gain access to that culture. Once access is granted, the researcher must then decide whether to take an emic or etic perspective. This choice is often dictated by the nature of the group being studied; however, the researcher must make an explicit decision before data collection begins.

The fundamental method of data collection in this research paradigm is field work. It is only by observing the members of a group in action that ethnographers can begin their description of the culture. Field work is not limited to observing the members of the culture; it can include examination of artifacts, such as art or written work. It is often helpful to adopt a non-holistic perspective so that the researcher can concentrate the observation on a single facet of the culture rather than on its entirety. Regardless of perspectives or orientations that are adopted, the main goal for the researcher at this stage is to ensure that the observations are conducted as unobtrusively as possible, which is vital for preserving the naturalistic nature of the study.

The researcher will often follow extensive observations with interviews, which may be conducted at random or with key informants. The amount of structure imposed on the interviews and the particular population interviewed will be dictated by the nature of the study and by the availability of appropriate participants. Data collection in ethnography is inherently longitudinal.

Because observation is theory-laden — i.e., subject to the researcher’s prior experiences and biases — data collected in an ethnographic study must be carefully interpreted. Member-checking interviews in which the researcher shares his or her conclusions with the group under study are one way to attenuate this problem; another is triangulation with multiple data sources.

**Data Analysis in an Ethnographic Study**

The unit of analysis for an ethnographic study tends to be the culture, as a whole, because the ultimate goal of this theoretical framework is to describe the whole. Ethnographic data tend to be inductively analyzed so that themes are allowed to emerge from the data. This approach to data analysis is central to the framework, since ethnography is descriptive in nature.

**Strengths and Criticisms of Ethnography**

The primary strengths of ethnography are its adaptability and its neutrality. Because ethnography allows for a wide definition of “culture” it is adaptable enough to be used in a seemingly endless number of contexts. It is also adaptable in the sense that it can be combined with many other research traditions, which is one of the main reasons that ethnographic methods are so widely used in the social sciences. Furthermore, the descriptive nature of ethnographic accounts lends itself to a neutrality not shared by some of the other theoretical frameworks. In other words, in describing a culture, the
ethnographer doesn’t, personally, take a stance on practices of the culture that are acceptable or unacceptable.

Interestingly, neutrality is also a major source of criticism regarding this framework (Anderson, 1989; Herbert, 2000). Anderson suggests that critical ethnography was developed because ethnography, by itself, was perceived as not being able to take a stance. A second source of criticism is that ethnography lacks a solid epistemological basis. Herbert (2000) suggests that many fields of the social sciences are reluctant to use ethnography because of this reason. Fetterman (1989) strongly refutes the latter claim by stating that the ethnographers cannot proceed in their research efforts “without understanding the epistemological basis for a selected model” (p. 15). Thus, the researcher’s perspective brings an epistemic basis to the work. One could, therefore, argue that this feature adds to the adaptability of this framework. Another criticism of ethnography is that ethnographic research is not generalizable (Spencer, 2001). Although describing the details of one group may inherently limit the applicability of the results to other groups, some of the literature examples that are discussed in a later section demonstrate how this point can be cleverly addressed.

Ethnomethodology

Developed by Harold Garfinkel (1967), ethnomethodology was proposed as an alternative to existing sociological research paradigms, such as symbolic interactionism (Chapter 3). Garfinkel’s proposal of this new lens was an attempt to shift the focus of sociological research from the entire system — the “macro-perspective” — to the individual members of the system, whom he called “actors.” Ethnomethodology, therefore, strives to understand how the “actors” make sense of their routine activities by “... [getting] at the norms, understandings and assumptions that are taken for granted by people in a setting because they are so deeply understood that people don’t even think about why they do what they do” (Patton, 1990, p.74). Thus, a major goal of ethnomethodology is to make the implicit explicit.

Ethnomethodology is based on the notion that the members of a group or culture, “... organize and render observable the features of society and social settings” through descriptive accounts (Leiter, 1980, p. 161). These accounts — i.e., personal stories of experiences in the culture that actors use to make sense of their daily activities — are the backbone of ethnomethodology because they define the boundaries of membership since members of a group communicate under the auspices of the “et cetera principle.” The et cetera principle is “a recognition that people never can say explicitly and completely what they mean but can rely on each other to do any ordinary filling in” (Brandt, 1992, p. 321). An actor attains membership in a group or culture when he or she is able to do the filling in that completes incomplete thoughts expressed in a conversation. Accounts are not just stories; they are explanations and justifications of events or objects. Furthermore, although the most common method of accounting is verbal, accounts can appear in any form. Accounts are said to have two important qualities: indexicality and reflexivity.
Indexicality means that expressions in accounts must be interpreted in the original context in which they were used (Benson & Hughes, 1983). This idea is not difficult to understand since even simple words used in common parlance can have different meanings based on the tone with which they are expressed and where they are placed in an account. Therefore, in this framework, “[m]embers are interested in the particular not in idealized, standardized or typical meanings ...” (Benson & Hughes, 1983, p. 101). The second important attribute of accounts is their reflexivity. Leiter (1980) suggests that the role of accounts is to unveil aspects of the setting. Once this is achieved, however, “... accounts about the society and its workings become constituent parts of the very thing they describe. They are, in short, “reflexive” (Benson & Hughes, 1983). This reflexive nature suggests that justification for a present or future behavior can be derived from past experiences.

Data Collection in an Ethnomethodological Study

Since the primary goal of ethnomethodological data is to understand how members of a group make sense of their routine activities, there are, primarily, two data collection methods for studies using this lens: accounting of a newcomer and disruption experiments. In the first method, which is particularly well-suited for conducting case studies, the researcher attempts to elicit the accounts of outsiders as they make sense of their daily practices in a new culture. In listening to the participants retell accounts of experiences in the culture, the researcher should place the emphasis on accounting by the participants, asking them to justify each of their actions, especially those involving decisions. It is by this process that the researcher is able to uncover the sense-making processes of newcomers.

The unit of analysis for these data is the individual. Brandt (1992) suggests that when analyzing such data, chronology can be a useful aspect of analysis in the ethnomethodological approach, since when an individual acts is as important as the act itself in establishing membership in a group. In addition to creating a chronology, data may be analyzed using inductive methods. Although ethnomethodology is a powerful way to uncover implicit norms of the culture, the data collection process is cumbersome, requiring many interviews with a participant, and often relies on the memory of the research participant. However, since the lens focuses on the participant’s sense-making, observational field work is not, typically, essential. An example of this type of research is addressed in the final section of this chapter.

A second method of data collection common to ethnomethodological research is called the disruption experiment (Garfinkel, 1967). In this method, the researcher does something extraordinary in a common, everyday situation and records the actors’ reactions to the disruption. The rationale for collecting this type of data is that as the actors attempt to bring order to a chaotic situation by making sense of it, they will reveal the tacit practices of their group. A classic disruption experiment is facing towards the back of a crowded elevator rather than the front (Patton, 1990).
Although disruption experiments are a basic technique of ethnomethodology, they must be used with caution. If the researcher is an authority figure, the participants will tend to defer to the pattern or example of the researcher, assuming the disruption is the norm. Garfinkel (1967) observed this problem during one of his first experiments in which he asked a group of students to discuss their personal problems with an “advisor” who was hidden behind a screen. Although the advisor responded “yes” or “no” based on a sequence predetermined by the researchers, the students followed that advice even when answers were contradictory. Disruption experiments also should not be performed on newcomers to a culture. Because novices are in the sense-making process, they cannot differentiate the extraordinary from the ordinary.

Strengths and Criticisms of Ethnomethodology

Ethnomethodology’s strengths are, primarily, two-fold. The first is its ability to reconcile the dilemma of individual versus social learning. One of the paradoxes created by social-learning paradigms is the role of the collective versus the individual in learning (Cobb, 1994). Ethnomethodology cleverly resolves this issue by focusing on the individual’s meaning-making processes as a member of a culture, thus, making room for both perspectives. The second strength of ethnomethodology is its compatibility with many post-positivist frameworks, such as constructivism (Chapter 2) and situated cognition (Chapter 11). For example, like constructivism (Bodner, 1986), ethnomethodology does not seek to reveal or elucidate an absolute reality; rather, reality is constituted by the experiences of its actors. Furthermore, the indexical nature of accounts suggests that ethnomethodology is compatible with the notion of situated learning, since they both aver that learning is necessarily indexed (Brown, Collins, & Duguid, 1989).

Although the relativist positions of ethnomethodology allow compatibility with paradigms like constructivism, this subjectivity is also the source of its greatest criticism. Because ethnomethodology is centered on the experiences and meanings of the individual within a culture, it cannot be used to make judgments of any sort, especially to take moral or other ethical stances. This attribute is especially unattractive to critical theorists who address power and inequity issues (Sharrock, 1989. A second criticism of ethnomethodology is aimed at its more recent offshoot, conversation analysis (Atkinson, 1988; Sharrock, 1989. By focusing ethno-methodological studies primarily on discourse, scholars such as Atkinson and Sharrock argue that conversation analysis overlooks the basic principles of ethnomethodology — indexicality and reflexivity — because it decontextualizes the interactions.

Chemical/Science Education Research Using These Frameworks

As we have seen, ethnography is appropriate for describing an entire culture or group; ethnomethodology focuses on an individual’s meaning-making process as a member of a group or culture. Thus, ethnomethodology not only presumes that a culture exists, but that there are at least rudimentary ways to describe it and/or define its boundaries.


Chapter 10: Ethnography and Ethnomethodology

Examples of Ethnographic Research

Because of the open-endedness of ethnography, virtually any descriptive study would be appropriate for this lens. However, a major purpose of these studies has been to introduce a new culture to members of an existing culture. Often the new group is a minority of the larger population. In education, therefore, this body of research has concentrated on describing various subgroups of students, in an attempt to inform authorities in education about problems from the students' perspective. For example, studies of inner-city youths have helped curriculum designers better understand the obstacles faced by a group with whom they, typically, have little contact.

To date, there have not been any studies in chemical education using ethnography as the theoretical perspective or lens. A search of the relevant literature, however, has identified a few studies in the general field of science education.

In a series of studies, Crawford and collaborators extensively used ethnography to understand how students develop into scientists. In one study (Kelly & Crawford, 1997) the authors studied high-school physics students as they collected and analyzed experimental data to determine “what counts as science in the science classroom.” In subsequent work, Crawford, Kelly, and Brown (2000) studied the ways in which students, teachers, and practicing scientists construct methods of inquiry in the sciences and how each group defines “knowing.” More recently, Crawford (2005) investigated the non-written communications between teacher and students in an effort to define students’ scientific knowledge.

Studies by Hayes and Deyhle (2001) and Darby (2005) show how comparative research can be done using ethnography as the theoretical perspective. Hayes and Deyhle (2001) sought to understand some of the factors that promote inequities in education by studying two elementary schools from the same school district. The students in one school were predominantly Caucasian and from high SES backgrounds while the students from the other school were predominantly non-Caucasian and from low SES backgrounds. Darby (2005) used ethnography to investigate students' perceptions of different instructional strategies in science education to help her create “engaging pedagogies” for her students.

Finally, a couple of studies using critical ethnography have been reported. In both of these reports (Barton, 2001; Seiler, 2001), the authors' intentions were to introduce the science education community, by way of their studies, to the framework of critical ethnography. Both studies concentrated on using inner-city students' work in the sciences to develop a better understanding of how to improve their education.

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2 For the purposes of this chapter, the literature was assumed to consist of the major journals in chemical and science education: *Journal of Chemical Education*, *The Chemical Educator*, *Chemistry Education: Research and Practice* (including *University Chemistry Education*), *Journal of Research in Science Teaching*, *International Journal of Science Education* (including the *European Journal of Science Education*), *Science Education*, *Science and Education*, and *Research in Science Education*.
Examples of Ethnomethodological Research

When concentrated on the experiences of newcomers ethnomethodology is a powerful framework for performing process research — i.e., research on how individuals perform a task — since it can reveal the barriers that students must overcome when learning a new discipline (Brandt, 1992). The tendency of ethnomethodology to elicit the tacit often reveals practices that are so ingrained in a profession’s routines that even experienced teachers would not have thought to explicitly address these topics in an instructional setting.

Other theoretical frameworks, such as phenomenography (Chapter 8), are effective for answering questions such as “how do students solve mechanism problems in organic synthesis?” (See for example, the paper by Bhattacharyya & Bodner, 2005). They are not as powerful as ethnomethodology, however, for answering questions such as “how do individuals learn to solve mechanism problems in organic synthesis?”

Ethnomethodology is also highly effective in studying professional practice, or as Schön (1987) calls it, defining the epistemology of professional practice. In this area, research can help reveal key practices of professionals that are so implicit that they don’t realize how important these routines are.

Although ethnomethodology is potentially a powerful theoretical framework for chemical education and science education research, a search of the literature reveals surprisingly few accounts using this framework. McGinnis and Simmons (1999) used ethnomethodology to study teachers’ perceptions of introducing controversial science-technology-society (STS) topics into their curricula. The authors wanted to investigate how five K-12 teachers’ beliefs about subjects in STS affected their ability or desire to implement said topics in their classes.

Two other reports describe the experiences of newcomers to a culture. In the first, Bleicher, Tobin, and McRobbie (2003) examined the daily activities of a chemistry teacher and his students. The researchers’ goal was to understand how discourse between teacher and pupil can affect learning. In a pair of related articles, Roth and co-workers (Bowen, Roth, & McGinn, 1999; Roth, Bowen, & McGinn, 1999) investigated how science students begin to evolve into scientific researchers. In doing so, the authors studied how college students and professors of ecology interpret data in their field and differences in the ways these data are presented in textbooks versus research journals.

A Detailed Example of Ethnomethodological Research

The author’s doctoral dissertation will be used to showcase the use of ethnomethodology in chemical education research (Bhattacharyya, 2004). The main goal of this study was to take a step toward understanding how students learn to solve organic synthesis problems.
As in any qualitative study, adopting a theoretical framework requires a familiarity with some of the key factors involved in what is being studied. Although this insight typically comes from reviewing the literature, there were not enough data in the literature on organic synthesis problem solving when this research began. Thus, significant amounts of pilot data were gathered to help define the landscape (Bhattacharyya & Bodner, 2005; Calimsiz, 2003). The initial studies were based on problem solving in organic chemistry and involved both undergraduate and graduate students. The combined results suggested that graduate-student participants would have to be recruited to address the goals of a study of the process by which students learn how to solve organic synthesis problems and that the data collection was going to have to occur over a period of time rather than in a single interview.

As the focus turned towards graduate students, a major issue became apparent. Graduate students develop sophisticated, practitioner-like problem-solving skills while members of a research group, which is a social-learning environment. Examples of social learning that occurs within a research group include formal or informal problem-solving sessions, discussing the content of papers in the relevant literature with peers both in and out of academic settings, attending professional meetings, and consultation of predecessors’ laboratory notebooks. In an attempt to reconcile the paradox of individual versus social learning, ethnomethodology, for aforementioned reasons, seemed to be the ideal framework because it could be used to understand the experiences of an individual in a culture, thereby, resolving the paradox of social versus individual learning.

Because this framework presumes the existence of a group or culture, the next step was to explicitly define that group and set some boundaries. Thus, synthetic organic chemists were defined to be a community of practice (Chapter 12) because they routinely use language and tools that are unique to the pursuit of synthetic chemistry. These aspects of synthetic chemistry are specialized enough that a well-trained chemist from another discipline would not be able to readily participate in a discussion between practicing synthetic chemists. The specialist language of synthetic chemistry is its reactions. These reactions may be named, such as the Wittig reaction, or they may be unnamed and referred to by the author(s) and work in which they were used. These reactions are a language specific to synthetic organic chemistry because they denote ideas and concepts that only a practitioner could appreciate. For example, the simple phrase “Wittig reaction” can evoke:

- The starting materials used and the product obtained from the reaction;
- the mechanism of the reaction;
- the conditions by which the E- or Z- olefin may be obtained; or
- congener reactions such as the Horner or Wadsworth-Emmons reactions.
The two most frequently used heuristics exclusive to organic synthesis are retrosynthetic analysis and the arrow-pushing formalism (see the discussion of APF in Chapter 2) as a way of describing reaction mechanisms. Less obvious features that are unique to organic synthesis include the importance of the literature, the manner in which molecules are represented and viewed, and even the aspects of a reaction that are given importance.

The synthetic schemes in the literature or drawn on paper by members of this community of practice become the ethnomethodological accounts of this research because these schemes are the basis for much of the communication among synthetic organic chemists. The *et cetera* principle applies to these schemes because simple reaction steps, such as the quenching steps through which the addition of acidic protons are achieved, are rarely included. These schemes have indexicality, because common abbreviations in these schemes are indeed contextual. An “R,” for example, can represent anything from very simple alkyl groups to complicated carbon skeletons, depending on the particular synthesis being done. Finally, these schemes are reflexive because literature precedence is the most frequent type of support synthetic organic chemists give for the steps in their new synthetic proposals.

Adoption of the ethnomethodological framework was a major step in this study because it helped translate the overarching goal into specific guiding questions, which, in turn, helped determine the research participants and data collection and analysis procedures. All of these decisions about research design were based on the premise that one aspect of maturity in synthetic organic problem solving is achieved by membership in the community of practice of synthetic organic chemists, i.e., understanding its conventions.

Three guiding questions were generated for this research:

- How do graduate students in organic chemistry learn to solve organic synthesis problems?
- What processes do graduate students in organic chemistry use to solve organic synthesis problems?
- How does acculturation among graduate students affect the problem-solving process?

Since the goal was to understand how acculturation affects problem solving ability, chemistry graduate students who were members of research groups with a primary focus on organic chemistry were recruited. Two types of participants were sought. One group contained first-year students enrolled in a graduate course in organic synthesis for which one of the main assignments was a term-long synthetic proposal of a previously unsynthesized molecule. The second set of participants consisted of third-year students who were working on a total synthesis for their Original Proposal (OP), a requirement for the Ph.D. program in chemistry. These two groups allowed the
researcher to examine how students develop as they become progressively more immersed in the culture of organic chemistry.

In her study of writing process research, Brandt (1992) used an ethnomethodological approach which depended heavily on interviewing participants while they worked on writing tasks. She elucidated the participants’ sense-making procedures by making them account for each event during the writing task. Although a similar, naturalistic approach was used for the data collection in this study, the participants were not interviewed while they worked on their projects because of the long periods of time devoted to their project and the tendency of this effort to be distributed over weeks if not months. Instead, periodic interviews were conducted in which participants reflected on their work on the project. Participants were also asked to keep reflective diaries, which revealed minor, insignificant discrepancies with the interview data. Due to the inconsequential nature of the reflective journals, they were not used in the eventual data analysis.

Although the primary source of data was individual interviews with participants, the researcher also attended the meetings for the organic synthesis course to understand the classroom environment to which the students in the first group were exposed. The focus of the interviews was the participants’ work on their projects and their justification for each problem-solving maneuver. Because the goal was to have the participants justify points that may have seemed self-evident to them, it was important to explain to the participants that the questions posed by the researcher during the interviews should not be interpreted as suggesting that they were going in the wrong direction; the questions were designed to help them articulate their thought processes. These interviews were conducted weekly until the participants had completed their projects and gotten feedback from the professor of the organic synthesis course, in the case of the first-year graduate students, or from their examination committees, in the case of the third-year graduate students. During the course of all the interviews, the researcher took field notes and recorded post-interview observations as needed. Finally, photocopies of all the participants’ written artifacts, including scratch work, were collected by the researcher.

Because the unit of analysis for ethnomethodological research is the individual, the three sources of data — transcripts, researcher notes, and artifacts — for each participant were repeatedly examined to establish a chronology of events for each individual. Thus, individual case records were generated to describe each participant.

The individual cases were separated into the two groups of participants: the first-year graduate students and the third-year graduate students. From the pooled data, emergent themes that described each group were generated (Patton, 1990). The common themes from each group were then compared and contrasted to find differences in the problem-solving approaches of each group. From this comparison, the data coalesced into an overarching theme that described the experiences of all the participants. Final conclusions were drawn from this overarching theme.
Validity was assured in the following manner. First, the conclusions that were developed were grounded in the data (Strauss & Corbin, 1998). Second, the study was done in a naturalistic setting. The participants worked on problems they chose and were engaged in activities that fulfilled the requirements of their Ph.D. program. Furthermore, they worked at their own pace, rather than having a time limit imposed by the researcher. Third, because the final conclusions were drawn from comparing groups rather than individuals, the effects of individual differences were minimized.

Because the focus of this chapter is on the design of a research study, the specific results of this work will not be discussed in detail. However, it is important to note that by using this framework the researcher was not only able to address the goal of the study, but he was also able to address the following topics:

- The effects that the perception of task authenticity had on learning;
- Some of the factors that promoted the change from student-like behavior to practitioner-like behavior; and
- The way membership in a community of practice affects an individual's development in the field at large.

Conclusions

The two frameworks described in this chapter offer powerful methods for the qualitative researcher. The creativity of the research reported by Darby (2005) and Hayes and Deyhle (2001) demonstrate that ethnographic studies need not stop at a purely descriptive state. When carefully conducted they can be used to perform comparisons between sets of data.

Finally, although ethnomethodology has been underutilized in chemical education research, the example shown in this chapter suggests that it is a powerful framework for fundamental learning research. Furthermore, this paradigm may serve as a key framework as researchers strive to develop the epistemology of professional practice in chemistry (Samarapungavan, Westby, & Bodner, 2005; Schön, 1987).

References


Situated Cognition

MaryKay Orgill
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Biography

MaryKay Orgill is an Assistant Professor of Chemistry at the University of Nevada, Las Vegas. Her education has been eclectic and her professional life somewhat schizophrenic so far. She studied chemistry at Brigham Young University to prove that a girl could “do chemistry” and do it well. She was surprised to find during her undergraduate studies that she actually liked chemistry — and loved teaching it. Not willing to be tied to only one kind of learning or working, she enrolled in graduate school at Purdue University to study both biochemistry and chemical education, completing a degree in each of those fields. She continued to pursue both interests as a first-year faculty member with a joint appointment in biochemistry and science education at the University of Missouri-Columbia. During that year, she took on the extra challenge (and incredible learning experience) of teaching a high school chemistry class. In 2004, she moved to her home state of Nevada to take a position at UNLV, where her research focuses on undergraduate chemistry and biochemistry education and where she enjoys working with undergraduate chemistry students and teachers in the local school district. In 2006, students at UNLV named her their favorite chemistry professor.

Introduction

A fairly new theory of learning, “situated cognition” or “situated learning” was originally developed in response to a cognitive science perspective that focused specifically on the decontextualized individual as learner and which assumed that knowledge was an entity that could be gained or transferred from one person to another (Brown, Collins & Duguid, 1989; Lave, 1993, 1997). Situated cognition posits that knowledge exists not as a separate entity in the mind of an individual, but that knowledge is generated as an individual interacts with his or her environment (context) to achieve a goal. In other words, situated cognition theorists see learning as a contextualized and situated process. Kirshner and Whitson (1997) describe the struggle between the cognitive science and situated cognition perspectives as follows:

The central philosophical assumption against which situated cognition theories struggle is the functionalist belief in mind-body dualism. Viewing the world of a
person’s ideas, beliefs, and (intellectual) knowledge as autonomous — essentially disconnected form their bodily (i.e., lived) experience, and hence from their sociocultural context — provides broadly for a devaluing of lived experience in favor of “higher” (abstracted) contemplative activity. (p. 4)

Situated cognition has roots in many different theoretical perspectives, including anthropology, critical theory, Vygotskian sociocultural theory, social interaction theory, philosophical situation theory, ecological psychology, ethnomethodology, practice theory, and Deweyian pragmatism (Bredo, 1994; Greeno, 1998; Kirshner & Whitson, 1997). Both Jean Lave and colleagues John Seely Brown, Allan Collins, and Paul Duguid have been credited with developing the situated cognition theory, but their work clearly has many precedents. They are certainly not the first researchers to indicate that there is a relationship between an individual and his or her environment that influences learning.

Although situated cognition was originally developed as a theory of learning, some researchers are using the principles of situated cognition as a theoretical framework to guide their educational research. In this chapter, I will discuss the situated perspective on learning and the implication this perspective has for research in science education. It should be noted that situated cognition is a theory that is still under development. As such, many of its tenets and methods are not firmly established at this point.

**Situated Cognition and Legitimate Peripheral Participation**

**Situated Cognition**

Proponents of situated cognition see learning as more than the process of the acquisition of knowledge. They suggest that learning is a continually occurring, adaptive process that is situated in a context (Bredo, 1994; Clancey, 1993, 1995; Greeno, 1997; Greeno & Moore, 1993; Kirshner & Whitson, 1997; Lave & Wenger, 1991; Suchman, 1993). That learning is situated does not simply mean that learning occurs in a particular environment or context. Instead, situation cognition theorists would say that learning is a generative process in which knowledge is created as an individual and his or her context interact in an authentic activity to achieve a goal (Clancey, 1993). Dewey (1963) states that “an experience is always what it is because of a transaction taking place between an individual and what, at the time, constitutes his environment” (p. 43). During the activity, the individual and context influence and change or construct each other. As such, the learner and his or her context (including the people located in that context) should not be seen as separate entities. According to Roschelle and Clancey (1992), “representation and meaning are not prior to social and physical interaction but are constructed in activity” (p. 444).

Situated cognition theory suggests that our understanding of a concept is constantly under construction (Brown et al., 1989). Every experience that we have influences how we view a concept. In turn, our understanding of the concept influences how we act and interact in a new situation; and the experience we have in the new situation will, again,
change how we view the concept. Our experiences influence how we view a concept, and our understanding of a concept influences future experiences. Take, for example, the use of a particular tool. We may read about a tool and logically understand a possible use of the tool. That understanding will influence how we initially attempt to use the tool. However, the act of using the tool (or of watching other people use the tool) may elucidate other possible uses of the tool, which will affect how we use the tool in the future. Our view of what the tool is and what it is useful for will constantly be under modification with each new experience with the tool.

The context in which learning or meaning-making occurs is much more than a physical location. It includes not only the physical objects in the context, but the other people in the context, as well as the social, ethical, and historical norms that guide how people interact with the objects in the environment and how they interact with each other. Lave and Wenger (1991) state that “cognition and communication in, and with, the social world are situated in the historical development of on-going activity” (p. 51). According to Brown et al. (1989), most learning is social and done in a context. Interactions between individuals often result in knowledge. Therefore, they argue that “within a culture, ideas are exchanged and modified and belief systems developed and appropriated through conversation and narratives, so these must be promoted, not inhibited” (Brown et al., 1989, p. 40).

Many supporters of situated cognition would go so far as to say that all learning is situated and influenced by social and historical norms. Even an individual who is studying on his own by reading a textbook is influenced by the social norms that created the textbook (Clancey, 1995; Greeno, 1997). In fact, many situated cognition theorists do not like to use the term “situated cognition” because it suggests that only some types of learning are situated. Greeno (1997) prefers the term “situative” when referring to the situated cognition theory:

I use the term “situative” to designate a theoretical perspective rather than “situated learning” or “situated cognition,” because those other terms suggest that some learning or cognition is situated but other learning or cognition is not situated. In the situative perspective, all learning and cognition is situated by assumption, so use of “situated” as a modifier of “learning” or “cognition” is syntactically misleading. (p. 16)

*Legitimate Peripheral Participation*

In order to further explain the ideas of situated cognition, Lave and Wenger (1991) introduced the concept of *legitimate peripheral participation* (LPP). They argue that learning is a process of increasing participation in a community of practice (CoP). A CoP (see Chapter 12) is a group of individuals who share common goals, ideals, norms or practices. In this view, a learner is seen as a “newcomer” to the community of practice. Initially, the newcomer’s interactions with the community might begin through observations of the CoP on the *periphery* of the community — observing how members of the community behave and interact and trying to determine the rules and values that
guide the community and their culture (Brown et al., 1989; Clancey, 1995; Hung & Chen, 2001; Roschelle & Clancey, 1992). Legitimate peripheral participation is more than observing a community, though. Ultimately, legitimate peripheral participation must involve participation. It involves a newcomer’s participating in tasks, functions, and activities that are authentic and that can be seen as legitimate actions for a member of the community (valuable to members of the community). As the newcomer learns more about how to act and be a member of the CoP, his or her participation in the community increases. Ultimately, the “newcomer” becomes an “old-timer” with a stake in the future of the community. Thus, while the CoP has an influence on the individual and his or her learning, the individual also influences the CoP and its future. Essentially, LPP is seen as a process of enculturation into a particular CoP (Roschelle & Clancey, 1992).

Legitimate peripheral participation does not have to be a formal process. It can occur through everyday interactions. The learning that occurs during LPP is not necessarily a unidirectional process in which knowledge is gained through interactions of newcomers with old-timers. Learning could also occur as newcomers interact with each other. For example, much of what I learned about being a member of the chemistry graduate student CoP, I learned informally from other newcomer graduate students and their “war stories” about interactions with their research, their peers, and the graduate college.

As a result of legitimate peripheral participation with a CoP, newcomers become incrementally attuned to the implicit rules that guide the behavior of the members of the community (Greeno, 1994, 1998; Greeno & Moore, 1993). Roth (1996) describes the process in these terms:

To be a member [of a community of practice], one has to share its (linguistic) conventions, standards, behavior, viewpoints, and so forth. … The process of becoming a full member in such a community can thus be described as a trajectory from legitimate peripheral to core participation in the community’s practices. (p. 182, italics in the original)

An individual can simultaneously be participating on the periphery of multiple CoPs. He or she might adopt some of the principles and behaviors of one CoP and some of the principles and behaviors of another CoP. Engestrom and Cole (1997) call humans a species of “border crossers,” in that we all belong to multiple CoPs and are constantly crossing between these CoPs. I, for example, am a member of the science educator CoP; but I am also a member of CoP that consists of my family members. My behaviors in each CoP are slightly different, but my membership in each of the various CoPs is what determines who I am, my identity. Indeed, the process of legitimate peripheral participation in various communities of practice is often seen by situated cognition theorists as a process of identity formation. As I have been increasing my participation as a member of the university professor community, my identity as a university professor has become more firm.

The picture I have painted in the previous paragraphs about the process of becoming a member of a CoP is somewhat ideal. CoPs are not necessarily groups of friendly old-
timers who welcome the introduction of newcomers. After all, the newcomers will eventually become old-timers who influence the future of the CoP, a future that may not be desired by all of the original old-timers in the community. In many instances, the old-timers and the culture in which their CoP exists may deny certain newcomers from obtaining legitimate peripheral participation in the CoP — consciously or because of the norms that have been historically generated in the community (Brickhouse, 2001; Lave & Wenger, 1991; Walkerdine, 1997). For example, Case and Jawitz (2004) report on the experiences of chemical engineering students during their internship experiences. Some of the students were assigned menial tasks during their internships instead of tasks that are meaningful to the members of the chemical engineering community (i.e., asked to make coffee or file papers instead of participating in the management of a plant). These students were denied access to legitimate peripheral participation in the community because they were not allowed to participate in authentic tasks. As a result, their identities as future chemical engineers were affected. Roth and McGinn (1998) state that when newcomers are denied LPP, they are not able to become full members of a CoP: “unless the tools and activities that learners use directly lead to the everyday practices of a particular community (e.g., physics, biochemistry, microbiology), target learning is actually undermined and interstitial practices develop” (p. 224).

Research Based on a Situated Cognition Framework

Research guided by situated cognition focuses not only on the interactions between individuals and their contexts and how those interactions contribute to learning, but also on issues of legitimate peripheral participation. Situated cognition researchers have examined the types of LPP that are required for becoming a full, participating member of a CoP. They have also examined issues related to the denial of LPP to certain individuals or groups of individuals, including women and members of various ethnic and racial groups (see Chapters 14, 15, and 16). Lave and Wenger (1991) have commented on the need to examine the denial of LPP to particular groups:

Hegemony over resources for learning and alienation from full participation are inherent in the shaping of the legitimacy and peripherality of participation in its historical realizations. It would be useful to understand better how these relations generate characteristically interstitial communities of practice and truncate possibilities for identities of mastery. (p. 42)

Assumptions of Situated Cognition

The principal assumptions of the situated cognition theory are related to the nature of reality and the nature of learning. According to this theory, knowledge and learning do not exist independent of the relationships between individuals and their contexts. There is no fixed reality; the individual and their environment co-construct each other (Bredo, 1994). Knowledge is not an entity that can be gained by an individual in a classroom. As noted by constructivists (see Chapter 2), it cannot be transferred intact from teacher to student. Knowledge is constantly under construction. It is created as individuals act or
participate with their environments or contexts (Lave & Wenger, 1991). Bredo (1994) states that “mind is an aspect of the person-environment interaction” (p. 24).

Situated cognition also assumes that learning occurs through a process of legitimate peripheral participation into various communities of practice and that “participation is always based on situated negotiation and renegotiation of meaning in the world” (Lave & Wenger, 1991, p. 51). Each community of practice is driven by implicit rules that guide the behavior of the members of the community. As Lave and Wenger (1991) noted, situated cognition seeks to identify those implicit rules:

Learning, transformation, and change are always implicated in one another, and the status quo needs as much explanation as change. Indeed, we must not forget that communities of practice are engaged in the generative process of producing their own future. (p. 58)

The context in which learning occurs is not simply a location: it is seen as a legitimate participant in the process of meaning-making. According to Lave (1993), “meaning is not created through individual intentions; it is mutually constituted in relations between activity systems and persons acting, and has a relational character. Context may be seen as the historically constituted concrete relations within and between situations” (p. 18).

Finally, situated cognition assumes that there is a social component to learning (Bredo, 1994; Wilson & Myers, 1999) and that language is “a means for social coordination and adaptation” (Bredo, 1994, p. 29). Situated cognition researchers examine language to determine how meaning is created. It should be noted, though, that language is only one type of data that can be used to determine how individuals and their environments interact to create knowledge. In order to truly determine how meaning-making occurs, multiple data sources should be examined.

**Situated Cognition-Informed Research**

**Research Foci**

The aims of the situated cognition framework are not clearly defined at this point in its development. However, several authors have suggested different research foci for a situated cognition-influenced study. Each of these foci has one thing in common: they concentrate on how people learn while involved in authentic, meaningful activities (Bredo, 1994; Clancey, 1995; Greeno, 1998). Wolfson and Willinsky (1998) state that “those investigating situated learning … pay special attention to the learning that goes on within apprenticeships, coaching, repeated practice, reflection, and collaboration” (p. 23).

Whether an activity is authentic depends on the learning environment and the CoP involved in the study. If a researcher is examining how chemistry students interact with their classroom context to create knowledge and understanding, an “authentic” activity is one that takes place in the classroom and has meaning for the community of
chemistry students. If the researcher is examining how a new graduate student learns to be a member of a research group, however, an authentic activity would be related to the practices of the research group.

Greeno (1998) summarizes some of the goals of situated cognition research as follows:

The goals of this research include coming to understand principles that organize that practice, which is a traditional goal of ethnography. Research goals can also include coming to understand cognitive contents and behavioral skills involved in processes of participation, thereby including the cognitive and behaviorist perspectives in the research agenda. At the same time, there is another goal of obtaining information and understanding that can support changes in resources and activities that would strengthen the practice. (p. 22)

Accordingly, the following research foci are possible for a study informed by situated cognition:

- Interactive systems of activity — the interactions between an individual and his or her environment that generate learning (Bredo, 1994; Greeno, 1998);
- The features of an environment that contribute to an individual’s accomplishing a learning goal — the constraints and affordances of the environment (Greeno, 1998);
- “The structures of the world and how they constrain and guide behavior” (Wilson & Myers, 1999);
- The tacit assumptions that underlie practice and which can be elucidated through observations of interactions of an individual and his or her environment — particularly when the individual is a newcomer to a CoP (Greeno, 1998); and
- Issues related to legitimate peripheral participation in a CoP or access to that participation (Lave & Wenger, 1991).

Methods

There are no established methods for conducting a situated cognition-informed study; however, there are methods that are consistent with the principles of situated cognition, and those methods are typically ethnographic. The primary source of data for most situated cognition studies is observations of people interacting with and in their environment while they perform authentic, meaningful tasks within a CoP (see, for example, Bianchini, 1997; Clancey, 1994; Osterlind, 2005; Roschelle & Clancey, 1992; Roth, 1996). The interactions may be video- or audiotaped; alternatively, field notes may be recorded of the interactions. In order for the data source to be useful in a situated cognition study, the focus of the observations should be on the interactions
between the learner and his or her environment or on the features of the environment that support the learner’s meaning-making process — not simply on individuals or on the context. The data from observations may be complemented with artifacts that are produced during the learning activity.

Observations made while participants work on authentic tasks can be followed up with interviews in order that the researcher can identify the meanings of interactions when those meanings are not immediately accessible through observation (Bianchini, 1997; Roschelle & Clancey, 1992; Roth, 1996). These interviews tend to occur during the learning activity or soon after because, according to the principles of situated cognition, each new experience the participant has will change his or her view of that experience. In some cases, where the researchers have not had access to the specific learning environment, individual and focus group interviews have been the main data source (see, for example, Case & Jawitz, 2004). In this situation, the interviews focus on the interactions that the individuals had with their learning environments.

Although there does not seem to be an official statement about the role of the researcher in the data collection process for a situated cognition-influenced study, Wilson and Myers (1999) suggest that researchers may be participant observers in the learning activity. Not every study informed by situated cognition uses participant observation, however. In many cases (see, for example, Roth, 1996), the researchers try to maintain a distance between themselves and the individuals they are observing so as to minimize the influence they have on the learning activity. In either case, researchers must be aware of the potential influence their presence in the environment has on the learning activity.

**Units of Analysis**

Just as the aims and research foci of situated cognition research are not well defined, neither is the unit of analysis for a situated cognition-informed study. Several possible units of analysis have been suggested by different authors, including:

- A “person plus” unit of analysis, in which the individual and context are not different levels of understanding, but intertwined (Wilson & Myers, 1999);

- The sociocultural setting in which activities are embedded (Kirshner & Whitson, 1997);

- Discourse (Engestrom & Cole, 1997; Gee, 1997);

- The personal identities formed by individuals in different environments or discourses (Engestrom & Cole, 1997; Walkerdine, 1997); and

- Intentions — individuals’ choice of initial goals and how actions are renegotiated in and with the environment in order to reach the goal (Young, Kulikowich, & Barab, 1997).
The key factor in a situated cognition study is that the unit of analysis must focus on the interaction between the individual and his or her environment or context. Data tends to be analyzed in the same manner as data collected in an ethnographic study (Chapter 10).

**Benefits and Criticisms of Situated Cognition**

Situated cognition gives educational researchers a different lens through which to examine learning. Instead of focusing on the individual and their mental representations of knowledge (as is done in the Models and Modeling perspective, see Chapter 4), researchers using the situated cognition perspective pay attention to the context in which learning takes place and how the learner and his or her environment interact to create knowledge. Although, to date, this framework has not been widely used in science education research, the perspective may yield new insights into how students learn in particular environments and what contextual resources aid or hinder their learning.

However, the fact that many of the tenets of the situated cognition perspective are still under development leaves the framework open for criticism. Most of the criticisms are directed at situated cognition as a perspective on learning and may exist primarily because the critics of situated cognition do not completely understand the proponents’ vision of the perspective. In this section, I will describe these criticisms and situated cognition’s response to the criticisms.

Proponents of situated cognition describe all learning as situated in a context. The situated nature of knowledge is a problem in and of itself, according to the theory’s critics (Anderson, Reder, & Simon, 1996; Vera & Simon, 1993). If all learning is connected to a specific context, how can we account for the transfer of knowledge from one context to the next? Situated cognition theorists counter by saying that transfer occurs when a learner recognizes a similarity in features of the environment that support learning (affordances):

This is not to say that cognitive activities are completely specific to the episode in which they were originally learned or applied. In order to function, people must be able to generalize some aspects of knowledge and skills to new situations. Attention to the role of context removes the assumption of broad generality in cognitive activity across contexts and focuses instead on determining how generalization of knowledge and skills occurs. The person’s interpretation of the context in any particular activity may be important in facilitating or blocking the application of skills developed in one context to a new one. (Rogoff, 1984, p. 3)

Critics also suggest that assuming knowledge exists in the interaction between an individual and his or her environment means that individual, abstract representations of knowledge do not exist. Supporters of the cognitive science perspective argue that there is no evidence to back up this claim (Vera & Simon, 1993). Greeno (1997), however, states that “in the situative perspective, use of abstract representations is an
aspect of social practice, and abstract representations can contribute to meaningful learning only if their meanings are understood” (p. 13).

The situated cognition theoretical framework is also subject to criticism. The results of a situated cognition-informed study are connected to the learner/environment interaction that was examined in the study; therefore, the results of such a study may not be generalizable to other populations or contexts. Philosophically, the idea that situated cognition research could be applied to other situations or populations runs contrary to the principles of the situated perspective, which emphasizes a specific individual/environment connection (Bredo, 1994).

Rodriguez (1998) complains that “situated cognition … ignore[s] both the agency that individuals have (or lack) to transform their own sociocultural contexts and how those contexts provide (or deprive) individuals of agency” (p. 597). I find this criticism to be somewhat unwarranted, however. Several situated cognition studies focus on issues of denial of legitimate peripheral participation to underrepresented groups. Situated cognition could easily be combined with principles of critical theory (Chapter 14), feminism (Chapter 15), or the Afrocentric framework (Chapter 16) in a study that examines how underrepresented groups are denied legitimate peripheral participation in particular CoPs. Brickhouse (2001) sees great promise for the use of situated cognition in these types of studies.

From a research design and data analysis perspective, it may be difficult to conceptualize or describe an “interaction” between an individual and his or her environment. It is less difficult to conceptualize a description of an individual or his environment than a description of the interaction between the two. What should be the unit of analysis? As I have mentioned previously in this chapter, several authors have suggested different units of analysis; however, no one unit of analysis has been accepted by the situated cognition community (Engestrom & Cole, 1997; Lave, 1993).

**Examples of Situated Cognition Research in Science Education**

There have been studies that have compared situated learning environments to more traditional learning environments (see, for example, Griffin, 1995); however, there are a limited number of studies in science education that have been guided by situated cognition as a theoretical framework. In most of these studies, researchers observed learners in context to determine how meaning-making occurred and how the learners’ interactions with their context contributed to the meaning-making process. Clancey (1994), for example, examined how two students and a computer program interacted to negotiate a common understanding of what a “straight” line is. In a similar study, Roschelle and Clancey (1992) observed physics students who were using a computer program designed to teach the concept of “motion.” The students interacted with each other and the program to determine which aspects of motion they should pay attention to and how to represent the motion in vector notation. Roth (1996) observed a grade 4-5 classroom that was completing a civil engineering unit. He examined how students interacted with each other to generate understandings of different engineering...
principles. He also studied how the classroom context influenced students’ learning and how, in turn, what students learned influenced the classroom context.

Bianchini (1997) took a slightly different perspective. She examined students who were working in groups in a 6th-grade Human Biology class. She was interested in how students learn during groupwork and whether certain students were denied access to groupwork (a form of legitimate peripheral participation in the classroom) and, thus, to learning. She videotaped groups as they interacted and then interviewed individual students. She found that students’ access to groupwork was influenced by the students’ perceived social and academic status: “high-status students had significantly higher rates of on-task talk than their middle- or low-status counterparts, and that those students who talked more learned more as well” (p. 1039).

**Detailed Example of a Situated Cognition Study**

Case and Jawitz (2004) conducted a situated cognition study in response to Brickhouse’s (2001) suggestion that situated cognition could be used as a framework to study situations in which certain gender or racial/ethnic groups have been denied access to legitimate peripheral participation in a particular community of practice. They examined the internship experience of chemical engineering students in South Africa. In particular, they were interested in exploring issues of how gender and race affect access to legitimate peripheral participation in the community of chemical engineers during the vacation work experience and how students’ identities as future chemical engineers were influenced by the type of participation they were allowed in the community. Each of these interests is consistent with situated cognition’s focus.

Because context plays a legitimate role as a participant in the knowledge-creation process, Case and Jawitz began their study with a discussion of the environment in which the vacation work would occur. Because of apartheid, black students had historically been denied access to the educational experiences required for participation in the community of chemical engineers. Although the number of black chemical engineering students has increased dramatically over the past 20 years, chemical engineering in South Africa remains dominated by white males. Case and Jawitz argue that the culture of chemical engineering in South Africa is not particularly friendly to women or underrepresented groups. They hypothesized that the culture of the chemical engineering CoP would influence chemical engineering students’ internship experiences.

The research questions that guided the study were consistent with situated cognition’s emphasis on legitimate peripheral participation and identity formation. They focused on the interaction between the students and the context of their vacation work experience:

- How did the student experience and interact with the “community of practice”?
- Can what the student did in the workplace be described as “legitimate peripheral participation”?
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- How did the student respond when access to legitimate peripheral participation was denied?

- How was the student's identity as an engineer-to-be influenced by the situated learning experience? (Case & Jawitz, 2004, p. 419)

The participants in the study were 16 chemical engineering students of various gender and racial/ethnic backgrounds. Because Case and Jawitz did not have immediate access to the interns’ work locations, they gathered data about the students’ experiences through both focus-group interviews and individual interviews. The interviews focused on the interactions the students had with their vacation work environment. The interviewer in both cases was not connected with the project otherwise. The choice of interview facilitator was deliberate. Case and Jawitz felt that students would be more comfortable describing their interactions with the vacation work context to a “neutral” party. The two types of interviews yielded different data. During the focus group interviews, students discussed issues they may have forgotten to mention otherwise, simply because another member of the focus group mentioned the issues. The individual interviews may have allowed some participants to express sensitive issues that they would not have discussed in a group.

The researchers identified several factors that influenced students’ access to legitimate peripheral participation and, consequently, identity formation, of which I will only mention two examples. Some of the students, including female students and black students, were given menial tasks (such as making coffee or filing papers) as part of their internship experience instead of meaningful experiences that would allow the students to learn what it is to be a member of the chemical engineering community. As a result, one student commented that, after his internship experience, he did not see himself as being “that type of engineer.” His identity as an engineer-to-be was negatively influenced by his experiences. Case and Jawitz (2004) summarize:

We have seen the potential for good experiences to enhance and develop both black and female students in their choice of career path, but also the possibility that negative experiences can be extremely destructive in this regard. ... It is clear that relevant and meaningful work has the potential for significantly enhancing a student’s sense of identity and self-worth while the denial of the opportunity to do such work can force students to doubt themselves and their career choice. (p. 428)

The mentor that was assigned to each of the students had great influence on the students’ access to legitimate peripheral participation in the community. For example, mentors, who were often white males, tended to invite the male students to socialize after work. These socializing experiences became a source of informal mentoring about what it means to be a member of the chemical engineer. The female students were not typically invited to socialize with their mentors. As such, they were denied access to this type of informal mentoring:
The presence of a mentoring engineer appears to have substantial potential in facilitating access to legitimate activity. ... Furthermore, the engineer’s personal views on race and gender issues appear to play an important role in dealing with vacation students, especially those who are not white and male. (Case & Jawitz, 2004, p. 429)

Overall, the authors found situated cognition to be a useful framework for examining issues of access to legitimate peripheral participation and of identity formation:

The study examined some of the difficulties experienced by these students, and the theoretical perspective enabled findings which explain the interactions of race and gender issues in these instances. In addition, the theory allowed for the identification of key persons or actions which allowed students to transcend these structural problems. (p. 429)

Conclusions

Situated cognition is an underused and still-developing theoretical framework, but it has the potential to refocus educational research on the role of context in the learning process and on how individuals interact with and use their resources to negotiate meanings. As such, it should be used when the researcher is interested in the role of the context in learning and specifically when the researcher is interested in the interaction between the individual and his or her context. It should not be used when the focus is simply the decontextualized individual (as it is in phenomenography, see Chapter 8) or simply the context.

Situated cognition could be a particularly useful theoretical framework for examining the process of becoming a member of an authentic community of practice. In such a study, a researcher might examine the features of a context that support or hinder the learning trajectory from legitimate peripheral participation to core participation in that community. Brickhouse (2001) states that situated cognition may be useful for studying how underrepresented populations are allowed (or denied) access to legitimate participation in a community and how that participation (or lack of) affects the individuals’ development of identity:

Learning is not merely a matter of acquiring knowledge, it is matter of deciding what kind of person you are and want to be and engaging in those activities that make one a part of the relevant communities. ... The concept identity focuses attention on the individual, but expands our view of the individual to include social structures. It accounts for the importance of both individual agency as well as societal structures that constrain individual possibilities, both of which are necessary for any adequate understanding of gender relations. (p. 286)

It seems certain that the context in which learning takes place has an effect on what is learned. Situated cognition has the potential for elucidating the influence of context on the learner (and the learner on the context), which can provide insights about how
students learn in both apprenticeship-like environments and the classroom. It therefore deserves continued examination as a guiding framework for science education research.

References


Communities of Practice

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Biography

Alexius Smith Macklin is an associate professor of library and information science at Purdue University. Her research interests are in information and communication technology (ICT) literacy and the use of communities of practice and instructional design models to integrate these skills into situated learning environments. She specializes in interdisciplinary and international uses of problem-based learning for implementing and assessing information and communication technology (ICT) curricula. Currently, she is designing and teaching a course in nursing informatics for incoming freshmen.

Introduction

Communities of practice are groups of people who share a concern, a set of problems, or a passion about a practice and who deepen their knowledge and expertise by interacting on an ongoing basis (Wenger, 2000). Typically, these groups evolve through interactions such as professional discourse and collaboration and have the goals of increasing efficiency and understanding. Scientists, for example, frequently form networks to collaborate with other researchers and, as a result, are often more productive because they share their knowledge to gain reputation and social capital within a community of their peers (Surowiecki, 2004). In other words, experts in an organization or discipline become more successful by helping and mentoring others. This same theoretical framework is applicable to educational settings. Rosebery, Warren, and Conant (1992) described the effects of collaborative inquiry on the acquisition of scientific ways of knowing and reasoning among language-minority students in middle and high school. Their findings suggested that the students’ reasoning skills improved as they learned to communicate ideas and engage each other in dialogue.

Socially constructed activities, such as discourse and collaborative inquiry, are the types of interactions encouraged in a community of practice, and they are different from those of traditional learning communities in that knowledge and understanding develop around
authentic problems or tasks (Brown, Collins, & Duguid, 1989; Wenger, 1998). The traditional learning community attempts to simulate real-world activities to engage members in critical thinking and problem solving, but the tasks are not authentic — meaning they do not evolve out of the community from a shared need, concern, problem, or task. Instead, they are contrived by experts to meet specified learning needs of novices. An example of this might be training new employees, with no previous experience, to fix a piece of equipment. Everyone starts at the same point, with the same training materials, to complete a given task. Even if they collaborate to meet the end goal, they are still starting from a place of deficit where knowledge is disseminated to them, not created by them.

A community of practice, in contrast, would develop around the need to fix a piece of equipment. Those members with previous experience would collaborate with those who have none to identify what went wrong with the machine, determine how to repair it, test possible solutions, and record the steps taken so that, if and when it breaks in the future, there will be a resource to reference. Knowledge in this environment is socially constructed as members describe what they think the problem is and establish a method of communicating and working together. As they engage in sense-making conversations about issues of concern and problem solving strategies, they divulge individual expertise and skills that become part of a collective knowledge base (Jonassen, 1999; Roschelle, 1992). Through discussion, debate, and discourse, the group determines how best to use these unique contributions for the welfare of the community. The result is tacit knowledge from incremental, interactive, and collaborative participation (Jonassen, 2001). The practical know-how that evolves from this engagement is usually not openly expressed or stated in the act of completing tasks or solving problems (Polanyi, 1976); rather, it is knowledge that is drawn from convergent experience and reflection “on the job” (Schon, 1983) as the community learns to work together.

Wilson (1995) referred to this as situated learning — blurring the lines between theory and practice by incorporating elements of everyday cognition and meaningful experiences into the learning process. Outcomes of participating in these real-world activities include knowledge useful in managing oneself, others, and one’s tasks; knowledge applicable to both short-term and long-term contexts; and knowledge of ideal qualities as well as practical realities (Wagner, 1987). As members of the community of practice gain more “on-the-job” experience, their workplace intelligence increases and they become more proficient at tasks, including problem solving in their field of expertise (Wagner & Sternberg, 1985). The principles and procedures they consistently use to solve problems and complete tasks comprise what is, or becomes, common practice — essential qualities of which include mutual engagement, shared repertoire, and joint enterprise among members (Wenger, 1998).

**Mutual engagement** refers to negotiated activity where individuals work to establish a frame of reference for behaving and communicating within the group. Rogers (2000) described this as an exchange of meaning — challenging, testing, and revising common perspectives about practice and procedure in a way that is respectful of all
contributions, even if there is disagreement among members. Through the acknowledgment of individual experiences and the development of relationships among members of the community, mutual understandings develop from revelations of similar experiences. Traditional learning communities differ from communities of practice in this respect because practice does not evolve from collective knowledge or experience; rather the focus is on individual growth and skill development from imparted knowledge about principles and procedures for accomplishing certain tasks or solving problems. There is no interpretation of practice, no negotiation of meaning, and no shared repertoire.

The *shared repertoire* in a community of practice refers to a pool of resources that members not only share but also to which they contribute on an ongoing basis. These include tangible tools and artifacts, such as manuals and documents, and intangible tools, such as common discourse or routine methods of accomplishing tasks (Lesh & Lehrer, 2003). Each tool is meant to capture and externalize the thinking — or the mental models — of the members of community from each person’s unique perspective. The culmination of individual representations is, in essence, the collective knowledge of the group, as negotiated for common use. Mutual engagement provides the frame of reference to renegotiate any ambiguities in shared meanings that may develop from new understandings or experiences while using these resources (Bielaczyc & Collins, 1999). From these negotiations, common goals develop that allow the group to continue extending the boundaries and interpretation of practice. In traditional learning communities, there is no shared experience or history on which to build a collective knowledge base, no compilation of resources, and no unified endeavor from which to develop a common goal.

In addition to establishing a collective knowledge base and setting mutual goals, the following components distinguish the community of practice from traditional learning communities: (1) varying levels of expertise simultaneously represented and (2) fluid peripheral-to-center movement that symbolizes the progression from novice to expert (Johnson, 2001). The first difference refers to members with more expertise working collaboratively with newcomers. As knowledge about principles and procedures is acquired through experience and interactions with experts, the novice members gain expertise (Dufresne, Gerace, Hardiman, & Mestre, 1992). There is considerable variance, however, in levels of expertise. Not everyone in the community is expected to be an expert in everything. Each member is required to maintain an active role, but not do the same job or make the same contributions. Alternatively, traditional learning communities do not account for diversity in ability among members because the assumption is that everyone is starting from the same intellectual place to solve a problem or complete a task (Greeno, 1977; Voss & Post, 1988). Within this environment, there is a sense of uniformity and expectation that everyone will contribute equally.

The community of practice takes into consideration all variability in experience and contributions, noting that not everyone can contribute equally due to limitations in experience, intellectual capacity, and emotional maturity (Gardner, 1983). The degree to
which people play central roles, therefore, is determined by their sense of identity in the
group (Lave & Wenger, 1991) and their ability to contribute to collective knowledge and
goal development. Peripheral roles, or those of the novice, are valued for their
contributions, too, but expert knowledge is considered a primary resource. These roles,
and the flexibility between them, mark the second difference for traditional learning
communities and communities of practice. Bielaczyc and Collins (1999) described the
fluidity of centrality and peripherality as context-dependent where members are able to
contribute more or less based on their personal knowledge of the task. This means that
sometimes the novice is the expert — and sometimes it is the other way around,
depending on the circumstances. As members of the community move in and out of
various roles, they begin to develop their own interests in pursuit of the common goal,
thus taking on their identity in the group.

Legitimate peripheral participation is the process of engaging and involving newcomers
in activities and social exchanges within the community (Lave & Wenger, 1991). Peripherality
indicates the possibility of members’ contributing at different levels of
expertise, depending on knowledge and skill, as defined by the community. For
example, an expert at fixing one type of machine may become a novice when a newer
model breaks down; but if he is able to draw on prior experiences to improve the
collective knowledge base with a sophisticated, and accurate statement of the problem,
then he once again achieves expert status. These meaningful contributions establish
legitimacy and place within the community because they provide powerful
representations to support the learning of others who may not have had similar
experiences (Jonassen, 2004; Roth & Roychoudhury, 1992). By creating temporary
frameworks, or scaffolds, experts can enhance the abilities of novices and encourage
them to perform at levels higher than expected. This is accomplished through coaching
and constant feedback, thus fulfilling the purpose of the community of practice: to
promote learning via communication among their members (Ertmer & Russell, 1995).

The function of the community of practice in the classroom is to promote activities and
discussions that teach learners how to engage, participate, and contribute to a collective
knowledge base. Within this learning environment, the teacher’s role is facilitator,
organizing and directing these activities as students become responsible for their own
learning and the learning of others. This job includes co-constructing both goals and
criteria for meeting those goals with the students, evaluating whether or not those goals
were met, and using peer and self-evaluation to monitor the intellectual and social
growth of the group (Palloff & Pratt, 1999). For science teachers, in particular, this
means finding ways to encourage students to think and talk like scientists. These
dialogs function as a way of formulating, testing, and sharing ideas where students raise
questions, propose hypotheses, and extend their scientific knowledge. As with learning
any new concept, competence is gained through practice, participation in problem-
solving activities, and argument using the rhetoric of the discipline. In time, this
discourse increasingly comes to resemble the discourse of working scientists (Roth,
McGinn, Woszczyna, & Boutonné, 1999).
Aims of Communities of Practice

The aim of the community of practice as a learning environment is to foster a culture of discovery and engagement, where both individuals and the group, as a whole, are learning how to learn (O’Neill, 2001). As a theoretical framework, the community of practice serves as a means to study how shared knowledge evolves and how groups learn. Traditional learning communities do not support this type of investigation because skill development and understanding are assessed on an individual basis, where there is no evidence of how collective knowledge is used to support the learning process. Researchers, however, are currently using communities of practice as a diagnostic tool for understanding knowing and reasoning by examining the varying degrees of participation within authentic learning environments. This is known as “situated learning” (see Chapter 11) because knowledge is situated in practice for a significant purpose, where members of the community work to solve authentic problems (Brown et al., 1989; Lave & Wenger, 1991). Learning, therefore, occurs in the act of solving the problem and in the social arrangements in which the activity is taking place.

The community of practice itself provides a theoretical framework to study the nature of knowledge development through language and discourse. For example, as students present ideas about some scientific phenomenon, they make inferences, predictions, and observations based on assumptions from prior knowledge or experiences. When they engage in debate with other students, they learn to justify and explain their reasoning and suggested actions.

In contrast to learning paradigms that focus on the transmission of information, a discourse perspective such as that provided by the community of practice framework implies learning through active participation when scientific language is used (McGinn & Roth, 1999). To encourage this type of behavior, activities should be designed to generate — reveal — significant information about the ways of thinking that produced them. Specifically, the tasks should be authentic in nature and they should focus on the development of constructs (models or conceptual systems) that provide the foundation for deeper and higher order understandings (Kelly & Lesh, 2000).

Lesh (2002) explained that to learn about the nature of students’ developing knowledge, it is useful to focus on tasks in which the resulting products demonstrate significant information about the ways of thinking that produced them. This means that students need to be able to communicate — through descriptions, explanations, and constructions — how they interpreted a task or problem-solving situation. Within the community of practice, students plan problem-solving strategies, communicate/challenge ideas, monitor progress, test various solutions, and explain outcomes to each other. Through testing, revealing, modifying, and refining their thinking, the collective knowledge of the group changes as they develop models for making sense of their experiences. An important characteristic of these kinds of thought-revealing activities is that students generate meaningful solutions (descriptions, explanations, and constructions) to integrate into their own knowledge base and to share with others. An essential component of the theoretical framework of the
community of practice is the shared repertoire (artifacts and resources) developed by its members, from which knowledge and understanding evolve. These products, created in the classroom, perform the same role of documenting and exposing critical information about thinking and learning in social environments.

Assumptions of Communities of Practice

Communities of practice are based on the assumption that informal social networks help improve organizational performance by supporting the development of communication and common understandings about “how work is done,” what information is relevant and important to that work, and other factors that shape the organization’s view of reality (Simon, 1979). For the purpose of applying these assumptions to school-based practice in education, the social constructivist theory of learning (see Chapter 2) is most closely aligned to the concept of communities of practice (Palincsar, Magnusson, Marano, Ford, & Brown, 1998). This approach puts students in situations where they must construct knowledge by testing and refining their thinking through activities that are meaningful to them. In order for knowledge to be constructed, however, learning must be anchored in experience and concrete understanding. Lave and Wenger (1991) identified four features that are fundamental to this theoretical perspective: (1) active construction, (2) situated learning, (3) community, and (4) discourse. As in thought-revealing activities, constructivist learning occurs when students actively create their own knowledge by trying to make sense out of material that is presented to them.

Sense-making in communities of practice takes place through dialog and the development of a common language and artifacts (Pea, 1993). Engaging students in activities that require them to use these artifacts or explain their thinking about a problem situation or task using the language of the community is critical, but not enough. They should also be able to find ways of appropriating scientific discourse so that it can serve their own sense-making purpose (Bakhtin, 1975/1981). McGinn and Roth (1999) suggested using court cases in which scientific knowledge plays an important role or legislative debates as starting points for teaching this discourse. Like all communities, scientists have a professional vernacular that allows them to communicate with each other to accomplish everyday tasks, as well as complex experiments. When students are routinely involved in the conversations of the scientific community, they acquire the necessary vocabulary to comprehend what is being said. Eventually, through various types of social interactions, they will learn to use and apply ways of making sense that are characteristic of scientists (Rosebery et al., 1992).

Social interactions play a fundamental role in the theoretical framework of the community of practice. They allow members to engage in debate, ask questions, state opinions, negotiate meanings, and resolve conflicts. All of these behaviors are believed to lead to reflection and internalization of new understandings (Brown, Metz, & Campione, 1996). In many ways, this is similar to Vygotsky’s (1978) theory of social learning, which assumes that cognitive development appears twice: first, between people (interpsychological) and then inside the individual (intrapsychological). A second aspect of Vygotsky’s theory is the idea that the potential for cognitive development
depends upon the "zone of proximal development" (ZPD): a level of development attained when people engage in social behavior (see Chapter 2). Full development of the ZPD depends upon extensive social interactions (Vygotsky, 1978, 1986). Vygotsky's theory assumes that skills developed with guidance or peer collaboration exceed what can be attained alone. Within the framework of the community of practice, the ZPD is part of mutual engagement where members observe each other testing, challenging, and revising ways of thinking. This iterative method of learning is critical to the formation of a collective knowledge base from which members solve problems and gain deeper understandings of the thinking processes of the community.

Social learning theory emphasizes the importance of observing and modeling the behaviors, attitudes, and emotional reactions of others (Brown & Palincsar, 1989; Jonassen & Henning, 1999). Bandura (1977) states:

Learning would be exceedingly laborious, not to mention hazardous, if people had to rely solely on the effects of their own actions to inform them of what to do. Fortunately, most human behavior is learned observationally through modeling: from observing others one forms an idea of how new behaviors are performed, and on later occasions this coded information serves as a guide for action. (p22)

The community of practice provides a theoretical framework for research designed to understand how observing and modeling behaviors help newcomers become indoctrinated into the group. Lave and Wenger (1991) are quick to note, however, that observation is useful only as an introduction to actual engagement. At some point, individuals must begin to contribute to the collective knowledge base by engaging in the process of selecting from alternative ideas, varying representations, and differing perspectives (Lesh & Doerr, 2003). This actual participation establishes legitimacy for all members, as they continue to share and grow in their competence.

Criticisms of Communities of Practice

Barab and Duffy (2000) indicated that there are misconceptions regarding how some schools use communities of practice as an arena for learning. They suggested that, in the cases they studied, knowledge is commoditized and learners are alienated from the full experience — which results in a separation between the development of their identities and the development of their skills. Their work raised the question, “how do we facilitate the emergence of learning environments that engage students as legitimate peripheral participants — develop their self in relation to society?” One suggestion they offered is the use of practice fields, where students join in activity groups to investigate and engage in practices that are consistent with practices of real world practitioners. These practice fields offer students the opportunity to work in a collaborative environment on the kinds of problems they will likely encounter outside of school. They also suggested that the concept of situated learning should focus more on what it means to be a functioning part of a community than the situatedness of meaning or content (i.e., problems that reflect a real world situation).
Barab and Duffy (2000) further question the advantages of having students teach each other or of bringing in experts to set up a particular context in which the learning occurs. The goal of participation in community is to develop a sense of self in relation to the society of which we are a part — a society outside the classroom. The community in a community of practice is not just people coming together to work on a task. The key variables in the community concept involve giving students a legitimate role (task) in society through participation or membership. They describe communities as having three components:

- A common cultural and historical heritage, including shared goals, understandings, and practices;
- Individuals becoming part of an independent system; and
- The ability to reproduce as new members work alongside more competent members.

Within this learning environment, students should explore real problems in real contexts and engage in discourse that will lead to increased understandings. Barab and Duffy (2000) were not convinced this was happening in the classrooms they investigated. More research needs to be conducted to determine the effectiveness of using communities of practice as a theoretical framework for studying social networks to support classroom learning.

**Methods of Communities of Practice**

Johnson (2001) noted that case studies are the major reporting style used in research on communities of practice. Case-study methods involve an in-depth, systematic examination of single or multiple instances or events. As such, these studies ask the complex “how” and “why” questions that reinforce or enrich the researcher’s understanding of why an event happened as it did and what might become important to look at more extensively in future research (Yin, 1994). Social scientists, in particular, have made wide use of case studies to examine contemporary real-life situations and provide the basis for the application of ideas and extension of methods. It is important to mention, however, that the case study itself is not a methodological choice, but a choice about what is to be studied (Stake, 2000). For example, the aim of a community of practice is to support learners who want to more deeply understand some aspect of, or problem in, their shared practice. A researcher may only be interested in knowing how the group arrived at an acceptable representation of the problem, in which case only one small element of the whole community is being investigated. The choice of methodology is determined, therefore, by the specific research question being asked.

As a theoretical framework, the community of practice is a means by which to study learning as a social activity. From this perspective, central questions to be investigated might include: How have people in the community of practice constructed their shared reality? What are their reported perceptions, “truths,” explanations, and beliefs? What
are the consequences of their constructions for their behaviors and for those with whom they interact? (Patton, 1990). These inquiries are not designed to produce generalizations about how learning occurs in the community, but to investigate knowing and reasoning among members of the community. Lewis, Watson, and Schaps (1999), for example, described children learning social and ethical behaviors. They found that these behaviors were demonstrated successfully most often when the children had opportunities to practice and see others practice them, and when they were able to discuss what these activities meant in relationship to other situations (i.e., resolving classroom conflicts). Within the framework of a community of practice, therefore, research goals go beyond wanting to know what individuals learned from participating in authentic problem solving activities to understanding how the group supported knowledge acquisition and use.

Kelly and Lesh (2000) suggested using teaching experiments to study the nature of developing knowing and learning in individuals and groups. Well-designed teaching experiments create conditions that optimize opportunities to observe, document, or measure change within the learning environment. In a community of practice, this can be accomplished by: (1) creating situations where the group needs to develop interpretations of their experiences; (2) structuring interactions so that these interpretations can be tested, assessed, extended, refined, rejected, or revised for a specific purpose; (3) providing tools (artifacts, symbols, and language) to facilitate the construction of ideas and models; and (4) using formative feedback and consensus-building to develop and improve thinking. This learning environment would provide a rich opportunity for investigating and reflecting upon thought-revealing activities, as described earlier. By focusing on the decision and sense-making processes of learners within the community, investigators could develop explanations about how groups and individuals learn to learn.

There are numerous ways to determine how (and how well) individuals learn a range of complex concepts. Standardized tests, for example, are a popular data source for measuring competencies, but they do little to reveal the processes by which knowledge is acquired. Furthermore, they do not provide any information about the role of groups in supporting cognitive development. To study knowledge development, data need to disclose how the learner is thinking and how that thinking changes over time. The data sources in teaching experiments in the theoretical framework of a community of practice are designed to collect information about individual and group representations of problems, about interactions among learners negotiating meaning, and about consensus building strategies. The data that result from these experiments are learner-made artifacts and tools that demonstrate steps taken to state the problem, identify information needs, theorize about possible solutions, test and refine ideas, and communicate results. These data should be captured in several ways so that results can be compared — or triangulated — for validation of analysis.

The logic of triangulation is based on the premise that no single method can account for all possible explanations. Because each method reveals different aspects of empirical reality, multiple methods of data collection and analysis lessen the chance of error in
Creswell (2003) used a combination of data sources to study events in a community of practice. Examples of data sources that might be obtained in studies based on the communities of practice theoretical framework can be found in Table 1.

Table 1. Examples of data sources in communities of practice

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Collection Plan</th>
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<tbody>
<tr>
<td>Semi-structured interviews</td>
<td>Immediately following participation in a thought revealing activity, ask individual students 5-6 questions about their experience and their interpretation of the problem to be solved:</td>
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<tr>
<td>— includes both prepared questions and questions that arise during the interviewing process to acquire information from the respondent.</td>
<td>• Describe, in your own words, the problem your group was solving.</td>
</tr>
<tr>
<td>— includes both prepared questions and questions that arise during the interviewing process to acquire information from the respondent.</td>
<td>• What did you know about this problem before starting the process of solving it?</td>
</tr>
<tr>
<td>— includes both prepared questions and questions that arise during the interviewing process to acquire information from the respondent.</td>
<td>• What do you know now?</td>
</tr>
<tr>
<td>Still notes — methods of collecting data simply by watching what people do. Field notes are the comments written to record what was observed.</td>
<td>Be as neutral as possible when asking probing questions: “Tell me more” or “Can you be more specific?”</td>
</tr>
</tbody>
</table>

Develop a protocol for observation prior to entering the field. For example, a checklist of things to look for, specific questions to answer, and space for writing in field notes are all good starting points. Using this tool will ensure that the data is gathered in a systematic and structured way and will make analysis easier.
Learner-made artifacts — documentation produced by the participants.

Use in the theoretical framework of a community of practice:
To confirm observations and interviews, making the findings more credible.

Design activities to produce auditable trails of documentation in the form of:

- Transcriptions of students’ interactions and interpretations of their experiences
- Written or oral representations of the problem statements
- Learner-made procedures for testing hypotheses about their problem statements (logs or journals are good sources to capture these data)
- Artifacts and products
- Rubrics for providing feedback and evaluating revisions

Read, note, and reflect on the materials until a focus or theme emerges from the categories of information and perspectives available.

Data Analysis

Qualitative data analysis involves organizing what was said, heard, read, or documented so that it can be analyzed to make sense of what was learned (Glesne, 1998). Often, data analysis occurs more or less concurrently with data collection. While information is being gathered, the results begin to take shape as patterns and themes emerge. To make sense of the data, it is necessary to find a way of reflecting on and organizing them. Strauss and Corbin (1998) recommended that, especially in the early stages of analysis, researchers keep a reflective field log of notes documenting thoughts as they occur. They referred to this preliminary process of analysis as “memo writing,” the point being that each thought contributes to the overall understanding of the big picture contained within the data. These resources determine which data are viewed as significant to the study. Once data are selected for further analysis, files (bins) are organized by categories based on relevant subject matter. For example, the theoretical framework of a community of practice in the science classroom might have several areas of interest, including discursive practices, hands-on participation, artifacts, and individual interpretations of scientific concepts. Once these data sources are identified, a rudimentary coding scheme can begin to draw information from the protocols used to collect them.
Payne (1994) described two main approaches to coding data from protocols:

- Code instances in which certain types of thought seem to occur within a protocol. The frequency of occurrences of different types of reasoning can then be computed across problem types or individuals.

- Break the protocols up into short phrases or segments. Each phrase should refer to what constitutes a single task assertion or reference by the subject. These segments can then be coded and analyzed.

Coding and categorizing in this manner allows researchers to identify the types of thinking evident in the data. Additionally, interpretive marginal notes can be made along the protocol transcripts (Miles & Huberman, 1994). In the case of integrated observational and interview transcripts, researchers should compare the verbal statements to the actions of the participants, allowing theory to emerge through the analysis of the data.

Roth et al. (1999) describe this process as follows:

Our formal data analyses were conducted in sessions with two to four of the authors as participants according to precepts of Interaction Analysis on the basis of videotaped data sources (Jordan & Henderson, 1995; Suchman & Trigg, 1991). We played the videotapes, stopping and replaying them as often as needed and whenever a team member felt something remarkable happened. At the same time, we also ascertained the accuracy of the transcripts as to the utterances, overlaps, emphases, and so forth. When we had isolated an event as significant, we searched through all data (not just videotapes) to see if the event represented a class of events. These analysis sessions were taped and recorded in field notes; a flip chart was used to allow a permanent record of notes and drawings made during the meetings. Tapes, field notes, and flip charts also became part of the data. (p. 311)

In this description of a coding process, all of the behaviors, discussions, and events are documented systematically for examination. In addition to triangulating data sources, the analysis process was validated by multiple researchers agreeing on interpretation and usefulness of the data to the study. Hollway and Jefferson (1997) offered four core questions to help guide interpretation when working singly or in a group:

- What do you notice?
- Why do you notice what you notice?
- How can you interpret what you notice?
- How can you know that your interpretation is the ‘right’ one? (p. 55)
It should be noted that this process may take some time and repetition, as opinions may vary about what is important and what the data actually mean. After consensus is reached about the significant information and how it should be used and interpreted, the data are translated into meaningful text for dissemination.

**Potential Educational Benefits of Communities of Practice Research**

Recent studies (McGinn & Roth, 1999; Palincsar et. al., 1998; Scardamalia & Bereiter, 1994) indicate that the community of practice theoretical framework is an effective model for creating and studying a highly situated authentic learning environment in the classroom, where instruction emphasizes the idea that much of what is learned is specific to the situations in which it is learned (Sweeney & Paradis, 2004). These experiences include activities that are participatory, interactive, and representative of real-world events (Wenger, McDermott, & Snyder, 2002). From an instructional perspective, learning is anchored in real uses, where problem solving and critical thinking are required (Resnick, 1987). Individuals participating in the exchange of information shape the knowledge, skills, and identity of the community within that context. The benefits include increased idea creation, increased quality of knowledge for problem solving, and an increased sense of belonging. The connection to a group, where everyone's unique contribution is important, is a key concept to the development of a community of practice, and confirms the importance of socialization in the learning process (Soden & Halliday, 2000).

Socialization into the culture of a discipline within a community of practice is promoted by extensive and repeated exposure to practitioners in the discipline (Brown et al., 1996). In science education, this means providing conditions to help students become scientifically literate by engaging them in scientific discourse. For example, McGinn and Roth (1999) described using current scientific debates to focus discussions by providing students with a series of journal articles that present opposing points of view on particular topics. As they participated in deliberations about what they were reading, students essentially entered into the mutual engagement of the community of practice. In the search for meaning and understanding, they needed to discuss what they knew about the topic, identify what they did not know, and work through confusion and misunderstandings in the texts and overall concepts being presented. In this venue, science education reflected the situated, contingent, and contextual nature of science while also acknowledging the diverse range of communities and locations where science is created and used. Projects in this type of learning environment should be collaborative in nature and locate the science in real-world applications that are likely to be of interest to scientific and community-based organizations.

Expertise from participating in these activities comes from a progressive series of encounters, each involving an element of routine performance and a corresponding element of reflection and deliberation (Scardamalia & Bereiter, 1994). Edelson, Pea, and Gomez (1996) described a four-step process in the development of expertise in science-based classroom communities:
- Investigate science practice: observe the ways in which scientists work.

- Identify tacit knowledge used in science practice: recognize the scientific principles, data collection tools and models used to enhance the data, and how-to knowledge concerning the use of those tools.

- Scaffold the science practice by making the tacit explicit: structure activities to assist students to pursue meaningful questions.

- Refine the tools in response to formative evaluation. Through a combination of observation and direct user feedback, evaluate the patterns of use that emerge and use these evaluations to redesign the tools.

In this process, the theoretical framework of the community of practice facilitates both the students’ engagement in a range of activities, from observation to manipulation of data and tools, and the students’ immersion into the scientific community through discourse and collaboration (Singer, Marx, Krajcik, & Chambers, 2000). As the rhetoric and tools of the discipline become more familiar, students can begin to appropriate how others integrate and use them to revise, validate, or reinvent their own thinking.

**Examples of Communities of Practice Research in Chemistry/Science Education**

A thorough search of three databases was conducted to locate relevant studies that used communities of practice as a theoretical framework for science education:

- Educational Resources Information Center (ERIC), a comprehensive database of education research and practice;

- PsycInfo, an index of literature in psychology and related areas including sociology and education; and

- Academic Search Premier, a general database that indexes journals, magazines, and newspapers from multiple disciplines.

These resources were selected because they provide access to journals such as *Journal of Chemical Education, Chemistry Education: Research and Practice, Science Education*, and *Research in Science Education*. The results from searching for the terms “communities of practice” and “chemistry education,” however, yielded low returns. A more productive search was executed when the terms were broadened to include biological and physical sciences, technology, mathematics, and education. From this search strategy, the ten studies listed in Table 2 were chosen as being representative of studies of communities of practice in science education. This was not meant to be an exhaustive search, nor was it entirely characteristic of communities of practice in the classroom. The following list of studies is only a sample of the kinds of research being conducted on the use of communities of practice to improve learning.
Table 2. Examples of Communities of Practice Studies in the Classroom

<table>
<thead>
<tr>
<th>Reference</th>
<th>Research Questions/Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Johnson, 2001</td>
<td>Can communities of practice in their true definition be established, maintained, and supported in an online environment?</td>
</tr>
<tr>
<td>McGinn &amp; Roth, 1999</td>
<td>How can science education be a starting point for trajectories of legitimate peripheral participation in science-related discourses and practices?</td>
</tr>
<tr>
<td>O’Neill, 2001</td>
<td>Does student involvement with online mentors influence the ways in which they use the customary “tools of argument” in a genre of scientific writing?</td>
</tr>
<tr>
<td>Pea, 1993</td>
<td>How is a conceptual change in scientific thinking achieved through meaning negotiation and appropriation?</td>
</tr>
<tr>
<td>Rickey &amp; Stacy, 2000</td>
<td>What is the role of community in promoting metacognition in science education?</td>
</tr>
<tr>
<td>Rogers, 2000</td>
<td>How can we create learning environments and experiences that bring our learners together to form learning communities?</td>
</tr>
<tr>
<td>Rosebery et al., 1992</td>
<td>To what extent do students appropriate scientific ways of knowing and reasoning as a result of their participation in collaborative scientific inquiry?</td>
</tr>
<tr>
<td>Roth et al., 1999</td>
<td>How is content and form of classroom discourse influenced by different combinations of artifacts?</td>
</tr>
<tr>
<td>Singer et al., 2000</td>
<td>How does a set of design principles create standards-based curriculum materials that engage students in scientific inquiry, make use of new technologies, and promote learning?</td>
</tr>
<tr>
<td>Sweeney &amp; Paradis, 2004</td>
<td>To what extent does a laboratory model serve as an effective means of enculturation for prospective science teachers?</td>
</tr>
</tbody>
</table>
The articles in Table 2 focused primarily on discursive practices used in communities of practice to promote learning in science classrooms. For example, Rosebery et al. (1992) investigated the effects of a collaborative inquiry approach to science on language minority students in middle and high school. They wanted to know how students’ conceptual knowledge, hypotheses, and explanations changed as they engaged in think-aloud activities. Pea (1993) also studied conceptual change as students collaborated to solve problems in situated learning environments. He analyzed their conversations and use of artifacts to understand meaning negotiation and appropriation from a sociocultural perspective. McGinn and Roth (1999) were interested in establishing opportunities for students to participate in experiences where science is created and used. Each of these research endeavors applied the community of practice framework to investigate the intricacies of social interaction to support knowledge development, and the impact of authentic learning situations on problem solving.

A Detailed Example of a Community of Practice Study in Science Education

One study conducted by Roth et al. (1999), in particular, used a community of practice as a theoretical framework to explore how the content and form of classroom discourse was influenced by different combinations of artifacts (i.e., overhead transparencies, physical models), social configurations, and physical arrangements. Over a four-month period, they collected data from videotaped activities, interviews, observations, artifacts, and photographs in a middle school science classroom studying a unit on simple machines. These data were analyzed to determine the impact of four different activity structures in terms of the social configuration (whole class, small group) and the origins of the central, activity-organizing artifact (teacher-made, student-made). Their results suggested that different artifacts, social configurations, and physical arrangements led to different interactional spaces, participant roles, and levels of participation in classroom conversations and to different discursive forms and content. Overall, they reported that the students developed considerable competencies in discursive and materials practices related to simple machines.

The research design for this investigation was straightforward and simple. First, a problem based on gaps in the literature on the discursive practices of students in science and mathematics was determined. The researchers claimed that the studies published usually involved small numbers of students (8-15) and noted that interaction processes do not scale up to larger classes. They further stated that the existing research investigating classroom discourse does not attend to the particularities of discourse that arise from interactions of artifacts, social configurations, and physical arrangements. This is where the theoretical framework of a community of practice model becomes important to the research design. Because the aim of a community of practice is to promote learning through social interactions and negotiated meaning, Roth et al. set their study up to analyze how these middle school students mediated speaking in turns, developing ideas and cohesion, and communicating their ideas to each other.

The study was conducted in a Grade 6-7 urban public middle school, where the teachers were committed to improving science education. An anonymous survey
revealed that students wanted a more hands-on approach to learning science; and while teachers were willing to incorporate those types of activities, they felt they needed outside help to support the necessary changes. The research team agreed to facilitate a teacher in-service professional development day and support in-class teaching by assisting in planning science lessons and team teaching in exchange for the opportunity to document associated changes in teaching and learning. Participants for the in-depth case study included one teacher-researcher with over 12 years of experience in the classroom, two of which had been in middle school, and the classroom teacher, who had over 21 years of experience teaching, but only one of which had been in a middle-school classroom. There were 26 students in the course: 10 sixth graders (5 girls and 5 boys) and 16 seventh graders (7 boys and 9 girls). Some of the students were learning disabled; others had social and emotional disorders. In all, this setting was a difficult assignment for both the researcher and the teacher.

Data collection started as soon as the unit was introduced. Students organized themselves into small groups to work on open-ended problem-solving activities designed to elicit thought processes and mental models. For example, one problem was hypothetically from a local company asking students to submit a proposal for machines that could operate by hand if gas-powered machines failed to operate. In this proposal, students needed to include construction plans, working models, a written description, and a presentation demonstrating how their model(s) worked. Both qualitative and quantitative data were collected to determine the following:

- What did the students learn during the unit on simple machines?
- Does the unit benefit all students equally well?

The quantitative data was gathered from a 2 (boys, girls) x 2 (Grade 6, Grade 7) multivariate analysis of variance, with students' written and oral posttests as the dependent variables, to determine if gender might be a factor in performance. Results indicated that there were no statistically detectable effects for gender in this study. The qualitative data were collected from multiple sources and transcribed for coding and analysis. These data suggested that there was a link between the levels to which individual students could engage and their development of science discourse. This was especially evident in small group conversations where individual opportunities for participation were high, as were opportunities for creating and exploring new ways of talking.

This study highlights how a community of practice framework provided students conditions to practice discourse and participate in conversations in environments they consider “safe.” These included small-group structured investigations and unstructured design and construction activities. During design and construction, the researchers observed high levels of interaction within and between groups and an associated rapid adoption of materials and discursive practices after they had been invented or introduced. As students interacted with each other, they learned to use these devices, tools, and new scientific concepts in ways that were meaningful to them. They also
learned the concept faster and more efficiently than in whole-class presentations, where they listened and watched passively. Unlike a community of practice in the workplace, however, legitimate peripheral participation did not apply to many of the classroom interactions because there was no expertise in the group. Everyone was starting at the level of novice. As a result, the purpose for using a community of practice framework for this investigation was to create situations where students were able to improve their participation in discursive practices about specific objects that related to learning complex concepts about simple machines.

Conclusion

The theoretical framework of a community of practice is an effective means for studying discourse among community members. Changes in thoughts, attitudes, beliefs, and practices can be observed and documented in the ways in which both individuals and the group, as a whole, use materials and artifacts, and how they converse and mediate conflicts with each other. In the classroom, this is particularly useful for studying how knowing and understanding takes place. The results can provide valuable insight into correcting misunderstandings about complex concepts and offering alternative methods of reaching students who may not learn from traditional approaches. When used as a diagnostic tool, the community of practice is a powerful approach for redesigning curriculum to include opportunities for learning and developing practice, and generating and discovering new knowledge. As studies by Roth et al. (1999) and Rosebery et al. (1992) demonstrated, when provided opportunities to practice discourse, students' knowledge of scientific concepts and ability to use the language of scientists increased.

In addition, Wenger (1998) argued that a community of practice framework in schools places students on an “outbound trajectory toward a broad field of possible identities.” (p. 263) From this perspective, he stated, education needs to be thought of as a means by which communities and individuals continually renew themselves. This process goes beyond the socialization skills necessary in social theories of learning (Bandura, 1977; Vygotsky, 1986). It also requires that identity itself become an educational resource:

It can be brought to bear through relations of mutuality to address a paradox of learning: if one needs an identity of participation in order to learn, yet needs to learn in order to acquire identity of participation, then there seems to be no way to start. Addressing this, most fundamental paradox is what … education is all about. (Wenger, 1998, p. 277)

Finding a solution to this dilemma necessitates answering questions such as “how do teachers of science invite learners into the discourse of the discipline of practicing scientists?” and “how can the continued growth and development of students’ identities be supported beyond the classroom experience?” The theoretical framework of a community of practice may be one way for researchers and teachers to investigate best practices collaboratively to find methods of improving learning outcomes for all students.
References:


Chapter 12: Communities of Practice


Telling the Whole Story via Narrative Analysis

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and

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Biographies

Joseph W. Shane is an Assistant Professor of Chemistry and Science Education at Shippensburg University, one of fourteen state-owned liberal arts schools in Pennsylvania. In addition to teaching general chemistry to both majors and non-majors, he teaches the methods classes for secondary science teacher candidates and serves as their supervisor during student teaching. He received both his Ph.D. in Science Education and M.S. in Chemistry from Purdue University and his B.S. in Chemistry from the University of Delaware. During the eight-year interim between graduate degrees, he taught chemistry at Noblesville High School in Noblesville, Indiana. He feels quite fortunate to have an academic position that allows him to work in both chemistry and science pedagogy. Even though his teaching load is quite heavy, Joe still finds time to continue his research into how teachers implement educational policies in their classrooms.

Trisha Anderson received her undergraduate education from Brigham Young University. She received a broad education there as her wide-ranging interests led her from proposed major to proposed major. Her love of science eventually led her to obtain her BS in Biochemistry. As she studied chemistry there, she had the fortunate opportunity to serve as a teaching assistant for general and organic chemistry classes, where she found a natural niche combining both her love of science and her love of teaching. Upon graduating from Brigham Young University, she was able to pursue these combined interests by beginning graduate study in Chemical Education at Purdue University, where she is working on her Ph.D. degree.
Coupling Narrative Analysis with other Theoretical Orientations

As Bodner argued in the introductory chapter of this book, qualitative researchers often borrow tenets from more than one theoretical orientation to guide their inquiries. Constructivism, for example, is frequently used as a basis for understanding how research participants generate knowledge of a particular scientific principle. Researchers, however, may combine constructivist epistemologies with other frameworks — phenomenology, action research, critical theory, etc. — to further define their roles throughout the research process and to guide the types of questions that they ask.

In this chapter, we describe how we complemented two theoretical orientations — hermeneutics and phenomenography — with narrative analysis, a novel framework in and of itself (Clandinin & Connelly, 2000; Polkinghorne, 1988, 1995). We found narrative analysis to be particularly powerful for guiding the data analysis and representation phases of our research. By coupling these frameworks, we have constructed coherent and comprehensive theoretical foundations for addressing several dimensions of the “researcher-as-instrument” metaphor, the central theme of this text. We begin our introduction to narrative analysis with an overview of this theoretical framework followed by two detailed examples from our work in science and chemistry education.

Background and Brief Literature Review

Three sources have heavily influenced our work with narrative analysis: Narrative Inquiry: Experience and Story in Qualitative Research (Clandinin & Connelly, 2000), Narrative Knowing and the Human Sciences (Polkinghorne, 1988), and Narrative Configuration in Qualitative Analysis (Polkinghorne, 1995). As these are seminal works on narrative as it applies to qualitative research, we recommend that readers whose interest in narrative analysis is sparked by this chapter turn to these references for more detailed information.

Unlike theoretical orientations that are historically linked to a few specific individuals, narrative analysis in qualitative research is influenced by multiple traditions including anthropology, clinical psychotherapy, and organizational psychology. Clandinin and Connelly (2000) described additional connections between narrative analysis and tenets of John Dewey’s educational philosophy — most notably, the holistic nature of experience (Dewey, 1938).

In a narrative analysis, the researcher examines data and reports results by constructing one or more stories that are held together by common themes or plots. Or, as Polkinghorne (1995) stated, a narrative is a “discourse form in which events and happenings are configured into a temporal unity by means of a plot” (p. 5). Developing plots, or emplotting the data, is the primary analytic goal. These plots are developed in an emergent sense — a hallmark of most theoretical orientations in qualitative research — and serve to define a beginning and an end to the story, to provide criteria whereby
specific events are selected for the narrative, to build to conclusions or denouements from a complex set of events, and to ensure that the component parts contribute to the holistic meaning of the narrative (Polkinghorne, 1995). Both Clandinin and Connelly (2000) and Polkinghorne (1988, 1995) have argued that narratives woven together with plots are the primary mechanisms through which human beings experience the world and organize information. As such, they assert that narratives should be a central feature of research in the human sciences, which have all too often suffered by attempting to emulate the methodologies of the natural sciences (Polkinghorne, 1988).

Polkinghorne (1995) identified two meanings of the word narrative to distinguish it from other qualitative research traditions: analysis of narratives and narrative analysis. With respect to analysis of narratives or paradigmatic analysis, researchers collect data, considered to be narratives or stories by themselves, and then determine generalizable categories or taxonomies. Qualitative researchers frequently present their results using a list of categories or assertions followed by corroborating excerpts from their data. By contrast, a narrative analysis integrates the data and the researcher’s interpretations throughout the body of a storied or emplotted text. The conclusions, therefore, are presented within the narrative rather than as ex post facto results of the data analysis. As Polkinghorne (1995) noted, “analysis of narratives moves from stories to elements, and narrative analysis moves from elements to stories” (p. 12). Rather than deconstructing an encounter with a participant or circumstance into separate elements, as is frequently done in qualitative research, the researcher synthesizes the data into a narrative, paying attention to the details that bring to light the encounter’s purpose and goal (Polkinghorne, 1995). In our work, we applied the latter definition of narrative analysis, which is also referred to as narratology (Patton, 2002).

Polkinghorne (1995) also argued that narratives must incorporate the historical and cultural settings of the research — notions which are consistent with many orientations presented in this text. The researcher not only narrates the story within this framework, but also locates or historicizes the data within a specific context (Goodson, 1997).

As a simple illustration, Polkinghorne (1995) offered a one-sentence story: “The king died, the prince cried” (p. 7). Both halves of the story contain some degree of meaning. When these separate occurrences are combined into a story, however, a new level of meaning or “relational significance” appears (Polkinghorne, 1995, p. 7). The king’s death appears to have caused the prince to cry, and the storyteller would need to further develop the connections and context via plots to lend further insight. This becomes the primary task of the researcher in narrative analysis because the raw data in either this abbreviated regal tragedy or in any qualitative inquiry is not already in storied form.

There are several arguments in the literature for why narrative analysis is a useful research tool, but relatively few examples exist as to how the tenets of narrative analysis are put into practice. A themed issue of the journal Teaching and Teacher Education, for example, provides several commentaries regarding narrative in educational research. Doyle (1997) commented on using narratives to describe how
teachers enact educational policies, which he described as storied processes. Such research, he claimed, was a necessary departure from traditional policy research focusing on controlling and improving teachers’ practice. Goodson (1997) echoed these conclusions by suggesting that narrative representations of teachers’ voices were essential in our era of bureaucratically and technically controlled education. Elbaz-Luwisch (1997) questioned whether “top-down” models of educational research and policy have yielded genuine improvements in teaching and, therefore, suggested teacher narratives as an alternative approach. In his summary remarks, Fenstermacher (1997) noted that narrative had been particularly valuable for understanding teachers’ beliefs and, building on these remarks (Fenstermacher, 2002), called for more narrative research in educational policy implementation and evaluation. He contended that such research assists our understanding of how policy is shaped on a local level, evaluates the relative effectiveness of policies in different contexts, and helps teachers, administrators, and policymakers understand their own unique historicity (Fenstermacher, 2002).

In one of the few qualitative research reports that use narrative analysis as a theoretical framework, Conle (1997) generated plots and wrote stories to understand and communicate how a group of teachers participated in school governance. Her work was guided by using teachers’ voices to “explore how their own histories and teaching priorities coexist with demands that emerge from administrative contexts” (Conle, 1997, p. 138). In the narrative she created, Conle integrated teachers’ self-reflections regarding their personal histories and priorities for teaching, descriptions of the administrative structure of the school, and her personal history and reactions to teachers’ reflections. Conle (1997) presented the results of the study through what she termed *experiential narratives* that reflected her continually changing understandings of how the teachers participated in making schoolwide decisions. In subsequent reports, Conle (2000, 2001, 2003) argued for narrative as both a qualitative research tool and as a powerful medium for guiding teachers’ pre- and in-service professional development.

Within science education, Shapiro and Melrose (1998) performed such an inquiry by assisting pre-service science teachers and nurses in writing narratives to reflect upon and strengthen their understanding of their professional training programs. Geelen (1997) combined ethnography and narrative analysis to write three stories which described and shaped science teachers’ experiences at a newly opened middle school. Segal (1999) and Tobin (2000) took rather unique approaches to narrative analysis by performing self-studies and generating autobiographical narratives to describe and improve their practice as science teacher educators. Such inquiries are consistent with Roth (2000) and Calabrese Barton’s (2000) assertions from a special issue of *Research in Science Education* that argued for general use of narrative analysis and autobiography in science education research. Connelly and Clandinin (1986) made similar recommendations for using narratives to capture science classroom environments.

These inquiries epitomize narrative in educational research. They tend not, however, to clearly explain the exact procedures through which plot lines were determined (i.e. how
the data were emplotted) and how the narratives were ultimately written. We will, therefore, outline two examples from our current work in the hope that we can provide more specific guidance, especially to the novice qualitative researcher.

**Using Narrative to Capture Science Teachers’ Beliefs**

In our first example, the first author conducted two rounds of focus group interviews with 23 high school science teachers from three school districts to gain insights into their beliefs about the intended and actual impacts of standards-based reforms on their personal practice and on their profession. These interview data — transcribed and organized into chronological case records for each school — were only one source of information that we synthesized *en route* to developing a holistic, historical understanding of the teachers’ beliefs. Other sources of data included a statement of the primary researcher’s personal experiences with and beliefs about standards-based reforms, *Indiana’s Academic Standards for Science* (Indiana Department of Education, 2003), *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993), the teachers’ educational and professional backgrounds, school profile data, and a set of six research notebooks documenting the primary researcher’s ongoing insights and personal transformations of understanding.

We argued for hermeneutics in Chapter 6 as an appropriate theoretical backdrop to define the types of data we collected and our roles in the research process. As we collected interview data and relevant documents, however, we realized that the hermeneutics literature provided little guidance as to how to analyze and represent or communicate our findings. Moss (1994), for example, argued that the central goal of a hermeneutic inquiry was to synthesize all of the relevant data from an inquiry into a uniform whole, but offered few concrete suggestions as to how this might be done. Narrative analysis, in a sense, picked up where hermeneutics left off (Patton, 2002); and we found Polkinghorne’s work (1988, 1995) to be a powerful theoretical and practical complement.

Constructing appropriate, comprehensive, and comprehensible plot lines and developing a specific outline for the narrative were the primary challenges throughout the inquiry. As we have discussed previously, the goals of narrative analysis are to write an emplotted story which takes all of the data into account and to communicate the findings by building to one or more conclusions. In our research (Shane, 2005), we found the 23 participants’ personal teaching philosophies to be the primary plot line that determined how they described their experiences with and beliefs about standards-based reforms. Two additional plot lines centered around the degree of administrative oversight at the three high schools — Urban, Rural, and Suburban — with respect to implementing Indiana’s science standards and the teachers’ beliefs about how standards impacted their students and their profession. To reflect the interconnectedness of these plot lines, we chose an inside-out approach to organizing the narrative, beginning with the participants’ personal philosophies of teaching and the corresponding relationships to Indiana’s science standards, continuing to the administrative expectations at the school and district level, and ending with the
teachers’ vision for standards beyond their local contexts. The general outline for the narrative is shown in Figure 1:

<table>
<thead>
<tr>
<th>1. Teaching Philosophies and Indiana’s Standards: Neutral to Contradictory Relationships</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Suburban’s biology teachers</td>
</tr>
<tr>
<td>b. Rural’s science teachers</td>
</tr>
<tr>
<td>c. Chemistry, physics, and earth science teachers</td>
</tr>
<tr>
<td>d. Urban’s biology teachers</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>2. Students and Administration: One Distinction and One Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Urban High School</td>
</tr>
<tr>
<td>b. Suburban High School</td>
</tr>
<tr>
<td>c. Rural High School</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. Visions of Standards and the Nature of Compromise</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Teachers willing to compromise</td>
</tr>
<tr>
<td>b. Teachers reluctant to compromise</td>
</tr>
<tr>
<td>c. Teachers’ recommendations for changing Indiana’s science standards</td>
</tr>
</tbody>
</table>

**Figure 1. Outline of Narrative Representation**

Although it is beyond the scope of this chapter to present the entire narrative, given that it was approximately 50 pages long, a brief description of the conclusions and, more importantly, how those conclusions emerged is warranted. In the first part of the narrative, we used Suburban’s five biology teachers to illustrate a triad of teaching philosophies: affective, preparative, and scientifically-oriented. *Affective* refers to those philosophies that focus on students’ preferences, interests, or emotions. *Preparative* means that teachers view their work as preliminary to something else, be it a pending standardized test, the next high school science course, college, the workforce, or self-sufficient citizenship. Teachers with *scientifically-oriented* philosophies described their work as portraying science as a dynamic process, science as a way to solve problems, and science as understanding relationships between concepts, classroom observations or experiments, and everyday experiences.

We then applied this triad to Rural’s three science teachers to begin to make the argument that our framework was generalizable across the subject areas, school environments, and the teachers’ years of experience. We simultaneously argued within this section that the teachers’ personal philosophies had profound implications for their beliefs about Indiana’s science standards. Specifically, teachers who described their philosophies in largely affective or preparative terms tended to take neutral stances toward the impact of Indiana’s science standards on their work in that the standards neither supported nor detracted from their goals. Teachers with more scientifically-oriented philosophies, by contrast, tended to believe that Indiana’s standards contradicted their work.
Chapter 13: Narrative Analysis

Next, we extended the triad and neutral-to-contradictory scheme to the remaining chemistry, physics, and earth science teachers before ending the first section with a description of Urban’s biology teachers. This structure simultaneously increased the generalizability of our conclusions and served as a transition to the next section where we discussed the teachers’ experiences and beliefs on a school and district level. Urban’s teachers’ work with standards was affected by their perceptions of their students’ immediate and personal needs and future plans to a greater extent than the teachers at either Suburban or Rural, who tended to emphasize students’ comprehension of scientific concepts. With respect to administrative oversight, however, we argued that a clear pattern or continuum existed across the three schools with respect to implementing Indiana’s science standards. Urban High School clearly had the most oversight followed by Suburban and, finally, Rural High School.

In the final section of the narrative, we stepped beyond personal philosophies and local contexts to describe how the teachers envisioned the current and future impacts of the standards on their students and on their profession as well as their recommendations for changing Indiana’s current science standards. The triad of teaching philosophies, once again, was an essential plot line. The less-experienced teachers and those with affective and preparative philosophies were willing to accept compromises to their personal autonomy and curricular depth in order to implement the standards, which many described as “an inch deep and a mile wide.” The veteran and scientifically-oriented teachers, however, believed that such compromises were detrimental to their instruction and to their profession. Finally, the participating teachers almost universally recommended fewer, broader standards to accurately reflect elements of their teaching philosophies, to provide more flexibility in addressing their students’ needs and interests, to promote areas of personal expertise, or to promote continuity across the high school science curriculum.

The initial draft of the narrative included large amounts of transcript and other excerpted data to ensure that we were both accurately and comprehensively representing our data sources, especially the individual voices of the 23 participating teachers. To increase the comprehensibility and story-like nature of the narrative, we significantly reduced the amount of excerpted data. This illustrates how a narrative is not merely another condensed, chronicled version of qualitative data. Rather, a narrative represents a reorganization and transformation of the data that communicates holistic meanings based on the researcher-cum-narrator’s unique and personal understanding. Finally, to lend additional credibility to our conclusions, several experienced qualitative researchers performed an audit on our final narrative by comparing it to our original data sources. Each agreed that the aforementioned plot structure presented our conclusions in a fair, comprehensive, and compelling manner.

Using Narrative to Capture Experience and Understanding in Organic Chemistry

Our second example was inspired by the second author’s personal experiences with learning and teaching undergraduate organic chemistry. Although we were initially
interested in students’ conceptual understanding of organic reactions, we eventually broadened the inquiry to include the strategies that undergraduates used to learn reactions, the factors that influenced their adopting or developing particular learning strategies, and how those strategies affected their conceptual understanding of organic reactions. Our focus, therefore, expanded to include not only students’ knowledge and intellectual development, but also the various experiences that influenced how their understanding evolved. We chose, accordingly, to use both constructivism (see Chapter 2 and Ferguson, 2003) and phenomenography (see Chapter 8 and Orgill, 2003) to account for epistemological and experiential dimensions of our inquiry.

During a two-semester organic chemistry course, the second author conducted a series of interviews with seven undergraduate chemistry and chemical engineering majors who were enrolled in an organic chemistry course and attended the corresponding course lectures. The students’ homework and exams provided a context for the semi-structured interviews, which probed the strategies that the students used to understand organic reactions, their interpretations of reaction mechanisms, their thoughts about the role of memorization in learning organic chemistry, the features of the lecture to which the students paid attention, aspects of organic chemistry that were either particularly easy or difficult for them, advice they had for future organic chemistry students, and descriptions of how their strategies changed during the course.

As in our previous example describing teachers’ beliefs about standards-based reforms, narrative analysis provided us with a mechanism to synthesize our various data sources: interview transcripts, course descriptions and syllabi, exams, homework, participants’ educational background, and the second author’s research journals documenting her personal insights and revelations. Our original approach to data analysis was to develop generalizable categories of description as suggested by phenomenographic research (Orgill, 2003). We quickly realized, however, that the participants’ diverse range of experience with organic chemistry did not lend itself to such categorization. We found that this approach actually hindered our understanding of the students’ individual experiences. In the narrative vernacular, we could not find universal elements within the data and we decided, instead, to write separate narratives for each participant (Polkinghorne, 1988, 1995). Consider, for example, “Parker,” a dedicated student who received one of the highest course grades in general chemistry during the previous year and yet struggled with organic chemistry.

To capture his experiences with organic chemistry, the second author organized the narrative around two complementary plot lines; Parker’s view of organic chemistry and his understanding of organic chemistry. Parker viewed organic chemistry as a set of increasingly complex rules that students and chemists applied to specific situations. For him, organic chemistry did not have an underlying structure or the common themes that he had seen in other classes such as general chemistry and mathematics. He could not answer the question of why the rules existed and, consequently, felt overwhelmed as the semester progressed. Such views had natural impacts on his understanding of organic chemistry — referring to his success in predicting products of various reactions, writing mechanisms, and designing synthetic pathways. The second author used this
emplotted structure to connect his perceptions or views of organic chemistry with his conceptual development.

The separate narratives simultaneously preserved the uniqueness of each participant’s experiences with and conceptual understanding of organic reactions and facilitated our understanding of the data. Finally, we used these separate narratives — a type of case record for each participant — as the basis for making several conclusions or denouements regarding how we might improve instruction in organic chemistry. Some of these include the following:

- Instructors should provide clear expectations as to how students should approach learning organic chemistry.
- Instructors should provide experiences that reinforce their expectations.
- Students should be provided with experiences that help them develop a positive attitude towards their ability to succeed in organic chemistry.
- Instructors should help students make the transition from general to organic chemistry.
- More emphasis should be placed on the symbolic meaning for the chemical representations that are commonly used in organic chemistry.

In contrast to our first example where we used a single narrative to represent the beliefs of 23 teachers, the second author used separate narratives as a means of understanding her seven participants. Both researchers used plot lines to organize the data, but the narratives drew conclusions at different points. Our inquiry into standards-based reforms drew the conclusions within the narrative, which was appropriate given the centrality of the participants’ teaching philosophies. It was appropriate in the second inquiry, however, to write separate narratives to communicate the uniqueness of each participant’s experiences with and understanding of organic reactions. The separate narratives, however, were the foundation upon which the final conclusions were derived.

Delimitations, Criticisms, and Recommendations

We found narratives to be particularly effective data analysis and representation tools for our recent teacher- and student-centered inquiries in science and chemistry education. We recommend that narratives be considered when inquiries warrant direct integration of the researcher’s perceptions and insights, the historical and local contexts of the guiding research questions, the participants’ personal and professional backgrounds, and the participants’ experiences with and beliefs about a particular phenomenon or circumstance. Narrative provides a means for bringing an emplotted structure to a diverse range of data sources and for communicating the conclusions in a holistic and intelligible sense.
As we have done with hermeneutics and phenomenography, narrative analysis can be coupled with other frameworks to provide more comprehensive foundations for qualitative research. Theoretical orientations emphasizing historical and cultural contexts as well as the researchers’ perspectives may also benefit from such a synthesis. In particular, we recommend that researchers who are using critical, feminist, or Afrocentric theories or action research consider narrative analysis. These frameworks, by nature, take context and the researchers’ perspectives into account and, perhaps, already include aspects of narrative analysis. Integrating the resources that we have cited here will serve to strengthen the theoretical basis.

Narratives might not be appropriate, however, for inquiries where holistic representation of all data sources is not essential to the final analysis. Context and the researchers' perspectives are, of course, general themes of any qualitative inquiry, but it is a question of degree. Most qualitative work will include detailed descriptions of the historical background and literature precedent for the research question, detailed descriptions of the participants, and the researcher’s personal background. These data sources may not, however, be directly relevant to the analysis and representation phases of every qualitative inquiry. For example, inquiries of a more cognitive nature such as problem-solving or misconception research may not benefit from narrative analysis. In these cases, constructivism and modeling may serve as more appropriate theoretical orientations.

Finally, although narrative is theoretically compatible with many qualitative inquiries, it is not without its critics. The criticisms, however, are often derived from the same tenets upon which narrative is based. The very notion of creating a story from data causes some concern that researchers may be fictionalizing their data or, at best, telling a tale that applies only to the specific context of that inquiry (Clandinin & Connelly, 2000; Doyle, 1997). Others argue that narrative is excessively intersubjective since the researchers include their own perspectives and transformations within the emplotted story (Clandinin & Connelly, 2000; Doyle, 1997).

Inasmuch as these criticisms question the assumptions that serve as the foundations of narrative analysis, we can neither dismiss them nor distance ourselves from them. Within the two narratives described previously in this chapter, we included data excerpts — e.g. interview transcripts and standards-based documents — to enhance the plausibility of the plot lines and to ultimately promote the credibility of our conclusions. Plausibility and credibility, however, needed to be balanced with comprehensiveness and intelligibility. We chose an appropriate amount of data to include in the final narratives to accurately represent the range of our participants’ experiences, beliefs, and knowledge and to provide the reader with a compelling and reasonably long story. Narrative analysis places the burden on the researcher to represent all of the data in the final story rather than selecting only particular elements. We, therefore, assert that claims of fictionalizing data are largely unfounded.

The question of generalizability is asked from nearly every theoretical perspective in qualitative research, and we often substitute the word transferability in reference to how
the conclusions from one inquiry relate to findings from other studies (Clandinin & Connelly, 2000; Lincoln & Guba, 1985). By definition, narratives are generalizable only to the specific context of the given inquiry. Narratives are not meant to stand on their own as universally applicable stories or analytical frameworks. Narratives intend to represent a particular phenomenon in a fair and holistic sense so that readers and other researchers can transfer the results by comparing and applying the conclusions to their own contexts and independent inquiries. Although readers may critique and perhaps disagree with a particular set of conclusions, multiple narratives and interpretations from a variety of contexts will ultimately enhance our overall understanding of a situation or phenomenon.

Finally, the nature of writing and telling a story is interpersonal. A narrative represents how the author came to understand the people and the situation of interest, which we and others (Polkinghorne, 1988, 1993) have argued reflects how human beings understand the world. Narrative analysis simply includes such intersubjectivity as part of the framework, but uses it as a strength or an inevitability rather than a weakness.

Beyond these endemic criticisms, we have found two additional problematic features of narrative. The first is a practical concern in that narratives tend to be long, which often precludes them from publication in research journals. Narratives tend to be more appropriate for dissertations and books.

The second concern is an ethical one. By providing extensive contextual details, a narrative risks the anonymity of the participants and the institutions where they study and work (Clandinin & Connelly, 2000). As with all qualitative research, narratives should use pseudonyms for people and places, but the author must also minimize the ability of readers to deduce identifying information. A thoughtful audit by an additional researcher who has been approved for this role in the research study by a human subjects committee is especially useful here.

In spite of these criticisms and the significant effort required to write a comprehensive story, we recommend that researchers consider narrative as an analysis and representation medium. We offer the following questions as a preliminary checklist for those thinking about using narrative analysis in their work:

- Should the historical, cultural, and local contexts of your research question be directly integrated within the data analysis?
- Should the participants’ backgrounds be taken into account in the data analysis?
- Should your perspectives and revelations as the researcher be included in the analysis and conclusions?
- Where applicable, is narrative analysis commensurable with your other theoretical orientations?
• Is narrative compatible with any space limitations that you have?
• Can you preserve the anonymity of your participants within the narrative?

We recommend that you seriously consider narrative analysis in your research if you can answer most or all of the above questions in the affirmative. We have found narrative to be a useful means of preserving and communicating holistic meaning, a common goal in qualitative research. Given the few reports in chemistry and science education that apply narrative analysis in a formal sense, we believe that there is much work to be done in this area.

References


Critical Theory

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Biography

Provi Mayo was born and raised in San Juan, Puerto Rico. She attended the University of Puerto Rico at Rio Piedras and received a B.S. in chemistry. Upon graduation, Provi enrolled in the graduate program at Purdue University, where she completed an M.S. thesis on the problems of bilingual science learners and a Ph.D. dissertation on the learning of abstract three-dimensional concepts by the visually impaired. While at Purdue, Provi served as a teaching assistant for both chemistry and biochemistry courses, as well as a course supervisor and substitute lecturer for chemistry courses. She also worked with various minority programs and the adaptive services program. After completing her Ph.D., she joined the faculty at South Dakota State University, where she teaches a variety of chemistry and education courses and works on research in chemical education. Provi is the proud mother of Elena and Rafael.

Introduction

Critical theory is primarily concerned with issues of power and justice. It has been used to deal with matters of race, economy, class and gender; and it concerns itself with the way education, religion, and other social institutions interact to construct a social system (Denzin & Lincoln, 2000). Within the realm of education, critical theory provides the tools to explore, determine, understand, and eventually address the issues important to each diverse group within the complex social, historical, political and institutional practices used to create the classroom environment in which students and their instructors interact (McLaren, 1995).

Critical theory can be traced back to a group of philosophers at the Institute of Social Research in Frankfurt, Germany, who initiated a conversation in the German tradition of philosophical and social thought. Frustrated by forms of domination emerging from capitalism, critical theorists such as Horkenimer, Adorno and Marcuse, saw in critical theory a method for temporarily freeing academic work from these forms of power. They came to view their academic disciplines as manifestations of the discourses on power relations in the social and historical contexts that produced them. Other critical theorists
such as Poster (1989) and hooks (1994) have argued that critical theory originates in the assumption that we live in a world of pain and that critical theory has a pivotal role in the alleviation of that pain.

Brookfield (2005) described five distinctive characteristics of critical theory. In my description of these characteristics, I will express them within the context of an educational research study. First, critical theory is grounded in a particular political situation that is stable and is likely to remain stable until certain conflicts within that aspect of society are resolved and society is transformed.

The second characteristic of critical theory as applied to educational research is its concern with generating knowledge that can be provided to individuals to help them understand their situation, with the goal of facilitating their freedom from one or more oppressive aspects of the classroom environment in which the study is being carried out. Critical theories seek to generate knowledge that will result in action that leads to a change in the society being analyzed. If change is not part of the process of generating knowledge, critical theorists believe that the process is not complete. Critical theory is transformative; its main goal is to produce social change, enlightenment and emancipation (Brookfield, 2005).

Brookfield’s third characteristic of critical theory presumes that it does not distinguish between the participants and the focus of the research. Critical theory’s usefulness depends on the participants’ recognition that the study in which they are participating represents a search for a better, more authentic way of life. The validity of critical theory is determined by the extent to which the participants believe that the study represents their hopes and dreams (Brookfield, 2005).

According to Brookfield (2005), the fourth defining feature of critical theory is that it is normatively grounded. Critical theory is grounded in the current instructional environment, while, at the same time, envisioning a less alienated, more just, and more democratic world. Critical theory’s goal is to create a more ideal alternative to the present situation, rather than merely generating a description of the present situation.

Finally, Brookfield (1995) argues that any verification of critical theory is impossible until the more ideal social vision it seeks to achieve is realized. Horkheimer (1995) captured this aspect of critical theory when he noted, “in regard to the essential kind of change at which critical theory aims, there can be no corresponding concrete prescription of it until it actually comes about” (p 220). Horkheimer also argued that it is a struggle to create the conditions needed to test the vision critical theory has of the society under study.

**Goals of Critical Theory**

Jensen (1997) argued that critical theory seeks to provide a better understanding of present social conditions, how these conditions evolved, and how they interact with each other. In order to provide this knowledge, critical theory encompasses a multi-disciplinary approach that combines perspectives drawn from many fields of study,
Chapter 14: Critical Theory

including history, philosophy, economics, politics, psychology and sociology. As we have seen, however, the generation of knowledge is not enough; critical theory’s ultimate goal is to transform our present society into a more just, rational, humane and reconciled society.

Critical theory provides a framework for understanding the environment in which it is being implemented. Denzin and Lincoln (2000) noted that critical theory does not determine how we see the world, but it provides a strategy for its exploration. Critical theory holds that knowledge is socially constructed, contextual, and dependent on interpretation. Held (1980) argued that one of the aims of critical theory is to assess the disparity between ideas and reality. These contradictions need to be disclosed and understood before one can close the gap between theory and practice, between perception and reality.

McLaren and Giarelli (1995) suggest that critical theorists want to understand hierarchies of contexts, types of knowledge, and ways to evaluate them in terms of their possible contribution to information that can be used to achieve critical emancipation. Through research, critical theory seeks to expose the reasons why societies and individuals are prevented from making decisions that affect their lives.

Critical theory has inspired studies in education that have focused on providing a “voice” to groups whose opinions have historically been suppressed (Giroux, 1998). The role of critical theory in education is closely linked with the needs of communities and has been of great importance in the development of new approaches to research that will investigate societies and support their evolution toward freedom. Some of these developments within the area of adult education, for example, were partially responsible for the origins of participatory action research in Latin America (Torres, 1995).

Methods Used in Critical Theory

Critical theory tries to understand societies, their hierarchies, and the reasons why decisions are made that positively affect one group while suppressing another. Because of the quantity of information needed to obtain the insight required to achieve this goal, qualitative methods are typically used in studies inspired by critical theory.

The goals of critical theory are also consistent with the choice of narrative as a research tool (Agger, 1998; Held, 1980), even though the knowledge expressed in narrative or stories (Chapter 13) is often fragmented. Critical theory is often paired with other methodological frameworks, such as ethnography (Chapter 10), case study, Action Research (Chapter 9), and critical race theory. Critical theory often serves as the inspiration, guide or theoretical base for a study while the second framework with which it is coupled provides the method for data collection and analysis (Agger, 1998).

The term critical ethnography is often used by researchers when critical theory is paired with ethnographic methods (Chapter 10). This approach has also been called critical research (Carspecken, 1996). Madison (2005) noted that the “critical” in critical
ethnography defines the types of questions, field notes, narratives, journals and case studies to be used during the research. The “ethnographic” part of critical ethnography describes the interaction between the interviewer and the interviewee, who are partners in this research as they construct memories, meanings and experiences together (Madison, 2005).

Lorsbach and Tobin (1995) used a critical theory perspective for a study of learning environments in a science classroom in order to have a transformative effect on these classrooms. The authors’ goal was to use a critical approach to assist students and teachers to develop a learning environment that leads to emancipation. The methodology these authors coupled to the critical theory framework was that of a case study in which the data were gathered primarily by performing interviews with students and a teacher as well as by doing observations of the students working on lessons on optics and static electricity.

Hanrahan (1999) used a theoretical framework based on a mixture of psychological, sociological, and critical theory to study scientific literacy. Her study combined the points of view of a science education researcher and a science teacher by using methods such as Action Research (Chapter 9) and ethnographic case studies (Chapter 10). The data collection techniques used in her study were based on recorded information from action planning and review meetings, in-depth and short interviews, as well as informal conversations with the teachers, staff and students that were audio taped and transcribed.

Data Analysis

As we have seen, critical theory as a theoretical framework is often paired with a methodological framework that contributes its research methods and data analysis techniques. As a result, there is no specific way in which critical theory data are analyzed because analysis depends on the methodological approach and the data sources used in the project. Denzin and Lincoln (2000) referred to data interpretation within critical theory as an "often neglected domain" and pair critical theory with hermeneutics as the basis for discussions of the analysis of interpretation of data obtained in critical theory research.

Carspecken (1996) described the process of extracting meaning from data collected during a critical theory study as a hermeneutic process for which there is not a definite procedure. The meanings extracted from the data must always come from the participants. The researcher's role is to gather, interpret without polluting, and deliver the message derived from the data. For more information on hermeneutics refer to Chapter 6 of this text.

Benefits of Critical Theory

The main goal of critical theory is to help people create an environment in which they are free to make their own choices regarding the way they decide to think, learn and
Critical theory resembles many of the other theoretical frameworks described in this text because the choice of critical theory as the paradigm on which a study is based has a significant effect on the choice of methodology by which data will be collected and the nature of the research questions that can be addressed in the study.

When applied to research in education, critical theory allows participants in the study to ask questions about their own situation so they can make positive and informed choices about their learning. Brookfield (2005) argued that one of the benefits of applying critical theory to education is the ability “to investigate how dominant ideologies educate people to believe certain ways of organizing society are in their best interest when the opposite is true” (p. 30). Critical theory also provides insight into how people identify and oppose the ideological forces that shape the classroom environment in which they find themselves. It helps students learn how to challenge structures and beliefs that serve the interests of a more powerful group instead of the well-being of society as a whole.

**Criticisms of Critical Theory**

Critical theory has often been criticized and misunderstood. Many of the critics automatically equate critical theory with “leftist” or Marxist attitudes (Brookfield, 2005). Within the context of science classrooms, many instructors might object to a theoretical framework that uses terms such as “oppression” and “emancipation.” I will try to justify the use of these terms in the next section of this chapter.

Agger (1998) described what he called “friendly” critiques of critical theory, which include “obscurantism” and “groundedness.” The critique of *obscurantism* reflects the stylistic difficulty and inaccessibility of the language used by some critical theorists. Agger (1998) acknowledged that this criticism is ironic since critical theory values democracy and equality, but the language of critical theory is often difficult to understand and, therefore, frustrating. Marcuse was singled out by Agger as the only member of the Frankfurt school who noticed this difficulty and avoided complicated prose without compromising the message and depth of his social and cultural criticism. Agger answers the criticism of obscurantism by asserting that “many critical theorists need to write more clearly, taking the time to explain their complicated concepts without feeling compromised or diverted from their intellectual project” (p. 164).

The criticism of *groundedness* results from the tendency of many critical theorists to be too close to the issues, everyday life, culture, and politics that influence their work. This makes their theoretical work appear as if it obeys the demands of organized political movements instead of serving as a guide and conscience for society (Agger, 1998). Critical theory is therefore fundamentally different from ethnography, which has been criticized for being too neutral (Chapter 10).

Agger (1998) argues that critical theorists must make concessions to the disciplinary grounding of many scholars involved with critical theory. To achieve this, critical theorists need to develop empirical implications of critical theory for writing and teaching critical theory to the rest of the population. Critical theorists need to use examples and
common language to avoid confusion and make their work accessible to researchers trying to learn and use critical theory. Held (1980) also noted that although the central thought for critical theory advocated by Horkheimer, Adorno and Marcuse was the process of liberation and self-emancipation, the theorists failed to conceive a proper relationship between their theory and the application of those ideas.

Kinichlcoe (1995) noted that some have criticized his research as a type of politicization. He argued that these critics incorrectly see the dialogue needed between the critical theorist and the teacher as a means for the theorist to impose his views and opinions, which it is not. Critical theory goes farther than politics; it provides a vehicle for groups that historically have been neglected to teach others about their situation through research studies.

**Published Examples of Critical Theory Influenced Studies**

The goal of this chapter is to introduce critical theory, to provide examples of research that has been influenced by critical theory, and to give advice to those who are new to critical theory on how to use this theoretical framework in educational research. Often, researchers use critical theory to provide a guiding force for a study and couple it with other research frameworks that provide the methodology for the project. When used correctly, this combination is a powerful and useful tool for getting the information needed to empower a given population.

Because of the complexity of critical theory, I have created two separate tables to describe examples of the use of critical theory in science education. The first table contains papers about critical theory and its development. The second table contains studies in which critical theory was combined with a second theoretical framework.

The literature cited in Table 1 includes studies of the link between teacher education and issues of race, socio-cultural theories, pedagogy, and law.

**Table 1. Literature about critical theory and its development.**

<table>
<thead>
<tr>
<th>Reference</th>
<th>Theme concerning critical theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breunig, 2005</td>
<td>How critical pedagogy theory can be combined with experiential education</td>
</tr>
<tr>
<td>Calabrese Barton, 2001</td>
<td>Interview with McLaren concerning the application of critical pedagogy</td>
</tr>
<tr>
<td>Cooke, 2005</td>
<td>Contemporary critical social theory and authoritarianism</td>
</tr>
<tr>
<td>Dixson &amp; Rosseau, 2005</td>
<td>Review of critical race theory framework literature</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Title</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Jordan &amp; Yeomans, 1995</td>
<td>Theory and practice in critical ethnography</td>
</tr>
<tr>
<td>Kompridis, 2005a</td>
<td>Determining the contemporary identity of critical theory</td>
</tr>
<tr>
<td>Kompridis, 2005b</td>
<td>Past and future of critical theory: alternate conceptions for critical theory</td>
</tr>
<tr>
<td>Ladson-Billings &amp; Tate, 1995</td>
<td>The development of a critical theory with a race perspective to address the limitations of the multicultural paradigm</td>
</tr>
<tr>
<td>Lynn &amp; Adams, 2002</td>
<td>Recent developments of critical race theory in legal theory and how it can contribute to education</td>
</tr>
<tr>
<td>Mariage, Paxton-Buursuma &amp; Bouck, 2004</td>
<td>Discussion of new educational justice discursive practices through the use of critical theory and socio-cultural theories</td>
</tr>
<tr>
<td>Masschelein, 2004</td>
<td>Relationship between contemporary critical educational theory and the “self reflective” life</td>
</tr>
<tr>
<td>Mezirow, 1981</td>
<td>Ideas of Habermas applied to adult learning and education</td>
</tr>
<tr>
<td>Olivos, &amp; Quintana de Valladolid, 2005</td>
<td>Discussion of bilingual education reform from the perspective of critical theory and pedagogy</td>
</tr>
<tr>
<td>Pinar, 2003</td>
<td>Discussion of queer theory, its roots and relationship to critical theory</td>
</tr>
<tr>
<td>Price &amp; Reus-Smit, 1998</td>
<td>The relationship and contributions that critical theory can make to international theory</td>
</tr>
<tr>
<td>Solorzano, 1997</td>
<td>Discusses the emerging critical race theory as a framework in the law field and its relationship to race, stereotypes and teacher education</td>
</tr>
<tr>
<td>Solorzano &amp; Yosso, 2001a</td>
<td>Links between critical race theory and its relationship with race and racial stereotyping in teacher education</td>
</tr>
<tr>
<td>Solorzano &amp; Yosso, 2001b</td>
<td>Discusses how critical race theory can offer a methodology to conduct and present research grounded in the experiences and knowledge of people of color</td>
</tr>
<tr>
<td>Walton, 2005</td>
<td>Application of Foucault’s analysis combined with critical theory to improve research on bullying in schools</td>
</tr>
</tbody>
</table>
Critical theory is often combined with other theoretical frameworks to create a concrete research design and method (Breunig, 2005; Calabrese Barton, 2001). The literature cited in Table 2 provides examples of studies in which critical theory was used as one of the research frameworks to provide a more solid research design. These examples combine critical theory with adult learning theory, ethnography, case-study methodology, race theory, constructivism, Action Research, and queer theory to address the research questions and interests. The wide variety of frameworks combined with critical theory demonstrates that, used properly, critical theory can be the inspiration for many research projects that aim to understand, teach, empower and make a difference in a population.

### Table 2. Examples of Critical Theory Studies in Science Education

<table>
<thead>
<tr>
<th>Reference</th>
<th>Methodological frameworks</th>
<th>Research purposes or question(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown, 2004</td>
<td>Adult learning theory; Transformative learning theory; Critical social theory</td>
<td>Create a process-oriented model responsive to the challenges education faces in order to keep justice and equity</td>
</tr>
<tr>
<td>Calabrese Barton, 2000</td>
<td>Critical ethnography</td>
<td>Should political research methodologies be considered to improve urban education?</td>
</tr>
<tr>
<td>Chapman, 2005</td>
<td>Case study; Critical race theory; Portraiture</td>
<td>Describes how matters of voice are placed within contextual issues such as method, framework, analysis and relationships between the participant and researcher</td>
</tr>
<tr>
<td>Fuzessy, 2003</td>
<td>Critical race theory; Cummins sociology model</td>
<td>Examination of Inuit students’ perceptions of the teacher’s role in Nunavic</td>
</tr>
<tr>
<td>Hammond, 2001</td>
<td>Critical ethnography</td>
<td>Emergence of a new multiscience as the participants’ “funds of knowledge” are used to complement and guide a new kind of science curriculum</td>
</tr>
<tr>
<td>Hanrahan, 1999</td>
<td>Sociological, psychological, and critical literacy theory</td>
<td>Effect of the use of affirmation dialogue journal writing in science learning for high school low socioeconomic adolescent science students</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Method</td>
<td>Description</td>
</tr>
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<td>---------------------------</td>
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<tr>
<td>Hoffman &amp; Burrello, 2004</td>
<td>Case study</td>
<td>How superintendents of a regional education agency shifted the focus of schooling from utility to teaching and learning</td>
</tr>
<tr>
<td>Jofili &amp; Geraldo, 1999</td>
<td>Critical constructivism;</td>
<td>Case study of a teacher who changed the induction process of biology concepts for her students</td>
</tr>
<tr>
<td></td>
<td>Action research; Case study</td>
<td></td>
</tr>
<tr>
<td>Lorsbach &amp; Tobin, 1995</td>
<td>Case study</td>
<td>How learning settings can play a transformative role in creating a more emancipatory learning atmosphere in the classroom</td>
</tr>
<tr>
<td>Lynn, 2002</td>
<td>Critical race theory;</td>
<td>Understanding the motivations and perspectives of male black teachers in public schools with a high African American population</td>
</tr>
<tr>
<td></td>
<td>Qualitative methods</td>
<td></td>
</tr>
<tr>
<td>Preston, 1992</td>
<td>Social, ethical, and critical approach</td>
<td>What are the social and ethical implications of computer education in secondary schools in Queensland, Australia?</td>
</tr>
<tr>
<td>Snyder &amp; Broadway, 2004</td>
<td>Critical and queer theory</td>
<td>How eight biology textbooks address sexuality outside the heterosexual norm.</td>
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</table>

By combining critical theory with adult learning theory, Brown (2004) developed a strategy to help future educational leaders develop proper skills, such as reflection on values and beliefs, as well as content and experience in order to equip them with the proper tools to support and address equity issues in education.

Through a combination of critical theory and ethnography, Calabrese Barton (2000) used critical ethnography to combine the experiences of the participants and the researcher to incorporate the students’ language, beliefs, and experiences into urban school practices. Hammond (2001) used critical ethnography to design a new type of science (multiscience) created by incorporating the teacher’s, the students’ and the community’s knowledge in order to improve education by addressing the similarities and differences in beliefs and knowledge of these three groups who contribute to the classroom environment.

Case-study methodology has been combined with critical theory by several authors (Chapman, 2005; Hoffman & Burrello, 2004; Lorsbach & Tobin, 1995). Case study provides the tools necessary to study the participants’ life experiences in order to understand their particular situation. Case-study methodologies provide a good design for special populations since they concentrate on the way particular groups of people
confront specific problems, taking a holistic view of the situation. Patton (1990) argues that case study offers a method for investigating and understanding complex social units. This method was used in conjunction with critical theory as a theoretical framework to better answer the research questions raised in the studies described in this paragraph.

Critical race theory was used by Lynn (2002) to understand the motivation of male black teachers who choose to work in the public school system in areas where most of the students are of African American descent. Fuzessy (2003) used critical theory to examine Inuit students’ perceptions of the non-Inuit teacher’s role in the course and how cross-cultural training might help these teachers cope with cultural dissonance.

Sociological, ethical and constructivist approaches were combined with critical theory in studies by various authors. Hanrahan (1999) studied how having students write a reflective journal affects their sense of empowerment toward a particular course. Preston (1992) studied the ethical and social implications that must be taken into consideration when offering computer education in secondary schools.

Queer theory, derived from critical theory, was used by Snyder and Broadway (2004) in applying qualitative methods to study how eight different high-school biology textbooks approached the issue of homosexuality.

**Detailed Example of a Critical Theory-Influenced Study**

As an example of a project for which critical theory was viewed as an appropriate theoretical framework, I will describe some of the work we have done to try to understand how blind students visualize abstract chemistry concepts such as the three-dimensional representations of molecules. Critical theory is appropriate for these students because we are trying to change an “oppressive” environment in which blind students struggle to complete introductory chemistry courses that are necessary for them to enter many academic fields. The research has the potential to be “emancipatory” if we can help blind and visually impaired students develop the skills and knowledge they will need to succeed in fields that have traditionally been closed to them. Although chemistry texts can be translated into Braille and figures from these texts can be transposed onto tactile paper for blind students, the documentation of blind students’ perceptions, imageries, and visualizations of the instructional materials provided for them can play a pivotal role in understanding how these students learn and what they need to help them learn better.

This project began as an idea when blind students I was tutoring in work with the adaptive services program at Purdue mentioned that they often disregarded figures in their textbook because they either took too much time to understand or they did not correlate properly with the images they derived from reading the text. The students also noted how hard it was for them to understand abstract three-dimensional material from the text and the figures provided for the class. After reading the literature on studies of learning by blind students (Herman, Herman, & Chatman, 1983; Hollins, 1986; Millar,
1977, 1994; Pring, 1989), I designed a critical-theory-laden study based on the following research questions:

- How do blind students translate abstract chemistry ideas in their textbooks into a two-dimensional image or drawing? What symbols do they use to represent the translated ideas? How do blind students decide to use certain symbols to represent the abstract material given to them in the text?

- What discrepancies arise when blind students compare their perceptions of abstract concepts from the text and their haptic perception of raised-line drawings of those figures? How do they reconcile these differences?

- What are visually impaired students’ mental images when they are given words used in chemistry such as precipitation and crystallization?

By understanding how the mental images of these students diverge from the figures used to introduce abstract ideas, this study sought to generate the knowledge needed to enable programs for visually impaired students to better meet their needs. Critical theory provided this study with the focus needed to eventually develop appropriate educational material that would provide non-sighted students with the emancipatory knowledge to develop as independent and successful students in the sciences.

Critical theory served as the inspiration for this study because it focused on learning about and empowering visually impaired science students. This theoretical framework was combined with symbolic interactionism (Chapter 3), which seeks to understand the meanings and interpretations given to symbols by participants in a community. These theoretical frameworks were then augmented by the use of a case-study methodology.

Symbolic interactionism was used in this study to identify and decipher the common symbols that visually handicapped participants develop through their learning experiences in order to cope with their difficulty with abstract material. The visualizations and symbols gathered were used to understand the students’ thought processes while reading a text versus “looking” at a figure prepared for them by the adaptive services group at Purdue.

In the course of this study, I tried to understand what symbols the visually handicapped participants used, where these symbols were extracted from, and what the symbols meant for them. The meanings attached to these symbols could be either verbal or visual, in the form of an image.

Yin (1994) defined case-study methodology as “an empirical inquiry that investigates a contemporary phenomenon within its real life context especially when the boundaries between the phenomenon and the context are not clearly evident” (p. 13). Merriam (1998) noted that a case study is descriptive in nature and that it contains a complete literal description of the phenomenon being investigated. Case studies include as many variables as possible and portray interactions among these variables over a long period.
of time. Usually the case’s description has qualitative characteristics since it uses prose and literary techniques to describe, elicit images, and analyze the situations under study. The use of case study as a methodological framework gave me the opportunity to discover and interpret the factors that played a significant role in the way visually impaired students visualize abstract, three-dimensional concepts they encounter in text and figures in their science courses.

In order to answer my guiding research questions, I conducted interviews with blind and visually impaired students that were both audio- and videotaped. The video component was used to capture the participant’s gestures and drawing style. One-on-one interviews with visually impaired students gave me the opportunity to gather data and interact with the participants in a way that provided access to their mental images, symbols, and drawings.

Each of the undergraduate students who participated in this study was interviewed for two hours on two separate occasions. Another source of data for this study was an interview with one of the faculty at Purdue who had taught a biochemistry course in which one of these participants in this study had been enrolled. This interview, which also lasted two hours, provided a more complete picture of the reality of having a visually handicapped student in a science classroom. The last source of data for this study was a three-hour interview with a blind chemistry professor at a predominantly undergraduate university.

The interview questions, shown in Table 3, were chosen to help me understand the visually impaired participants’ mental images and visualizations of three-dimensional material. I chose molecular geometry as the theme for this study because it required the participants to construct mental images and visualize abstract material. Once the topic for the interviews was chosen, I asked the adaptive services program at Purdue to provide examples of the material on molecular geometry they gave to visually impaired students when they enrolled in a general chemistry course at Purdue. These materials were provided in Braille and focused on trigonal planar, tetrahedral and trigonal bipyramidal geometries.

**Table 3. Sample of the questions asked to the different participants during the study.**

<table>
<thead>
<tr>
<th>Participants</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blind Undergraduate Students</td>
<td>1. The participants were asked to draw different shapes such as a triangle, square, xyz coordinate system, square, square based pyramid and cube.</td>
</tr>
<tr>
<td></td>
<td>2. The participants were given a Braille text describing different molecular shapes and were asked to explain using words or drawings what they understood and visualized.</td>
</tr>
<tr>
<td></td>
<td>3. The participants were given models and were asked to use them to describe their mental images of certain molecular shapes such as “trigonal bipyramidal.”</td>
</tr>
</tbody>
</table>
4. The participants were asked to describe mental images evoked by visually-charged terms that are used in chemistry such as “melting,” “precipitation,” “soluble,” “bonding” and “combustion.”

**Blind Chemistry Professor**

1. Describe the geometry around the boron atom for B$_2$H$_6$.
2. Borazine has a similar structure to benzene, with alternate B-N bonds. Draw and describe the structure.
3. Describe the shape of Fe(CO)$_5$.
4. The professor was given the text and figures which were used with the other participants. He was asked to explain how his mental images of the text correlated to the figures that were prepared for the students.

**Biochemistry Professor**

1. The professor was asked what tools and techniques he used to explain abstract concepts to the blind student in his class.
2. The professor was asked if he noticed a difference in his teaching in the classroom and if he noticed a difference in the sighted students’ performance.

My role in the interview was to observe the individuals being interviewed in a manner that would enable me to describe the setting, the activities that took place, the people who participated, and the meaning of what was observed from the perspective of the participants. Like other forms of qualitative research, descriptions of what was observed during the interviews conducted using a critical theory perspective should be factual and accurate, without being cluttered by irrelevant details. The quality of the observations is judged by the extent to which the descriptions of these observations permit the reader to enter and understand the situation being described.

Observations can be made and documented from two different perspectives: emic and etic (Patton, 2002). The emic perspective focuses on an insider’s perspective in which the researcher shares as intimately as possible the life and activities of the participants in order to develop an insider’s point of view. The etic approach involves observing the particular phenomenon or culture from outside to see its separate events in relation to similarities and differences as compared to events in other cultures (Patton, 2002). This study was done through an etic perspective; I was an outsider to the participant’s world and they provided me with glimpses into their reality during the interviews.

I observed the participants’ body language and use of symbols as they either drew and/or modeled during the interview. As an observer, I was able to ask the participants about their mental images, learning and course materials. The observational data gathered from the students and the professors’ interviews were used to supplement the audiotapes from the interviews.

The purpose and the methods for data gathering in this study were directly guided by critical theory, the theoretical framework in this project. The data analysis was done
following the guidelines for case study and symbolic interactionism, the methodological frameworks. The data gathered for each participant was organized in separate case files. During the analysis, I discussed what methods the participants used to answer the questions, what images they described throughout the interview, and how the participants worked with the molecular models. Each participant was discussed in a separate section and examples to support any statement in the conclusion were extracted from the case records. Also at the end of each participant section I provided a summary which compared and contrasted each of the main points made in the analysis of the participant’s data. The data and the participants’ ideas and feedback on the materials used during the project were given to the adaptive service program staff at Purdue. In accordance with critical theory, the participants, as well as I, the researcher, had the opportunity to learn how they visualize, explore and understand the materials prepared for them by the adaptive services program. Also, the adaptive services program staff got feedback from the students how their services can be improved so they can better fulfill their needs. The students felt empowered because they had an opportunity to learn and participate in the development of scientific materials for other blind students who utilize the adaptive service program.

Conclusions

As noted previously, the goal of critical theory is to address issues important to diverse populations by generating knowledge that would help the individuals further understand and eventually change their situation. This knowledge will ideally empower these individuals to make the changes they feel are needed to improve their position within society as a whole. Critical theory helps the researcher accurately represent the participants’ goals. It also provides the tools to help the participants devise a plan to achieve these goals.

Usually, critical theory is used to study a population that has been ignored or forgotten by society. These populations are not in a position of power and are not able to change their situation on their own. Critical theory provides the guidelines and tools to give these populations the power to induce a favorable change. Critical theory was useful as a theoretical framework for my research project inasmuch as visually impaired students represent a very small fraction of the total student population and the instructional materials were designed by and made for sighted people. The subjects of this study had no input into either the development of the instructional materials or their adaptation for use with visually impaired students. This project provided the blind students who participated in the interviews with a “voice” to improve the materials that will be given to students who enroll in chemistry courses in the future.

References


Feminism

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Biography

Brenda Capobianco is an Assistant Professor of Science Education in the Department of Curriculum and Instruction and Affiliated Faculty in Women’s Studies at Purdue University. She also holds a courtesy appointment as an Assistant Professor in Engineering Education. She is the coordinator of Purdue’s elementary science teacher education program. Before entering academia, she was an award-winning middle science teacher for over ten years in Connecticut and an adjunct instructor of university science elementary and secondary methods courses. Brenda writes and teaches in the field of science education with interests in action research and issues of gender and culture in science education. Her research and publications focus on teachers’ development of practice through collaborative action research; teachers’ attempts at integrating feminist pedagogies using action research; and the construct of identity among young women in science and engineering.

Introduction

The goal of this chapter is to inform researchers of how feminism can be used as a theoretical framework for research in science education. To accomplish this goal I will review briefly how feminism is defined. Then I will describe the historical roots of feminism in science education. Lastly, I will describe feminist research methods practiced by science education researchers and provide compelling examples of feminist studies in science education. This chapter is designed to demystify feminism as a theoretical framework by examining what researchers and practitioners alike can actually do and furthermore, offer models to emulate or to modify. In this sense, I hope to take readers beyond a fundamental understanding of feminism as “fighting patriarchy” to a more progressive perspective of feminism as “producing knowledge” (Reinhartz, 1992) and “generating a discourse” necessary for establishing and sustaining equity and diversity in science education and society at large (Barton, 1998a).
Defining Feminism

In its simplest form, feminism is defined as “the advocacy of women’s rights on the grounds of political, social, and economic equality to men” (Jewell & Abate, 2001, p. 622). Feminism is premised on the recognition that gender is a phenomenon which helps to shape our society. Feminist researchers believe that women are located unequally in the social formation, often devalued, exploited, and oppressed (hooks, 1984; Kenway & Modra, 1992; Luke & Gore, 1992; Reinhart, 1992; Tong, 1998). Education systems, the knowledge which they offer, and the practices which constitute them, are seen to be complicit in this. Feminist researchers share the commitment to a form of politics directed towards ending the social arrangements which lead women to be “other than,” less than, put down, and put upon (hooks, 1984; Maher & Tetreault, 2001; Reinhart, 1992). Feminism, then, is a social theory and social movement, but it is also personal political practice.

For feminist researchers, feminism is a primary lens through which the world is interpreted and acted upon. Of course, feminism is not a monolithic discourse. There are, in fact, many feminisms informed by various social theories and research traditions and motivated by somewhat different social, political, and educational projects, each experiencing their own theoretical and practical problems (see Tong, 1998). For instance, liberal feminists might aspire to a world in which women have equal access to current social benefits and so develop an educational agenda premised on notions of “access and success” and equality with men. Liberal feminists have informed major legislation guaranteeing women equal education, pay, and opportunity (the Equal Pay Act of 1963; Title IX of the Education Act Amendments of 1972; the Equal Opportunity Employment Act of 1972). Socialist feminists, on the other hand, are concerned with the exploitative practices by which such benefits are products and their effects for women are gendered and classed social beings (Tong, 1998). Socialist feminists believe women’s oppression is not the result of individuals’ intentional actions but is the product of the political, social, and economic structures within which individuals live. Thus their educational project is directed towards ending education’s involvement in reproducing the complex, intersecting social relationships that are class and gender (Reinhart, 1992). Sometimes race and ethnicity are also encompassed in their agenda (Collins, 1990; hooks, 1984).

The fact that there are multiple definitions of feminism means that there are multiple feminist perspectives on research methods (Olesen, 1994; Reinhart, 1992; Rosser, 1997; Tong, 1998). One shared radical tenet underlying feminist research is that women’s lives are important. Feminist researchers do not cynically “put” women in their scholarship so as to avoid appearing sexist (Reinhart, 1992). Rather, for feminist researchers, females are worth examining as individuals and as people whose experience is interwoven with other women. In other words, feminists are interested in women as individuals and as a social category.
Historical Roots of Feminism in Science Education

There are two unique approaches to examining the construct of feminism in science education. The first approach was introduced by Brickhouse (1998) in her chapter on “Feminism(s) and Science Education” in the International Handbook on Research in Science Teaching. In this chapter Brickhouse outlines four major feminist traditions, including liberal feminism, radical feminism, socialist feminism, and poststructural feminism, and their respective influences on the development of the critiques of science. Her goal was to demonstrate how various feminist theories on science can enhance science curriculum and instruction and furthermore, offer an alternative framework for examining the nature of the discipline. The second approach has been introduced by Barton (1998a) in her book entitled, Feminist Science Education. Drawing from traditions carved out by scholars in women’s studies, Barton traces three progressive political and intellectual movements or “waves” in feminism and their impact on science education. In doing so, Barton has placed emphasis on significant reform movements in feminism and how these efforts initiated, if not provoked, major science education reform efforts that generated new and innovative curricular projects, programs, and lines of research that promoted conceptual understandings and scientific literacy for all students in science.

In the following section, I use Barton’s approach to describe the three important waves in feminism in science education and, in addition, highlight the effect these efforts made in changing the direction of curriculum, instruction, extra-curricular programs, and scholarship in science education.

First-wave feminism in science education

Feminism is rooted in the Women’s Liberation Movement (late 1960s to early 1970s) and is dedicated to changing those institutions and social practices such as science education that subordinate the interests of women to the interests of men (Brickhouse, 1998). Some of the earliest feminist reform movements in science education were linked primarily to debates about equity in science education (Baker & Leary, 1995; Brickhouse, 1994; Kahle & Meece, 1994). The reemergence of the women’s movement in the 1960s, along with the civil rights movement, led the science education community to take a critical look at the kinds of opportunities being granted to girls and minorities (Barton, 1998a). This wave of critiques of practices, referred to in women’s studies as “first-wave feminism” or “liberal feminism,” (Luke & Gore, 1992; Maher & Tetreault, 2001), focused on inferior treatment received by girls and minorities in schools and in other informal science education programs (Barton, 1998a). The liberal feminist perspective played an important role in the development of science education programs because it shifted emphasis from the ways in which girls and minorities were positioned as “inferior” and placed it on the kinds of structural and institutional constraints that posed barriers to successful participation in science by girls and minorities (Barton, 1998a; Brickhouse, 1994, 1998).
According to Barton (1998a), liberal feminism influenced science education programs in several significant ways. First, liberal feminist studies emphasized the ways of bringing women and minorities “into science” by focusing on achievement, attitudes, and participation in science (Baker & Leary, 1995; Harding, 1986; Jones & Wheatley, 1990; Kahle & Meece, 1994; Scantlebury & Kahle, 1993). Results from these studies were helpful in highlighting the ways in which women and minorities have been marginalized from entering the sciences; identifying classroom activities that fostered perceptions of science as uninteresting; noting a lack of role models, after school programs and incentives; identifying science teaching practices that perpetuated scientific knowledge as objective, rational, and androcentric; and utilizing educational practices that emphasized boys’ over girls’ achievements in science (Kahle & Meece, 1994).

Second-wave feminism in science education

According to Barton (1998a), “one of the more significant results to emerge from second-wave feminist studies in science education was the challenge to the values and standards of science and science education” (p. 4). These studies moved away from efforts at equity, toward exploring multiple ways of knowing and doing science that are reflective of the social, historical, and political context in which science has been constructed (Barton, 1998a; Barton & Osborne, 2001; Brickhouse, 1994; Roychoudhury, Tippins, & Nichols, 1993). Second-wave feminist studies in science education have focused on “the nature and practice of science” and on “ways of knowing in science.”

It is during this phase that feminist researchers in science education draw heavily on the work of feminist philosophers of science such as Harding (1986), Keller (1985), Bleier (1986), and Hubbard (1990). Harding (1986) and Keller (1985) examine the extent to which science may be a “masculine province” which excludes women and in turn, causes women to exclude themselves from it. They suggest science is masculine at three different levels: 1) at the surface level; 2) at the deeper intellectual level; and 3) in the core of the knowledge that is accepted as being scientific. At the surface, men compromise the majority of those who study, teach, and practice science. Examples and applications used in teaching are frequently masculine, and classroom interactions establish male dominance as a norm (AAUW, 1992; Rosser, 1990; Sadker & Sadker, 1994). At a deeper level, scientific thinking and knowing represent, if not incorporate, a masculine worldview (Keller, 1985). What is held as the essence of science among scholars of science is equivocated as being objective, rational, unemotional, and value-free. This explains the common premise for feminist-standpoint theory: “The difference in the social experience of men and women give them different ways of looking at life and interpreting events, and hence, different standpoints” (Harding, 1986, p. 17). Making a personal connection with the subject is unacceptable in science (Keller, 1985). Women may feel as outsiders in science classes when their emotionally connected ways of knowing are not warranted or their experiences are marginalized. Women should not have to reject their real-life experiences and try to assume the male viewpoint. According to second-wave feminists, how women experience science must be considered and valued as much as the men.
In sum, second-wave feminists suggest that the discipline of science demands that the perspectives and insights of women, minorities, and working-class students, who have been traditionally marginalized from participating in science, be included (Harding, 1991). Incorporating the lived experiences and voices of all individuals, especially the experiences of the groups still struggling for a voice and space in science, makes possible the construction of an inclusive science and science education. Much of the work conducted by second-wave feminist science educators has been grounded in a social constructivist framework (Rodriguez, 2001; Roychoudhury, et al., 1995). As a result, questions around the social construction of female-friendly (Rosser, 1990; 1997) and gender-inclusive science (Roychoudhury, et al., 1995) have begun to emerge. Feminist researchers in science education have used the movement to understand science as a social construct to initiate debate about ways of knowing science and the implications this has for science for all (Barton, 1998b; Barton & Osborne, 2001; Eisenhart, Finkel, & Marion, 1996).

*Third-wave feminism in science education*

The first- and second- waves of feminism have focused on the constructs of “gender and education” (Luke & Gore, 1992). Throughout these periods, the results of gender and education research led to changes both in how teachers teach science and in what science curricula students are expected to learn. In other words, feminist science education researchers have called for teachers to transform their goals, science content, and instructional practices to make science more attractive and inviting to all students, particularly women and minorities (Barton, 1998a; Barton & Osborne, 2001; Bianchini, Cavazos, & Helms, 2000; Brickhouse, 1994; Capobianco, in press; Mayberry & Rees, 1999; Richmond, Howes, Kurth, & Hazelwood, 1998; Rodriguez, 1998; Rosser, 1990, 1997; Roychoudhury, et al., 1995). One approach heralded by feminist researchers concerns the use of feminist pedagogy in the science classroom. According to researchers, feminist pedagogy entails changing not only what science is taught, but also how science is taught (Mayberry & Rees, 1999). It is directed at developing curriculum and instruction that validate the voices, experiences, and viewpoints of all students, especially female students; challenge existing practices as conventional and masculine in nature; place the role of the science teacher as facilitator; and empower students to redefine the role science plays in their own lives.

Since the second-wave of feminist research, there has been a moderate shift from emphasis on gender as a primary form of difference to emphasis on gender, race, class, and other socially significant dimensions (Barton, 1998a; Mayberry & Rees, 1999). Further, the third-wave of feminism demands self-reflexivity (Barton, 1998a; Lather, 1991). Lather (1991) states:

> ...if critical inquirers are to develop a praxis of the present, we must practice in our empirical endeavors what we preach in our theoretical formulations. Research which encourages self and social understanding and change-enhancing action on the part of developing progressive groups requires research designs that allow us as researchers to reflect on how our value commitments
insert themselves into our empirical work. Our own frameworks of understanding need to be critically examined as we look for the tensions and contradictions they might entail. (p. 80)

This feminist stance reflects a subjective, contextual, particular, and uncertain reading of the texts in material-theoretical lives: “There are no finite answers, no certainties in any one position” (Luke & Gore, 1992, p. 5). In short, it emphasizes the situated nature of knowledge (Haraway, 1988), power, and authority (Barton, 1998a).

In addition to recognizing science and curriculum as political texts and schools as drivers of hegemonic ideals, third-wave feminism also recognizes and draws its strength from teachers and students as “agents” and “actors” who actively shape and reshape their own understandings of the world from specific standpoints (Barton, 1998a). Scholarship that continues to emerge from third-wave feminism in science education is focused on issues such as the construction and reconstruction of scientific identities among young women (Brickhouse, Lowery, & Schultz, 2000; Brickhouse & Potter, 2001; Capobianco & Osborn, 2005; Carlone, 2004) and science teachers and scientists (Bianchini, et al., 2000; Helms, 1998; Kozol & Osborne, 2004) and social agency among science students (Barton, 1998b; Roth & McGinn, 1998; Rodriguez, 1998). At the core of this line of thinking is the concerted effort to understand and question the nature of science and scientific knowledge as well as how science can be situated within the larger society. For feminist researchers studying how students learn science, it entails a close examination of how children construct science out of their own questions and experiences, even when those experiences challenge societal norms (see Barton, 1998a; Howes, 2002) and/or studying how situated cognition provides resources for feminists to better understand science learning (see Brickhouse, 2001). For feminist researchers studying science teachers and teaching, it involves explorations in how teachers actively shape relationships around power and knowledge in the science classroom (see Capobianco, in press; Osborne, 1997). Examples of these third wave feminist studies in science education argue that science teaching is political and activist-oriented. For example, Capobianco (in press) has recommended that science teachers become researchers of their own practice and examine critically different ways of making science more accessible to their students. When this happens, teachers transform their practice, gain new knowledge, and generate a cluster of pedagogical possibilities for inclusive science teaching. By engaging in collaborative action research on feminist pedagogy, science teacher-researchers become actively involved in asking new questions about what science they teach, what role science plays in their lives, and who benefits from the uses of science and scientific knowledge.

Collectively, the main points of feminist research in science education indicate that if all students are to participate freely in science, science education needs to be re-created so that teachers and students can collaboratively create and analyze science and its role in their lives (Barton, 1998a). Hence, feminist research is inherently linked to action taken by students, teachers, and researchers of science education. The goal of feminist research in science education must be to create new relationships with science, to enhance teaching practices and curricula, and to change what we can learn about
ourselves as students, teachers, teacher educators, and researchers of science education. By retracing the historical roots of feminism in science education, researchers can better understand the variety of lenses that they can use to look at different actions taken to make science more inclusive.

**Is There a Feminist Research Method?**

In her collection of essays entitled, Feminism and Methodology, Harding (1987) explores basic and challenging questions about feminist research. One question in particular includes: Is there a distinctive feminist method of inquiry? To address this question, Harding argues that researchers must take into account the fact that discussion of “methods” (techniques for gathering data or evidence) and “methodology” (a theory and analysis of how research should be conducted) are often conflated with each other and with epistemological issues in feminist research. According to Harding (1989), the term, “method” is “often used to refer to all three aspects of research and consequently, it is not at all clear what one is supposed to be looking for when trying to identify a distinctive ‘feminist method of research’” (p. 2). In the following section, I describe different methodologies or what Harding calls “transitional epistemologies” used in feminist research. Then I describe general characteristics of feminist methods. Lastly, I elaborate on specific research methods commonly used by feminist researchers in science education.

**Feminist Methodological Frameworks**

Harding recognizes three types of feminist inquiry, which she refers to as “transitional epistemologies” (Harding, 1987, p. 3). These include: 1) feminist standpoint research; 2) feminist empiricism; and 3) postmodernism. According to Harstock (1993), a standpoint “carries with it the contention that there are some perspectives on society from which…the real relations of humans with each other and with the natural world are not visible” (Harstock, 1993, p. 159). Harstock contends that women’s circumstances “in the material order” provide them with experiences that generate particular and privileged knowledge that reflects both oppression and women’s resistance. Feminist standpoint theorists, like Smith (1987), Harstock (1993), and Rose (1983), argue that not just opinions but also a culture’s beliefs – what it calls knowledge – are socially situated. Feminist standpoint theorists focus on gender differences, on differences between women’s and men’s situations which give a scientific advantage to those who can make use of the differences. According to Brickhouse (1998), feminist standpoint research in science education is “a learned perspective that can provide challenges to science and help create theories and technologies that are more beneficial to women” (p. 1071).

Feminist empiricism begins with the position that science and its methods are basically sound, but some practices, procedures, assumptions, and findings of scientists are biased against women; because these practices are detrimental both to women and to science, they must be identified and curtailed. This is in contrast to feminist-standpoint
theory where a less-biased account of the world can be constructed by beginning investigations from the perspective of women.

Postmodernism emphasizes the multiplicity of identities of an individual - not just their gendered identities, but also, their racial, classed, and sexual identities - and it rejects a separation between subject (e.g. researcher/scientist) and object (e.g. nature of science). Thus, when carrying out research on gender and science education, researchers need to take into account that what it means to be a White male from an suburban setting or a Black female from an urban school is highly situated (Brickhouse, 1998). Research that analyzes data simply by placing all girls in one category and all boys in another does not take into account the diverse and intricate meanings of social categories, such as gender, race, or class.

Feminist standpoint research, feminist empiricism, and postmodernism are useful ways to look at different methodological approaches to feminist qualitative research. Furthermore, many feminist studies display different elements of these frameworks, combining and borrowing various tenets in an effort to generate, if not invent, alternative approaches to doing qualitative research. In the next section, I describe various research methods practiced by feminist researchers.

Feminist Research Methods


1. Feminism is a perspective, not a research method.
2. Feminists use a multiplicity of research methods.
3. Feminist research involves an ongoing criticism of nonfeminist scholarship.
4. Feminist research is guided by feminist theory.
5. Feminist research may be transdisciplinary.
6. Feminist research aims to create social change.
7. Feminist research strives to represent human diversity.
8. Feminist research frequently includes the researcher as a person.
9. Feminist research frequently attempts to develop special relations with people studied (in interactive research).
10. Feminist research frequently defines a special relation with the reader (p. 240)

Feminist researchers do not consider feminism to be a method per se. Rather they consider it to be a perspective on an existing method in a given field of inquiry or a perspective that can be used to develop an innovative method. This is why a chapter on feminism has been included in this book on theoretical frameworks for research in chemistry and science education. Research methods commonly practiced by feminist researchers fall into one of three categories: 1) listening to informants (e.g. interviewing, oral history, or reflective writing), 2) observing behavior (e.g. direct classroom observation), or 3) examining historical traces and records (e.g. genealogy). Feminist researchers generally do not favor one research method over another. In fact, feminist researchers often combine multiple methods supplied by basic research traditions (e.g. experimentation, ethnography, survey research, content analysis) or created by the research (e.g. drama, genealogy, group diaries). Multiplicity of methods allows feminist researchers to study the greatest possible range of subject matters and attain a broad set of goals. Interview and oral history research enable feminist researchers to hear women’s lived experiences first-hand; feminist case studies, cross-cultural research, and ethnography/autoethnography let researchers understand women in their contexts; feminist surveys allow researchers to understand variation within and among populations; and experiments make it possible to measure behaviors and attitudes without contextual distractions (Reinharz, 1992). In sum, there is no single “feminist way” to do research. There is little “methodological elitism” or definition of “methodological correctness” in feminist research. Rather there is a lot of individual creativity and variety.

**Feminist Analysis Techniques**

Many feminist researchers draw from and combine a variety of traditional approaches to qualitative data analysis. This includes techniques such as narrative analysis (Riessman, 1993), case study analysis (Yin, 2003), document analysis (Bogdan & Biklen, 1998), and grounded theory (Strauss & Corbin, 1998). One example of a qualitative data analysis technique unique to feminist researchers is called “voice-centered” narrative analysis. Introduced by Gilligan (1992), a voice-centered approach is primarily used by feminist researchers interested in discovering the complexity of the participants’ thoughts, feelings, and actions and, furthermore capturing the situational, personal, and cultural dimensions of their participants’ situations (Lawrence-Lightfoot & Davis, 1997). This involves the researcher scrutinizing transcripts from interviews (individual or group) several times, paying particular attention to subtle meanings and nuanced connections asserted by each participant. The researcher listens for the participants’ different voices they used to describe the plots of their respective storied experiences; their personal or professional identities; and how they experience themselves in their respective situations. Through construction and reconstruction of the participants’ voiced-centered stories, the researcher can create narratives grounded in the data (Clandinin & Connelly, 2000).
Issues Related to Conducting Feminist Research

Educational researchers need to take into consideration several key issues and concerns when conducting feminist research. In the following section I explore three key issues associated with conducting feminist inquiry in science education and provide examples of studies where researchers have attended to these concerns.

Researcher Bias

In qualitative research, the researcher needs to be confident that the material is unbiased in accurately representing social reality. In quantitative research, this is assessed in terms of “objectivity,” maintaining a space between the researcher and the researched so that the researcher is not influenced by the research process. In qualitative research, neutrality is possible by removing the distance between the researcher and the participant to ensure biases the researcher brings into the research are acknowledged and that the participant can confirm the validity of the depiction of their experience and social reality (Glesne, 1999). For example, in teacher action research, the goal is to include the teacher’s perspective and voice in all aspects of the research process. The assumption behind this agenda is that the material revealed will be more accurate and objective in representing the reality of the social experience and situation (Hollingsworth, 1994). By including the participants in the process, it is argued that the data will be unbiased and more truthful in representing the event in agreement with the participant. In both instances, the overall objective is for the data and the conclusions reached from the analysis of the data to be accurate and representative of the situation that was studied.

In feminist research, a participant’s personal experience is considered a valuable asset of the research project. Personal experience typically is irrelevant in mainstream research, or is thought to contaminate a project’s objectivity. In feminist research, by contrast, not only is the participant’s personal experience relevant, the researcher’s personal experience is relevant as well (see Role of the researcher, p.zzz). Mayberry and Rees’s (1999) essay on co-developing and co-teaching an innovative, interdisciplinary course titled “Earth Systems: A Feminist Approach,” provides a good example of how feminist researchers weave both their own experiences as well as the experiences of their students — male and female, natural and social science majors — into all aspects of the researchers’ account. Mayberry and Rees described their methodological approach as follows:

Personal experiences...provide the lens through which our discussion is refracted. We analyzed the written narratives of eight students collected from journal accounts compiled throughout the semester. We also conducted oral interviews with six students who volunteered to discuss the impact of the course on their knowledge of the relationships between earth processes and society as well as their commitment to social and environmental change. Finally, to provide an account of our experiences we draw on journals that we, the instructors, kept
Comparing their course-related experiences with that of their students allowed Mayberry and Rees to uncover the challenges both the instructors and students faced when combining geological education, sociological inquiry, and feminist pedagogy. Mayberry and Rees did not anticipate students’ initial discomfort with a vaguely structured course syllabus or sitting in a circle and opening all inquiry to discussion. These were instructional approaches Mayberry and Rees, as feminist instructors, were quite familiar with and anticipated students to respond positively. On the other hand, the instructors were surprised by some students’ fascination with feminist critiques of science while other students remained reticent to developing a more integrated or interdisciplinary perspective. In response to students’ personal experiences, Mayberry and Rees re-framed their course syllabus by incorporating more field-based and practice-oriented experiences (e.g. oil exploration game and a field trip to Death Valley) at the same time balancing a more socio-political agenda through whole class discussions. Mayberry and Rees’ work highlights the significant role that both the insider and outsider perspectives play in feminist research.

**Trustworthiness**

The notion of "validity" or what is called trustworthiness in qualitative research refers to the plausibility of the relationship between data and concepts; it implies the collective agreement of intended audiences that interpretations of data are not only compelling but convincing (Lincoln & Guba, 1985). This means that research procedures have to be "rigorous"; there has to be “quality control" throughout the stages of knowledge production (Lincoln & Guba, 1985). Some feminist researchers find the traditional discourse of rigor too "masculine" but others accept it, more or less willingly, because they feel it will lead to wider acceptance (mainstreaming) of the findings of feminist-inspired research and to a greater use of qualitative feminist research to guide public policy development. Feminist and other qualitative researchers have successfully challenged some of the traditional ways that validity and rigor are defined, and have helped raise the standards of social science by insisting that transparency in all aspects of the research process be a key criterion of validity and rigor (see Lather, 1991).

Feminist researchers address trustworthiness in different ways depending on how they frame their approaches to research (Olesen, 1994). Those employing research methods including interviewing and direct observation will seek out ways to establish credibility through strategies such as triangulation, member checks, and audit trails (Lincoln & Guba, 1985). Lather (1991) recommends that in addition to these traditional practices, researchers need to employ construct validity, face validity, and catalytic validity as further measures to build data credibility. By construct validity, Lather (1991) refers to an awareness of the researcher of the ways in which theories and other constructs are created. Face validity provides a ‘click of recognition’ (Lather, 1991, p. 67), a realization that what is being described or explained makes sense. Catalytic validity represents “the degree to which the research process re-orient, focuses, and energizes...
participants toward knowing reality in order to transform it…” (Lather, 1991, p. 68). Underpinning each of these strategies is one essential argument — feminist research is committed to capturing and representing differences while engaging in ethical and socially responsible research that demands both relevancy and rigor.

**Role of the Researcher**

A key feature of feminist research is the acknowledgment that the production of knowledge is a social process in which the researcher herself plays an important part (Luke & Gore, 1992; Reinharz, 1992). Feminists, along with other critical researchers, concern themselves with what constitutes valuable knowledge and in whose interests it operates (Wolf, 1996). For these reasons, the feminist researcher is encouraged to place herself within the research process.

The use of 'self as source' presents a very different relationship between the researcher and the researched when compared to that of the “traditional” researcher and subject. In feminist research, at the very least, both are to be regarded as having the same status as participants or collaborators in the same enterprise (Reinharz, 1992). The researcher carries a responsibility to critically assess her own, as well as the informants', changing positions and subjectivities (Lather, 1991). Each researcher brings particular values, interests and experiences to the research and has lived through particular circumstances. While these values, interests and experience do not necessarily determine particular points of view, they give researchers perspectives on topics and discussions. The feminist researcher must then be prepared to situate herself reflexively in the research account and provide an analysis of the social relations underpinning the research process (Lather, 1991; Luke & Gore, 1992).

The importance of this process of reflexivity for both qualitative and feminist research is in how it makes visible the ways in which the researcher, who is central to the research, both influences and is influenced by the research. Of significance is an awareness of how feminist researchers participate as subjects in their own research (Olesen, 1994). In her work with community college chemistry students, Barton (1998a) describes her position in her research as very personal, often using pronouns such as “our” instead of “their” when referring to her chemistry students, a choice that embeds herself in the group where she is studying versus distancing herself from it. Alberto Rodriguez (2001), a Latino male science teacher educator, describes reflexive accounts of his work in becoming a cultural warrior in science education.

Sharon Parsons (2001), a Black female science teacher educator, uses autoethnography to chronicle her sacred stories of transforming her practice as a feminist science educator. Both researchers position their science methods students as central to their own transformation as science teacher educators and researchers of feminist and cultural science studies.
Feminist Studies in Science Education

Feminist studies in science education can be found in scholarly journals such as the Journal of Research in Science Teaching, Science Education, International Journal of Science Education, Journal of Women and Minorities in Science and Engineering, and the Journal of Chemical Education. Other notable works on feminism in science education can be found in books, such as the International Handbook on Research in Science Education (Fraser & Tobin, 1998), the Handbook on Research in Science Teaching and Learning (Gabel, 1994), and Feminist Science Studies (Mayberry, Subramaniam, & Weasel, 2001).

There are relatively few studies on the role of feminism in chemistry education. Two articles deserve particular attention. In the first article entitled, “Women and chemistry: Shifting the equilibrium toward success,” Brickhouse, Carter, and Scantlebury (1990) examine the implicit assumptions and gender biases in chemistry curricula and offer more inclusive practices to help retain and recruit more women in the field. The idea that chemical research is competitive and highly authoritative is replaced with the notion that teachers can make science more female friendly by integrating cooperative group work, female role modeling, and students’ experiences, specifically girls’, as central to class discussions.

The second article titled, “What is feminist pedagogy? Useful ideas for teaching chemistry?” (Middlecamp & Subramaniam, 1999) combines feminist theory with pedagogy in the chemistry classroom. Middlecamp and Subramaniam (1999) define feminist pedagogy as sharing “its roots with alternative pedagogies but distinct in its focus on women and their experiences both in and out of the classroom” (p. 520). They view feminist pedagogy not as prescribing a series of formulas for chemistry teachers to implement, but as offering teachers ideas to inform their own instruction given particular teaching styles, student needs, and institutional constraints. In other words, they understand feminist pedagogies to “enhance our ability to use our individual ways of teaching to promote student interest and learning” (1999, p. 521). The authors identify several salient themes held across feminist pedagogies. These themes include recognizing women’s lived experiences and interpreting unequal gender relations; fostering existence of multiple authorities in the classroom; presenting people and knowledge as positioned within and across different contexts; empowering students to draw from their own resources; utilizing their own strengths; and serving as their own mentors; helping students find their own voices; and finally, challenging claims that scientific knowledge is free of value or interests.

Feminist Research Studies in Science Education

Research studies related to feminist science education fall into one of four categories: 1) gender equity studies; 2) transformative practices in science education; and 3) studies on gender and learning in science; and 4) studies of identity and agency in science education (see Table 1). Gender equity studies encompass research on girls’ attitudes, participation, and/or engagement in school science and/or outreach projects.
Examples of gender equity studies include the work of Baker and Leary (1995), Kahle and Meece (1994), and Jones and Wheatley (1990). Studies related to transformative practices involve ways of knowing, doing, and teaching science. Barton (1998a), Mayberry and Rees (1999), and Roychourdury, Tippins, and Nichols (1995) have focused primarily on how frameworks, such as feminism, critical theory, situated learning, and socioconstructivist or sociocultural theories inform how science teachers teach science, what science teachers teach, and how students interact with science. Studies on gender and learning explore one of two possible areas: 1) how the construct of gender shapes learning in science, or 2) how young women learn science in different environments. These studies include Brickhouse (2001) and Jones, Brader-Araje, Carboni, Carter, Rua, Banilower, and Hatch (2000), and Mason and Kahle (1989).

Research studies relatively new to feminist science education include the work of Brickhouse and Potter (2001), Brickhouse, et al. (2000), Capobianco and Osburn (2005), and Carlone (2004). These studies use the construct of identity to examine how young women view themselves as individuals and as participants in science. Research studies on social agency and science education examine the significant role teachers and researchers can play in bringing about social change for those in disadvantaged positions. Barton’s (1998b) article titled “Teaching science with homeless children: Pedagogy, representation, and identity” explores what it means to create a science for all from the perspective of urban homeless children. Common to these research studies is the unique way researchers draw on the work of critical and feminist scholars in science and education as well as on teaching and research to question how inclusive the science education community is in its efforts to understand the national imperative of science for all.

Table 1: Examples of feminist studies in science education based on four main categories.

<table>
<thead>
<tr>
<th>Reference Citation</th>
<th>Purpose of the study</th>
</tr>
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<tbody>
<tr>
<td>Gender equity studies</td>
<td>Examine the variables that influence females' success in science by experimenting with the outcomes of measures of formal reasoning ability.</td>
</tr>
<tr>
<td>Piburn &amp; Baker (1989)</td>
<td>Examine classroom interactions for gender differences that may contribute to the underrepresentation of women in physics and engineering courses and subsequent careers.</td>
</tr>
<tr>
<td>Jones &amp; Wheatley (1990)</td>
<td>Describe a synthesis of research depicting gender differences in science achievement.</td>
</tr>
<tr>
<td>Kahle &amp; Meece (1994) *</td>
<td>Describe a study that involved 40 girls in grades 2, 5, 8, and 11 in an effort to determine what influences girls' decisions to choose science.</td>
</tr>
</tbody>
</table>
Weinbugh (1995)  Presents a meta-analysis of literature which examined gender differences in students' attitudes toward science, and correlations between attitudes toward science and science achievement.

Bianchini, Hilton-Brown, & Breton (2002)  Investigates the role of dissent in a community of university scientists, engineers, mathematicians, and social scientists engaged in a two-year professional development project on issues of equity and diversity.


Transformative practices
Roychourdhury, Tippins, & Nichols (1995)  Examines the integration of feminist recommendations into a physical science course to gain new insights into the gender issues in science.

Barton (1998a) *  Entails an in depth look at science education from a feminist perspective


Mayberry & Rees (1999) *  Entails the results of developing and implementing a unique interdisciplinary course that infuses geological education with sociology and feminist pedagogy.


Studies on gender and learning
Mason & Kahle (1989)  Describes a teacher intervention program designed for teachers to modify classroom techniques and environments for fostering the participation of high-school girls and improving their science learning.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jones, et al. (2000)</td>
<td>Examines how elementary school students use tools when constructing new knowledge during science instruction, how gender intersects with tool use, and how competition for resources impacts access to tools.</td>
</tr>
<tr>
<td>Studies of identity and agency</td>
<td></td>
</tr>
<tr>
<td>Barton (1998b)</td>
<td>Explores what it means to create a science for all from the perspective of urban homeless children.</td>
</tr>
<tr>
<td>Barton &amp; Osborne (2001)</td>
<td>Examines current debates concerning schooling and the need for liberatory education; the social construction of science and identity; and systems of race, class, and gender oppression and domination.</td>
</tr>
<tr>
<td>Brickhouse &amp; Potter (2001)</td>
<td>Examines the scientific identity formation of two young women of color who attended an urban vocational high school.</td>
</tr>
<tr>
<td>Carlone (2004)</td>
<td>Examines the meaning of science and science students in a high school physics classroom and the ways in which girls participated. Suggests that students' agency in resisting or accepting the practice, identities, and knowledge of school science is worth understanding for the improvement of science education.</td>
</tr>
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* book or book chapter

**Conclusion**

Feminist research in science education involves tackling some of the most difficult issues and barriers faced by students, teachers, teacher educators, and researchers in science. Additionally it involves the amalgamation of research methods, methodologies, and epistemologies practiced by theorists and philosophers from the humanities, social
sciences and the natural/physical sciences. Drawing from the work of scholars in women’s studies, feminist researchers in science education have demonstrated that the boundaries between fields such as women’s studies and science have been transgressed and redefined.

Feminist researchers have made significant strides in the scholarship of science education, moving from issues of equity and diversity to concerns for identity formation and social agency as new and exciting research agendas. The scope of feminist science education research has also expanded from an earlier focus on gender and education to a more inclusive perspective that encompasses race, ethnicity, class, sexual orientation, disability, and other significant social dimensions. Above all, it appears that feminist research in science education is much more self-reflexive, culturally responsive, and sensitive to issues not only relevant to the researched and researcher but the research processes, as well. Given the diversity and complexity of feminist research practices in science education, it is not likely that there will be an accepted or uniform approach in the near future but rather a continued commitment to diversifying research methods and agendas to further our working understandings of what it means to make science accessible to all students.

References


The Afrocentric Framework
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Purdue University

Biographies

Chana Hawkins is a graduate student at Purdue University completing her master's studies in Science Education with an emphasis on the issues of underrepresented groups — particularly African Americans — in the context of science. She became interested in this subject while reflecting on her experiences during high school in southeast Michigan, her undergraduate studies in biochemistry at Xavier University of Louisiana (B.S. earned in 1998), her transition to graduate school, and her career as an African-American in science. Issues of African American cultural and historical concern have been part of her as far back as high school, when she researched literature and various expressive texts and conducted peer interviews about the state of the Black family. Her experiences in her family, the Christian church and ministry, what felt like school segregation in the 1990s, the community, and motherhood have all had a place in the work she is led to do. Before accepting her current position as Extension Educator at Michigan State University, she worked in K-12 school systems, with seniors and youth in the community and church, and as a chemistry instructor at Washtenaw Community College.

Michael Thompson received his B.S. in Biology/Chemistry in 1999 from Saint Joseph's College and his M.S. in Biochemistry from Purdue University in 2002. While working toward his doctorate in Biochemistry, Michael "saw the light" and decided to further his studies in Chemical Education at Purdue University. Currently, Michael Thompson is a Ph.D. candidate in the Chemistry Department at Purdue University with a research focus in Chemical Education.

Introduction

2003) is a potentially important theoretical framework for research in chemistry or science education because it reminds us that the European voice that dominates so many other theoretical frameworks is just one among many, and not necessarily either the best or wisest one (Mazama, 2001).

The Afrocentric framework was originally designed for use with African people and people of African descent (King & Mitchell, 1995). It provides a useful framework, however, for thinking about research that seeks to understand the ways of knowing used by other ethnic, racial, or cultural groups. The contribution that the Afrocentric framework makes to the discussion of theoretical frameworks for research in education is the assumption that people make meaning and understand the world from the perspective of their particular sociocultural and historical experiences of race, class, and gender. The Afrocentric framework assumes that meaning-making is not only an intersubjective achievement that occurs among or between individuals, but that it also involves transsubjectivity, that is, knowledge and meaning generated within the collective experience of a group (King & Mitchell, 1995).

From the perspective of the Afrocentric framework, the individual is not separated from the phenomenon or experience being studied; he or she is a living and dynamic producer of that experience. There is a strong element of critical theory in the Afrocentric perspective. King and Mitchell (1995) argued that the object of an Afrocentric inquiry is “the systematic knowledge of the condition of authentic African and African American existence and developing critical awareness as part of the process of cultural regeneration which racism makes necessary” (pp. 70-71). As King and Mitchell (1995) noted, “... an inquiry of this type seeks to enable people to understand social reality in order to change it” (p.71).

Eurocentricity “... presents the particular historical reality of Europeans as the sum total of human experience” (Asante, 1987 p. 171). Afrocentricity, on the other hand, does not condone assigning value to one particular ethnocentric orientation at the expense of degrading other groups’ perspectives (Asante, 1991). The Afrocentric framework seeks to produce a more humane response to the cultural and political phenomena confronted in Western society by people of African descent. It seeks agency and action and is very specific in its reliance on self-conscious action (Asante, 1998), as opposed to an objective, neutral, and detached mind frame and action (King & Mitchell, 1995). The Afrocentric framework poses as a revolutionary scheme, within the context of critical theory, because it challenges the tradition of a patriarchal, hierarchical, racialized society and the accepted dominance of one gender, class, race or sexual identity over another. Thus, in its most authentic presentation, the Afrocentric framework is antisexist, anticlassist, and antiracist. As Hoskins (1992) has argued, “Afrocentrism not only trains but also equips African peoples with the necessary tools and research methodology to engage in critical thinking and analysis of themselves, their history, and their future from their perspective and reference point” (p. 254). A vital outcome of such engagement is self-empowerment. Those involved in research in chemistry or science education might therefore wish to consider the Afrocentric framework as a perspective upon which to base studies of not only African or African-American populations, but...
other groups that have been viewed as marginal social categories — based on race, class, or gender — from the perspective of the dominant society.

**Origins of the Afrocentric Framework**

The origins of the Afrocentric framework can be understood by acknowledging the history of African people in an America that has historically operated in an economically, socially, politically, and religiously ingrained racial context. The Afrocentric framework is a reaction to an environment to which Africans and other ethnic or racial groups have been subjected, in which the dominant culture, through either deliberate or unintentional practices, suppresses the culture of the people it seeks to maintain in the margins. This process of actively working to marginalize the culture, social existence and contributions of people from non-dominant groups is a form of deculturalization. The Afrocentric framework also recognizes that these non-dominant groups have been subjected to *reculturalization*, or attempts to assimilate them into the dominant culture.

The historical origins of the Afrocentric paradigm, therefore, rest in the need of people of African descent to partake in the intellectual and communal production of knowledge about the experiences of people of African descent. The development of a doctoral program in Africological studies at Temple University in 1988 was viewed as providing the opportunity to build “... an army of scholars who were going to challenge White supremacy in ways it had never been challenged before — an army of scholars whose aim was to finally set us free from mental slavery” (Mazama, 2001, p. 403). In sum, the functionality of the Afrocentric paradigm is that it is a true paradigm for African liberation (Mazama, 2001). Afrocentricity was designed as a way of thinking that places the person of African descent at the center of the experience, of the knowledge production, and of the quest to answer questions relevant to the historical, present, and future life of the community represented by people of African descent.

**Afrocentricity as a Philosophical Model**

Schiele (1994), outlines Afrocentricity as a philosophical model that is “distinct from” and “oppositional to” Eurocentricity in terms of cosmology, ontology, epistemology, and axiology:

- Cosmologically, the Afrocentric framework views the structure of reality from a perspective of interdependency. All elements of the universe — people, animals, inanimate objects, and so forth — are viewed as interconnected. There is no separation between the spiritual and the material in the Afrocentric framework; reality is viewed as being simultaneously both spiritual and material.

- Ontologically, Afrocentricity assumes that all elements of the universe, including people, are spiritual. *Spirituality* is taken here to imply the nonmaterial or invisible substance that connects all elements of the universe.
• Epistemologically, the Afrocentric perspective places considerable emphasis on an affective way of obtaining knowledge — one that affects or excites emotion.

• Axiologically, Afrocentricity significantly underscores the value of harmonious interpersonal relationships; it offers a human-centered perspective toward life rather than an object- or material-centered perspective. In the Afrocentric framework, the value of maintaining and strengthening interpersonal bonds overrides the concern over acquiring material objects and accumulating wealth.

The Ontological in the Afrocentric Framework

Ontology traditionally focuses on the form and nature of reality (Guba & Lincoln, 1994). From the traditional perspective, matters of aesthetic or moral significance fall outside the realm of legitimate scientific inquiry. It might therefore be tempting to dismiss the Afrocentric idea of including spirituality as non-scientific since the denial of the presence of the moral question in traditional views of ontology stands in stark contrast to Afrocentricity. It is important to note, however, that proponents of the Afrocentric framework are not concerned with whether it should be viewed as "scientific" from the perspective of traditional ontology. The Afrocentric approach seeks to examine the form and nature of reality from the perspective of individuals of African descent, regardless of whether this perspective is "scientific." Rather than restrict itself to Eurocentric criteria of legitimate scientific inquiry, the Afrocentric framework asks "are there other ways of knowing?" — ways of knowing which, perhaps, researchers in science education have missed by conducting their studies within a Eurocentric frame of reference.

From an Afrocentric frame of reference, the moral and aesthetic aspects of reality are not only of great significance (Asante, 1998), but they are as much a part of the scientific enterprise as the traditional claims of neutrality, objectivity, and detachment (King & Mitchell, 1995). The Eurocentric view of the form and nature of reality explicitly denies what the Afrocentric view holds to be a truth of reality: the aesthetic and the moral are wholly and holistically significant to any inquiry. Inasmuch as the human experience is not void of moral and aesthetic questions, both moral and aesthetic issues must be raised within the context of studies of these experiences.

People of African descent have historically been marginalized, dominated, and invalidated by the dominant culture. This has also been true in terms of participation in and contribution to the development of science (Harding, 1993). Asante (1998) offers Afrocentricity as a moral as well as an intellectual approach that posits people of African descent as subjects rather than as objects of human history and that establishes a valid and scientific basis for the explanation of African historical experiences and ways of knowing that can affect research and practice in teaching and learning.
Epistemology in the Afrocentric View

The traditional questions of epistemology revolve around assessing what people know and why they believe something to be true (Hill-Collins, 2000). Within the context of Afrocentricity, “considerable emphasis is placed on an affective way of obtaining knowledge” (Schiele, 1994, p. 153). Akbar (1984) argued that “the focus on affect in Afrocentricity does not prevent recognition and use of rationality. Rather, affect, as a means of knowing, is viewed as offsetting the use of rationality” (p. 410).

The epistemological assumptions of Afrocentricity hold that the lived experiences of an individual provide the foundation of what that individual believes to be true and that the knowing gained through lived experiences becomes known through emotion or feeling (Schiele, 1994). Emotion or feeling is, therefore, not only a valid aspect of research on these experiences, but one that is critical to knowing from an Afrocentric perspective.

Consider what Asante (1998) refers to as African-American transcendence:

... the African finds energy and life in the midst of persons; he or she does not escape to the mountains or the valleys or the seashores to find the energy. There is no “great tradition” of withdrawal in the African or African American tradition; ours is preeminently a tradition of remarkable encountering with others. (p. 203)

Asante goes on to note that “encountering, for us [Africans/African-Americans], is always accompanied by words and, as such, it is profoundly verbal (p. 203).

It is in this verbal exchange that African-Americans have historically generated and validated what can be known; it is in this verbal exchange that a subjective attachment (in contrast to the Eurocentric objective detachment) allows the discoverer to be part of what can be known and what we can know about reality. Both individual and collectively shared experience become criteria of meaning and, therefore, how we know what we know.

Afrocentric theory is based on a cultural and historic perspective, a basis that inextricably ties the knower to what can be known. The nature of the relationship of the knower or would-be knower is intentionally, inherently, and explicitly rooted in the cultural and historic perspective; and human actions cannot be understood apart from the emotions, attitudes, and cultural definitions of a given context. The Afrocentric situated way of knowing and the relationship to what can be known assumes that what I know comes from both what I experience and what others experience — from what we have lived both intersubjectively and transsubjectively.

The Afrocentric Methodology

An Afrocentric methodology reflects certain principles of the philosophy and culture of the Black Experience: it is communal, spiritual and holistic. For example, this methodology recreates the simultaneous, holistic affirmation of black individuality and
collectivity, two opposing tendencies in the Eurocentric perspective that find harmonious expression in black life and in black art (Nobles, 1980; Stuckey 1987). The Afrocentric methodology requires that the knowledge produced must be emancipatory in the sense that it opens the heart (Mazama, 2001). This methodology recognizes that knowledge of the world contained in people’s daily cultural practice and social experience is generated from and grounded in their culture and experience and can be liberating as well (King & Mitchell, 1995).

**Background on Emancipatory Knowledge**

Emancipatory knowledge is rooted in a community’s desire to confront oppression, gain self-determination, and use knowledge for the purpose of uplifting the community. Historically, most of the research in education published in the U.S. has been generated by educators who are white, professionally educated, heterosexual, English-speaking, and middle or professional class. As a result, whether intentionally or not, this knowledge base tends to reflect the experiences and perspectives of dominant social groups. Sheurich and Young (1997) define the result of knowledge production that consistently has the effect of favoring whites as a group “epistemological racism.”

Emancipatory knowledge emerges from and embraces the social histories of historically marginalized communities (see the discussion of critical theory in Chapter 14). Emancipatory research is conducted with people from historically marginalized racial, ethnic or social classes, is often led by a researcher or research team who are indigenous members of one of these groups, and is interpreted within the intellectual framework of that group. Emancipatory research engages members of the community being studied as co-constructors or validators of the knowledge being produced.

Emancipatory research is often done by individuals interested in how members of a non-dominant group see themselves and their roles in society. The emancipatory domain therefore often focuses on “self-knowledge” or “self-reflection.” Results from this research can lead to emancipation from institutional and environmental forces that limit the control members of the non-dominant group can achieve over their lives.

One of the goals of emancipatory knowledge is insight that is gained through critical self-awareness. Knowledge is gained by self-emancipation through reflection, leading to a transformed consciousness or a “perspective transformation” (MacIsaac, 1995). Although emancipatory research takes advantage of self-knowledge obtained from self-reflection, it is important to recognize that no single individual is the sole contribution to either the definition of the problem to be solved or the success of actions taken to alleviate the problem.

Mazama (2001) summarizes the principles of Afrological methodology as follows:

> The African experience must determine all inquiry, the spiritual is important and must be given its due place, immersion in the subject is necessary, holism is a must, intuition must be relied on, not everything is measurable because not
everything that is significant is material, and the knowledge generated by the Afrocentric methodology must be liberating. … the methods used by Afrocentrists vary depending on their particular topic of study. However, Afrocentric methods devised by particular scholars must be informed by the principles outlined above. (p. 400)

The Afrocentric Method and Analysis

One method of data collection when conducting research using the Afrocentric framework is the “group conversation method” (King & Mitchell, 1995). This method is based on the central tenets of dialogue and dialectic, which are characteristics of the oral history of African people (Asante, 1987). The use of this method is consistent with what Freire (1993) has described as a thematic investigation, which involves the assessment of the thinking that occurs when one seeks to understand reality within the context of a community as individuals reflect on a situation. Dialogue allows teachers, scholars, and critical thinkers to cross boundaries and barriers that may have occurred due to race, class, professional standing, or other differences (hooks, 1994).

The group conversation method has its theoretical roots in critical reflection about participants’ shared experiences. This method acknowledges and reflects the communal and collective attribute associated with African and African-American culture, a communal and collective attribute connected through oral discourse based on the “spoken word” (Asante, 1987). Based on the Afrocentric Idea, this “spoken word” is the active principle that unifies African-American culture and traditional African culture. The “spoken word” has been described as having the power to bring things into being (Asante, 1987; King & Mitchell, 1995). In the group conversation method, the transcendent power of the “spoken word” is considered to be the essence of communal black spirituality. Speaking and listening to each other’s stories generates knowledge of the collective black condition and the self-insight needed to understand and respond effectively to the “challenge of Blackness” (Bennett, 1972). This challenge involves surviving with one’s soul intact in a society that is often hostile to blackness and black people (Prager, 1982).

It is through the lens of the “spoken word” that one emphasizes the communality and spirituality of the Black Experience. This approach to inquiry provides the context and process for a critical examination of one’s experience. By enabling the enhancement of the participant’s self-knowledge through identification of the social origins of one’s shared emotions and experiences, this approach to data collection takes on an emancipatory perspective.

The group conversation method is a metaphorically enhanced creative interviewing strategy that elicits reciprocal dialogue, which enables the researchers to learn with the participants about what “we” do and to reflect on why “we” do it. This interviewing strategy engages participants in a mutual search for self-understanding (Asante, 1987). In this approach to data collection, there is no objective researcher. The researcher is specifically connected to the conversation, the conversation must be rhythmic in nature,
and the conversation must be authentic. Rather than neutrality, reciprocity is the principle mode of relationship not only among the participants but between the participants and the researchers, who take a partisan stance toward improving the Black condition.

King and Mitchell (1995) showed how the group conversation method can be used in action. In their work, they used African-American literature to initiate group conversation and critical reflection about the participants' shared experiences within the context of raising sons. In the course of data collection, the researchers forfeited detachment and neutrality for interdependence with the participants, sharing perspectives about the common experiences of raising sons. For the researchers, who participated fully in the dialogue, this reciprocal, reflexive group conversation was a way of coming to know the Black Experience. As the participants and researchers reflected on the literature they had read and shared their personal experiences, thoughts, and emotions, the group became co-researchers in the inquiry process. For both the participants and the researchers, the group conversation was a way of becoming more critically aware of the collective Black Experience through reflexive examination of their own reality.

The Afrocentric Researcher and the Afrocentric Inquiry

Reviere (2001) outlined a set of basic beliefs researchers must hold to be considered Afrocentric. They must:

- hold themselves responsible for uncovering hidden, subtle, racist theories that may be embedded in current methodologies;
- work to legitimate the centrality of African ideals and values as a valid frame of reference for acquiring and examining data; and
- maintain inquiry rooted in a strict definition and interpretation of place.

Afrocentricity establishes agency as the key concept for freedom. It assumes that an individual is most free when that individual is most active on the basis of their own volition (Asante, 1998). This is equally true for both the researcher utilizing an Afrocentric framework and for the individuals with whom the researcher engages for action and agency. Believing that people are capable of reconstituting themselves as authentic beings requires that the researcher be engaged, be capable of listening with caring, and be accountable to the study participants.

The Afrocentric framework relies upon the ideas of center/location/place, dislocation, and relocation as key concepts. Mazama (2001) defines these concepts in the following manner:

- The concept of center (also location and place) is fundamentally based upon the belief that one’s history, culture and biology determine one’s identity, an identity that, in turn, determines our place in life, both material and spiritual.
... to practice and live one’s culture and to apprehend oneself in a manner that is consistent with one’s history, culture, and biology is to be centered or to proceed from one’s center.

- Dislocation occurs when one lives on borrowed cultural terms and/or when one apprehends reality through another group’s center …

- Relocation, therefore, is the re-centering of oneself and proceeding from the center of one’s history, culture, biology, and so on. (p. 397)

The researcher, through the choice of language, attitude, and direction, must explicitly reveal his or her answer to the fundamental question “who am I?” Asante (1998) and Reviere (2001) have argued that this is something that needs to be done both before the study is begun and after it has been completed. They refer to the result of this process of both introspection and retrospection as defining the researcher’s “place.” In the Afrocentric framework, language is defined as a regularized code that has been agreed upon by a community of users; attitude refers to a “predisposition to respond in a characteristic manner to some situation, value, idea, object, person, or group of persons” (Mazama, 2001, p. 397); and direction is the line along which the author's sentiments, themes, and interests lie with reference to the point at which they are aimed. It is the intentional and overt naming of place by the researcher and the centering of the inquiry authentically within the context of the African that creates the Afrocentric inquiry.

Mazama (2001) has argued that the following consensus exists among Afrocentric scholars regarding Afrocentric epistemology, methodology, and methods:

- A people’s worldview determines what constitutes a problem for them and how they solve problems. As a result, Afrocentric scholarship … must be centered in the experiences of African people.

- The essence of life and therefore of human beings is spiritual. This is not to deny the material aspect of life; however, when all is done and said, what remains is not the appearance of things but the indivisible essence of life that permeates all that is, the spirit — the ultimate oneness with nature, the fundamental interconnectedness of all things.

- Afrocentric knowledge is validated through a combination of historical understanding and intuition; that is, knowing is both rational and superrational. ...

- The ultimate aim is liberation, and thus, the Afrocentric methodology must generate emancipatory knowledge that will free us and empower us. (p. 399)
Research in Chemistry/Science Education on Afrocentric Issues

A search of the literature identified several studies that addressed some of the questions raised by the Afrocentric perspective, although none of these studies contained either an explicit reference to this theoretical framework or was carried out using a methodology consistent with the Afrocentric framework. Post, Stewart and Smith (1991), for example, used math/science self-efficacy surveys to study 111 Black first-quarter freshmen at a large Midwestern university. Maple and Stage (1991) used a set of three surveys over a four-year period to study more than 2000 Black students in order to explore the relationships among factors such as students’ choice of mathematics and science-related careers, parents’ education, locus of control, parental influence, school influence, test scores, mathematics attitudes, high-school mathematics and science experience, and achievement. Neither of these studies could be described as Afrocentric because of the absence of the dialogue and dialectic required in that framework.

Lewis and Collins (2001) reported a case study of three African-American college students that was done in order to understand the career decisions these students make. They noted that, although these students had all begun college interested in science-related careers, only one of the students was still interested in a career in science by the end of the study. This study was closer to being consistent with the Afrocentric framework, but the methodology relied on a series of one-on-one interviews rather than a focus group approach that would have introduced an intersubjective aspect into the dialectic.

A Detailed Example of an Afrocentric-Based Study in Chemical Education

On the basis of her own experiences as an undergraduate chemistry major and a graduate student in chemical education, the first author became interested in understanding some of the issues associated with recruiting and then retaining Black graduate students in chemistry. As she read the research literature — especially the quantitative research unsupported by critical qualitative analysis — she reacted to the absence of the student "voice" in this work. Black students were taken to be the objects of this research, rather than subjects who might be the primary source of analysis of the research objectives from their own perspectives. She concluded that the students were theorized, categorized, and quantified — all with minimal focus on realizing and critically analyzing the student voice.

She decided to build her M.S. thesis (Hawkins, in preparation) around the realization that there is a need to acknowledge the role that affective experiences play in retention of minority students — an affective experience that was unacknowledged in recruitment and retention efforts, an affective experience which is only superficially addressed in the commonly used surveys or questions to which students are asked to respond in traditional research on minorities.
She became convinced of the need for a body of research that focused on each of these students as a person, as a member of an ethnic group, as a member of a gender group, as someone who came from a particular socio-economic class, as a marginalized member of the scientific culture, and so on. She postulated that questioning the status and conditions that shape possibilities for Black students from the perspective of critical theory might help uncover why these groups have a high attrition rate and why these rates have remained virtually unchanged for nearly 30 years.

Her study was based on the assumption that the reality of being a Black graduate student was defined by a multiplicity of factors, including the student’s life, the support system among friends and/or family, the departmental support, the atmosphere of the department, the personal status of the graduate student, the student’s cultural values, the cultural values of the scientific enterprise, the conflict or congruence between personal cultural values and scientific cultural values, and so on. Her work was based on the assumption that these contextual factors were not likely to surface through superficial contact with the students. They had to be addressed explicitly through active participation by the students themselves, with the primary focus of the study being the voice of the students in order to understand the experiences of Black graduate students in science, in general, and chemistry, in particular. The goal of her work was therefore to explore the lived experiences of Black graduate students in chemistry at a major research university to gain an understanding of their cultural beliefs, their personal experiences and experiences in science, and their beliefs about the culture of science in order to give voice to a population that has not been previously addressed in such a manner.

The goals of this research were:

- To engage members of an underrepresented group in science (African-American graduate students) in an in-depth critical and dialogic/dialectic exploration of the factors that led to their decisions to pursue careers in science;
- To determine whether participants made or are making appropriate career choices;
- To include the voices — participants’ perspectives, perceptions, experiences — from the margins, from members of an underrepresented group as the principal source for understanding and analyzing the context in which these voices have lived. These voices serve as critique and action in this research approach.

The theoretical framework adopted for this study was a mixture of critical theory (Chapter 14) and the Afrocentric framework described in this chapter. Both frameworks were appropriate because the overarching goal of this work is to generate the knowledge that will enable action to be taken to increase the number of minority students who graduate with M.S and/or Ph.D. degrees.
Conclusion

As previously stated, Afrocentricity is intellectual in nature, but it also is analytical. Asante (1998) writes:

Afrocentricity’s intellectual assault on the dominance dogma is initially historical; that is, it presents a set of facts describing events and phenomena in such a way that a more valid interpretation of the agency of African people emerges in the circumstance of oppression. Second, the assault is analytical in the sense that it examines the conceptual frames of domination and makes a critique of domination in the linguistic, social, aesthetic, cultural, political and economic spheres. ... Another type of assault is purely analytical and deals with language itself, with conscious focus and reflection on even the terms we use. Unless we reflect on the terms we use, we may continue to use terms that encapsulate us, distort our historical reality, cloud our own minds, and render us impotent in the face of psychological, political, or cultural challenges (pp. 42-43).

Moreover,

Afrocentricity offers hope for actualizing the masses of Americans around the idea of African people as subjects rather than as objects. ... You cannot grant or accept agency for a people who have been marginalized, whether by others or themselves, without fundamentally altering the character of the society. (p. 42).

The Afrocentric framework provides a useful foundation for studies of aspects of the “Black experience” in chemistry/science education that are carried out by individuals of African or African-American descent. We believe, however, that it also provides a useful basis for thinking about critical research (see Chapter 14) that examines the lived experiences of other non-dominant groups that have been marginalized on the basis of race, gender, ethnicity, sexual orientation, or other factors.

References


Part

III

CRITICAL THEORY FRAMEWORKS