Part

II

HERMENEUTIC FRAMEWORKS

6

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 MacIssac (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, 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

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy.* New York: Oxford University Press.

Abd-El-Khalick, F., Bell, R.L., & Lederman, N.G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education, 82,* 417-436.

Adams, P.E., & Krockover, G.H. (1998). Getting there from here: The role of policy. *Journal of Research in Science Teaching, 35,* 707-709.

Anderson, R.D., & Helms, J.V. (2001). The ideal of standards and the reality of schools: Needed research. *Journal of Research in Science Teaching, 38,* 3-16.

Atwater, M.M. (1998). Science literacy through the lens of critical feminist interpretive frameworks. *Journal of Research in Science Teaching, 35*, 375-377.

Bodner, G.M. (2004). Twenty years of learning: How to do research in chemical education. *Journal of Chemical Education, 81*, 618-625.

Bodner, G.M., & MacIsaac, D.L. (1995, April). *A critical examination of relevance in science education research*. Paper presented at the meeting of the National Association for Research in Science Teaching, San Francisco, CA.

Brickhouse, N.W. (1989). The teaching of the philosophy of science in secondary classrooms: Case studies of teachers' personal theories. *International Journal of Science Education 11*, 437-449.

Brickhouse, N.W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education, 41,* 53-62.

Brickhouse, N.W., & Bodner, G.M. (1992). The beginning science teacher: Narratives of convictions and constraints. *Journal of Research in Science Teaching, 29,* 471-485.

Brooks, C.A. (1982). Using interpretation theory in art education research. *Studies in Art Education, 24,* 43-47.

Bryan, L.A. (2003). Nestedness of beliefs: Examining a prospective elementary teacher's belief system about science teaching and learning. *Journal of Research in Science Teaching, 40,* 835-868.

Collins, A. (1998). National science education standards: A political document. *Journal of Research in Science Teaching, 35,* 711-727.

Collins, A. (2004). Guest editorial. *Science Education, 88,* 1-3.

Coombs, F. (1994). Education policy. In S. Nagel (Ed.), *Encyclopedia of policy studies* (pp. 587-616). New York: Marcel Dekker.

Cronin-Jones, L.L. (1991). Science teacher beliefs and their influence on curriculum implementation: Two case studies. *Journal of Research in Science Teaching, 28*, 235-250.

Cuban, L. (1999). The integration of modern sciences into the American secondary school, 1890-1990's. *Studies in Philosophy and Education, 18*, 67-87.

Dagher, Z., & Cossman, G. (1992). Verbal explanations given by science teachers: Their nature and implications. *Journal of Research in Science Teaching, 29*, 361-374.

Eger, M. (1992). Hermeneutics and science education: An introduction. *Science and Education, 1*, 337-348.

Eger, M. (1993a). Hermeneutics as an approach to science: Part I. *Science and Education, 2*, 1-29.

Eger, M. (1993b). Hermeneutics as an approach to science: Part II. *Science and Education, 2*, 303-328.

Fenstermacher, G.D. (2002). A commentary on research that serves teacher education. *Journal of Teacher Education, 53,* 242-247.

Gadamer, H.G. (1976). *Philosophical hermeneutics* (D.E. Linge, Trans.). Berkeley, CA: University of California Press.

Gadamer, H.G. (1996). *Reason in the age of science* (F.G. Lawrence, Trans.). Cambridge: MIT Press. (Original work published 1979).

Gadamer, H.G. (2000). *Truth and method.* (J. Weinsheimer & D.G. Marshall, Trans.). New York: Continuum.

Garrison, J. (1996). A Deweyan theory of democratic listening. *Educational Theory, 46,* 429-451.

Geelan, D.R. & Taylor, P.C. (2001). Writing our lived experience: Beyond the (pale) hermeneutic? *Electronic Journal of Science Education, 5*, 1-14.

Ginev, D. (1995). Between epistemology and hermeneutics. *Science and Education, 4*, 147-159.

Goodson, I.F. (1997). Representing teachers. *Teaching and Teacher Education, 13*, 111-117.

Habermas, J. (1996). *Between facts and norms: Contributions to a discourse theory of law and democracy* (W. Rehg, Trans). Cambridge: MIT Press.

Halliday, J. (2002). Researching values in education. *British Educational Research Journal, 28,* 49-62.

Indiana Department of Education. (2003). *Indiana's Academic Standards.* Retrieved October 1, 2003 from http://www.doe.state.in.us/standards

Knodel, J. (1993). The design and analysis of focus group studies: A practical approach. In D. Morgan (Ed.). *Successful focus groups: Advancing the state of the art* (pp. 35-50). Newbury Park, CA: Sage.

Lederman, N.G. (1999). Teachers' understanding the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching, 36,* 916-929.

Morgan, D.L. (Ed.). (1993). *Successful focus groups: Advancing the state of the art*. Newbury Park, CA: Sage.

Moss, P.A. (1994). Can there be validity without reliability? *Educational Researcher, 23,* 5-12.

Moss, P.A., & Schutz, A. (2001). Education standards, assessment, and the search for consensus. *American Educational Research Journal, 38,* 37-70.

Obed, N. (1998). Marginalized discourses and scientific literacy. *Journal of Research in Science Teaching, 35,* 365-374.

Patton, M.Q. (2002). *Qualitative research and evaluation methods.* Thousand Oaks, CA: Sage.

Polkinghorne, D.E. (1988). *Narrative knowing and the human sciences*. Albany, NY: State University of New York Press.

Polkinghorne, D.E. (1995). Narrative configuration in qualitative analysis. In J.A. Hatch and R. Wisniewski (Eds.). *Life history and narrative* (pp. 5-23). Washington D.C.: The Falmer Press.

Ravitch, D. (1995). *National standards in American education: A citizen's guide.* Washington, DC: The Brookings Institution.

Ravitch, D. (2000). *Left back: A century of battles over school reform.* New York: Simon and Schuster.

Shane, J.W. (2005). *High school science teachers' beliefs about the intended and actual impacts of standards-based reforms*. Unpublished doctoral dissertation. Purdue University.

Southerland, S.A., Gess-Newsome, J., & Johnston, A. (2003). Portraying science in the classroom: The manifestation of scientists' beliefs in classroom practice. *Journal of Research in Science Teaching, 40,* 669-691.

Spillane, J.P., & Callahan, K.A. (2000). Implementing state standards for science education: What district policy makers make of the hoopla. *Journal of Research in Science Teaching, 37,* 401-425.

Stewart, J. (1983). Interpretive listening: An alternative to empathy. *Communication Education, 32,* 379-391.

Stewart, D., & Shamdasani, P. (1990). *Focus groups: Theory and practice.* Newbury Park, CA: Sage.

Tobin, K., & LaMaster, S.U. (1995). Relationships between metaphors, beliefs, and actions in a context of science curriculum change. *Journal of Research in Science Teaching, 32,* 225-242.

Tobin, K., & McRobbie, C.J. (1997). Beliefs about the nature of science and the enacted science curriculum. *Science and Education, 6,* 355-371.

7

Phenomenology

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Biography

Kirsten Casey is an Assistant Professor of Chemistry at Anne Arundel Community College. She decided to become at 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" (Cresswell, 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

Cohen, L., Manion, L., & Morrison, K. (2000). *Research methods in education.* London: Routlage

Cottrell, R. (2005) *Health promotion and education research methods: Using the five chapter thesis/dissertation model.* Sudbury, MA: Jones & Bartlett Publishers

Creswell, J. (1998). *Qualitative inquiry and research design.* Thousand Oaks, CA: Sage Publications

Denzin, N., & Lincoln, Y. (1998). *Strategies of qualitative inquiry.* Thousand Oaks, CA: Sage Publications

Fetterman, D. (1988). Qualitative approaches to evaluating education. *Educational Researcher, 17*, 17-23.

Hilosky, A., Sutman, F., & Shmuckler, J. (1998). Is laboratory-based instruction in beginning college-level chemistry worth the effort and expense? *Journal of Chemical Education, 75*,100-104

Marton, F. (1996). Is phenomenography phenomenology? Retrieved September 1, 1997, from http://www.ped.gu.se/biorn/faq/faq.phen.html

Polkinghorne, D. (1983). *Methodology for the human sciences*. Albany, NY: SUNY

Rieman, D (1986) The essential structure of a caring interaction: Doing phenomenology. In P. Munhall & C. Olier (Eds), *Nursing research: A qualitative perspective (*pp. 85-105). Norwalk, CT: Appleton-Century-Crofts

Roth, W.-M., & Bowen, G. M. (1999). Complexities of graphical representations during lectures: A phenomenological approach. *Learning and Instruction, 9*, 235-255.

Roth, W.-M., & Bowen, G. M. (2000). Learning difficulties related to graphing: a hermeneutic phenomenological perspective. *Research in Science Education, 30*, 123-139.

Roth, W.-M., McRobbie, C., Lucas, K. B., & Boutonné, S. (1997). The local production of order in traditional science laboratories: A phenomenological analysis. *Learning and Instruction, 7*, 107-136.

Sexton-Hesse, C. (1983). Criticial issues in empirical human science: The contribution of phenomenology. Paper presented at the Annual Meeting of the American Association for Adult and Continuing Education, Philadelphia, PA. (ERIC Document Reproduction Service No. ED 237 649)

van Manen, M. (1990). Researching lived experience. New York: State University of New York Press.

Volkmann, M. J., & Anderson, M. A. (1998). Creating professional identity: Dilemmas and metaphors of a first year chemistry teacher. *Science Education, 82*, 293-310.

Volkmann, M. J., & Zgagacz, M. (2004). Learning to teach physics through inquiry: The lived experience of a graduate teaching assistant. *Journal of Research in Science Teaching, 41*, 559-579.

8

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 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

Reference	Research Questions/Purposes
Aguirre & Haggerty, 1995	What are pre-service teachers' conceptions of learning?
Bhattacharyya & Bodner, 2005	What are the different ways graduate students propose organic mechanisms?
Boddy, Watson, & Aubusson, 2003	What conceptions do elementary students develop about a particular concept when their teachers use the 5E model of teaching?
Brass et al., 2003	What are university professors' and high school physics teachers' conceptions of "quality learning"?

Carlsson, 2002	What are students' ways of thinking about photosynthesis?
Case, Gunstone, & Lewis, 2001	What kinds of metacognitive knowledge and awareness do chemical engineering students develop as a result of participating in an innovative course?
Dall'Alba et al., 1993	What are students' conceptions of "acceleration"?
Ebenezer & Erickson, 1996	What are students' conceptions of "solubility"?
Ebenezer & Fraser, 2001	What are first year chemical engineering students' conceptions of the energy changes taking place in dissolution?
Ellis, 2004	What are university students' approaches to learning science through writing?
France & Davies, 2001	What are elementary teachers' strategies for teaching about values issues in technological problem solving?
Guisasola et al., 2004	What are university engineering students' and high school physical science students' conceptions of magnetic fields?
Hazel, Prosser, & Trigwell, 2002	What are biology students' learning orchestrations? (How do they manage their learning activities in response to task or course demands?)
Ingerman & Booth, 2003	What are the ways that physicists expound on their research?; How do university physics students approach an advanced physics problem?
Johnston et al., 1998	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?
Kesidou & Duit, 1993	What are students' conceptions of the 2nd law of thermodynamics (energy, irreversibility, heat transfer and temperature)?

Linder et al., 1997	What are the different ways in which physics tutors' metalearning abilities develop as a result of participating in a reflective practicum?
Lister et al., 2004	What are the variations in understanding that computer scientists have of the purpose of teaching data structures?
Liu et al., 2002	What are university students' conceptions of energy (in general and related to the solution process of ionic compounds)?
Lybeck et al., 1988	How do students decide which samples contain 1 mole of substances?
Marton, Fensham, & Chaiklin, 1994	What are Nobel prize winners' conceptions of scientific intuition?
Orgill, 2003	What are biochemistry students' conceptions of the analogies used in their classes?
Orgill & Bodner, 2004	What are the circumstances under which students find biochemistry analogies useful? How do biochemistry students believe analogies should be presented to be useful?
Selley, 1996	What are children's conceptions of light and vision?
Sharma et al., 2004	What are university physics students' understandings of gravity in an orbiting space ship?
Stromdahl et al., 1994	What are chemistry teachers' conceptions of the "mole'?
Tao, 2002	Of which aspects are students focally aware as they read science stories designed to foster nature of science understanding?
Tsai, 2004	What are high school students' conceptions of learning science?
Tullberg et al., 1994	What are students' conceptions of "1 mole"?; What are educators' conceptions of how they teach 'the mole'?

Yung, 2001	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, phenomenography 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 phenomeno-graphy, 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 phenomeno-graphy 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

Aguirre, J. M., & Haggerty, S. M. (1995). Preservice teachers' meanings of learning. *International Journal of Science Education, 17,* 119-131.

Bhattacharyya, G., & Bodner, G. M. (2005). "It gets me to the product": How students propose organic mechanisms. *Journal of Chemical Education, 82,* 1402-1407.

Boddy, N., Watson, K., & Aubusson, P. (2003). A trial of the Five Es: A referent model for constructivist teaching and learning. *Research in Science Education, 33,* 27-42.

Booth, S. (1997). On phenomenography, learning and teaching. *Higher Education Research and Development, 16,* 135-159.

Bowden, J., & Marton, F. (1998). *The university of learning.* London: Kogan Page.

Brass, C., Gunstone, R., & Fensham, P. (2003). Quality learning of physics: Conceptions held by high school and university teachers. *Research in Science Education, 33,* 245-271.

Carlsson, B. (2002). Ecological understanding 1: Ways of experiencing photosynthesis. *International Journal of Science Education, 24,* 681-699.

Case, J., Gunstone, R., & Lewis, A. (2001). Students' metacognitive development in an innovative second year chemical engineering course. *Research in Science Education, 31,* 313-335.

Dall'Alba, G., Walsh, E., Bowden, J., Martin, E., Masters, G., Ramsden, P., & Stephanou, A. (1993). Textbook treatments and students' understanding of acceleration. *Journal of Research in Science Teaching, 30*, 621-635.

Ebenezer, J. V., & Erickson, G. L. (1996). Chemistry students' conceptions of solubility: A phenomenography. *Science Education, 80,* 181-201.

Ebenezer, J. V., & Fraser, D. M. (2001). First year chemical engineering students' conceptions of energy in solution processes: Phenomenographic categories for common knowledge construction. *Science Education, 85,* 509-535.

Ellis, R. A. (2004). University student approaches to learning science through writing. *International Journal of Science Education, 26,* 1835-1853.

Entwistle, N. (1997). Introduction: Phenomenography in higher education. *Higher Education Research and Development, 16,* 127-134.

France, B., & Davies, J. (2001). Asking the 'right' questions. Identifying issues in developing a technological solution. *Research in Science Education, 31,* 137-153.

Guisasola, J., Almudi, J. M., & Zubimendi, J. L. (2004). Difficulties in learning the introductory magnetic field theory in the first years of university. *Science Education, 88,* 443-464.

Hasselgren, B., & Beach, D. (1997). Phenomenography – A "good-for-nothing brother" of phenomenology? Outline of an analysis. *Higher Education Research and Development, 16,* 191- 202.

Hazel, E., Prosser, M., & Trigwell, K. (2002). Variation in learning orchestration in university biology courses. *International Journal of Science Education, 24,* 737-751.

Hutchison, M. A., Follman, D. K., Sumpter, M., & Bodner, G. M. (2006). Factors influencing the self-efficacy beliefs of first-year engineering students. *Journal of Engineering Education*, *95*, 39-48.

Ingerman, A., & Booth, S. (2003). Expounding on physics: A phenomenographic study of physicists talking of their physics. *International Journal of Science Education, 25,* 1489-1508.

Johnston, I. D., Crawford, K., & Fletcher, P. R. (1998). Student difficulties in learning quantum mechanics. *International Journal of Science Education, 20,* 427-446.

Kesidou, S., & Duit, R. (1993). Students' conceptions of the second law of thermodynamics – An interpretive study. *Journal of Research in Science Teaching, 30,* 85-106.

Koballa, T., Graber, W., Coleman, D. C., & Kemp, A. C. (2000). Prospective gymnasium teachers' conceptions of chemistry learning and teaching. *International Journal of Science Education, 22,* 209-224.

Linder, C. J., Leonard-McIntyre, C., Marshall, D., & Nchodu, M. R. (1997). Physics tutors' metalearning development through an extension of Schon's reflective practice. *International Journal of Science Education, 19,* 821-833.

Lister, R., Box, I., Morrison, B., Tenenberg, J., & Westbrook, D.S. (2004, June). The dimensions of variation in the teaching of data structures. Paper presented at the annual Conference on Innovation and Technology in Computer Science Education, Leeds, United Kingdom.

Liu, X., Ebenezer, J., & Fraser, D. M. (2002). Structural characteristics of university engineering students' conceptions of energy. *Journal of Research in Science Teaching, 39,* 423-441.

Lybeck, L., Marton, F., Stromdahl, H., & Tullberg, A. (1988). The phenomenography of the 'mole concept' in chemistry. In P. Ramsden (Ed.), *Improving learning: New perspectives* (pp. 81-108). New York, NY: Nichols Publishing Company.

Marton, F. (1981). Phenomenography – Describing conceptions of the world around us. *Instructional Science, 10,* 177-200.

Marton, F. (1986). Phenomenography – A research approach to investigating different understandings of reality. *Journal of Thought, 21,* 28-49.

Marton, F. (1994). Phenomenography. In T. Husen & T. N. Postlethwaite (Eds.), *The international encyclopedia of education* (2nd ed., Vol. 8, pp. 4424–4429). Oxford, U.K.: Pergamon.

Marton, F., & Booth, S. (1997). Learning and Awareness. Maywah, New Jersey: Lawrence Earlbaum.

Marton, F., Fensham, P., & Chaiklin, S. (1994). A Nobel's eye view of scientific intuition: Discussions with the Nobel prize-winners in physics, chemistry and medicine (1970-86). *International Journal of Science Education, 16,* 457-473.

Orgill, M. (2003). *Playing with a double-edged sword: Analogies in biochemistry.* Unpublished doctoral dissertation, Purdue University.

Orgill, M., & Bodner, G. M. (2004). What research tells us about using analogies to teach chemistry. *Chemistry Education: Research and Practice, 5,* 15-32.

Pang, M. F. (2002). Two faces of variation: Oncontinuity in the phenomenographic movement. *Proceedings of the International Symposium on Current Issues in Phenomenography.* [online] Canberra, Australia. Retrieved September 20, 2005 from Australian National University, Centre for Educational Development and Academic Methods: http://www.anu.edu.au/cedam/ilearn/-symposium/abstracts.html.

Pang, M. F., & Marton, F. (2002). Beyond "lesson study": Comparing two ways of facilitating the grasp of some econimc concepts. *Proceedings of the International Symposium on Current Issues in Phenomenography.* [online] Canberra, Australia. Retrieved September 20, 2005 from Australian National University, Centre for Educational Development and Academic Methods: http://www.anu.edu.au/cedam/ilearn/symposium/abstracts.html.

Richardson, J. T. E. (1999). The concepts and methods of phenomenographic research. *Review of Educational Research, 69,* 53–82.

Rovio-Johannson, A. (1999, August). Constituting different meanings of the content of teaching and learning in Higher Education. Paper presented at the 8th European conference for Learning and Instruction. Goteborg, Sweden.

Runesson, U. (1999, August). Teaching as constituting a space of variation. Paper presented at the 8th European conference for Learning and Instruction. Goteborg, Sweden.

Saljo, R. (1997). Talk as data and practice – A critical look at phenomenographic inquiry and the appeal to experience. *Higher Education Research and Development, 16,* 173-190.

Selley, N. J. (1996). Towards a phenomenography of light and vision. *International Journal of Science Education, 18,* 837-846.

Sharma, M. D., Millar, R. M., Smith, A., & Sefton, I. M. (2004). Students' understandings of gravity in an orbiting space-ship. *Research in Science Education, 34,* 267-289.

Stromdahl, H., Tullberg, A., & Lybeck, L. (1994) The qualitatively different conceptions of 1 mole. *International Journal of Science Education*, 16, 17–26.

Svensson, L. (1997). Theoretical Foundations of Phenomenography. *Higher Education Research and Development, 16,* 159-171.

Tao, P.-K. (2002). A study of students' focal awareness when studying science stories designed for fostering understanding of the nature of science. *Research in Science Education, 32,* 97-120.

Trigwell, K. (2000). Phenomenography: Variation and discernment. In C. Rust (Ed.), *Improving student learning, Proceedings of the 1999 7th International Symposium, Oxford Centre for Staff and Learning Development* (pp. 75-85). Oxford, U.K.: Oxford.

Tsai, C.-C. (2004). Conceptions of learning science among high school students in Taiwan: A phenomenographic analysis. *International Journal of Science Education, 26,* 1733-1750.

Tullberg, A. (1998) *Teaching 'the mole': A phenomenographic inquiry into the didactics of chemistry*. Doctoral thesis, 118 (Goteborg: Acta Universitatis Gothoburgensis).

Tullberg, A., Stromdahl, H., & Lybeck, L. (1994) Students' conceptions of 1 mole and educators' conceptions of how they teach 'the mole'. *International Journal of Science Education*, 16, 145–156.

Walsh, E., Dall'Alba, G., Bowden, J., Martin, E., Marton, F., Masters, G., Ramsden, P., & Stephanou, A. (1993). Physics students' understanding of relative speed: A phenomenographic study. *Journal of Research in Science Teaching, 30,* 1133-1148.

Webb, G. (1997). Deconstructing deep and surface: Towards a critique of Phenomenography. *Higher Education, 33,* 195-212.

Yung, B. H. W. (2001). Three views of fairness in a school-based assessment scheme of practical work in biology. *International Journal of Science Education, 23,* 985-1005.

9

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 & McTaggert, 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, MacIsaac, & 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.

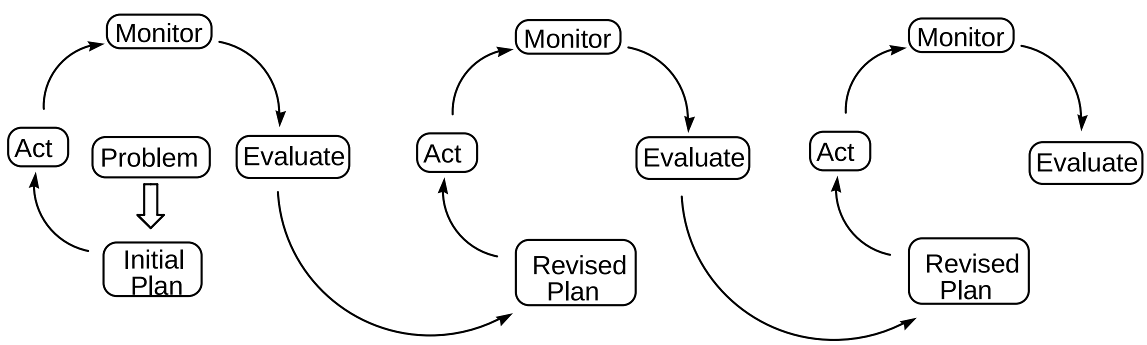

Figure 1. The Action Research Spiral

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 can not 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 was 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 McTaggert (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 developed 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

Akerson, V. L., & Reinkens, K. A. (2002). Preparing pre-service elementary teachers to teach for conceptual change: A case study. *Journal of Elementary Science Education*, *14*, 29-4.

Berkowitz, L., & Donnerstein, E. (1982). External validity is more than skin deep: Some answers to criticisms of laboratory experiments. *American Psychologist*, *37*, 245-257.

Bodner, G.M., MacIsaac, D., & White, S. (1999). Action research: Overcoming the sports mentality to assessment/evaluation. *University Chemistry Education, 3*, 32-36.

Brown, H. (2004). Action research in the classroom: A process that feeds the spirit of the adolescent. *International Journal of Qualitative Methods, 3*(1). Article 3. Retrieved January 1, 2006, from http://www.ualberta.ca/~iiqm/backissues/3_1/html/brown.html

Butler, S. (1999). Catalysing student autonomy through action research in a problem centered learning environment. *Research in Science Education, 29,* 127-40.

Chang, W. (2005). The rewards and challenges of teaching innovation in university physics: 4 years' reflection. *International Journal of Science Education, 27,* 407-425.

Creswell, J. (2002). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Upper Saddle River, NJ: Merrill Prentice Hall.

Fenstermacher, G. D. (1986). Philosophy of research on teaching: Three aspects. In M. Wittrock (Ed.), *Handbook of research on teaching.* 3rd ed., pp. 37-49). New York. Macmillan.

Gustavsen, B. (1993), Action research and the generation of knowledge. *Human Relations, 46,* 1361-1365.

Hewson, P. W., Tabachnick, R. B., Zeichner, K. M., Blomerk, K. B., Meyer, H., Lemberger, J., Marion, R., Park, H., & Toolin, R. (1999). Educating prospective teachers of biology: Introduction and research methods. *Science Education, 83*, 247-73.

Hodson, D., & Bencze, L. (1998). Becoming critical about practical work: Changing views and changing practice through action research. *International Journal of Science Education, 20*, 683-694.

Holly, M.L., Arhar, J., & Kasten, W.C. (2005). *Action research for teachers: Traveling the yellow brick road* (2nd ed.). Upper Saddle River, NJ , Prentice Hall.

Hopkins, D. (1985). *A teacher's guide to classroom research.* Philadelphia: Open University Press.

Kember, D. (2001). *Reflective teaching and learning in the health professions: Action research in professional education*. Malden, MA: Blackwell Science

Kemmis, S., & McTaggart, R. (1988). *The action research* p*lanner* (3rd ed.). Geelong, Victoria, Australia: Deakin University Press.

Kemmis, S., & McTaggart, R. (1990). *The action research reader.* Geelong, Victoria, Australia: Deakin University Press.

Kock, N.F., McQueen, R.J., & Scott, J.L. (2000). Can action research be made more rigorous in a positivist sense? The contribution of an iterative approach. *Action Research E-Reports, 9.* Retrieved this month day, year, from: http://www.fhs.usyd.edu.au/arow/arer/009.htm

Lauterbach, J., White, S., Liu, Z., Bodner, G.M., & Delgass, W.N. (1997). A novel laboratory course on advanced chemical experiments. *Journal of Chemical Engineering Education, 31*, 260-265.

Ledford, G.E., & Susan, A.M. (1993). Looking backward and forward at action research: Reply paper. *Human Relations*, *46*, 1349-1359.

Lewin, K. (1946). Action research and minority problems. *Journal of Social Issues, 2, 34-46.*

Madsen, A. L., & Gallagher, J. J. (1992). *Improving learning and instruction in junior high school science classes through the role of the support teacher* (Research Series No. 212). East Lansing, MI: Michigan State University, Institute of Research on Teaching.

McGinnis, R. J., & Pearsall, M. (1998). Teaching elementary science methods to women: A male professor's experience from two perspectives. *Journal of Research in Science Teaching, 35*, 919-49.

McNiff, J., & Whitehead, J. (2006). *All you need to know about action research*. Thousand Oaks, CA: Sage.

McTaggart, R., (1991). *Action research, a short modern history*. Geelong, Victoria, Australia: Deakin University Press.

Mills, G. (2003). *Action research: A guide for the teacher researcher* (2^{nd} ed.). Upper Saddle River, NJ: Prentice Hall.

Mumba, F, Chabalengula,V. M., Moore, C. J., Grogg, J., Plantholt, M., Thornton, C., & Hunter, W. J. F. (2003). An exploration of the content and nature of reflective practices of graduate teaching fellows in a school-university partnership project. *The Chemical Educator, 8*, 404-412.

Mumba, F. Chabalengula, V. Hunter, W. & Moore, C. (2006) Mathematics and science teaching fellow's conceptions of science teaching. Proceedings of National Association for Research in Science Teaching, San Francisco, April 3-6, 2006.

Orlikowski, W.J. & Baroudi, J.J. (1991). Studying Information technology in organizations: research approaches and assumptions, *Information Systems Research* , *2*, 1-28.

Pedretti, E., & Hodson, D. (1995). From rhetoric to action: Implementing STS education through action research. *Journal of Research in Science Teaching*, 32, 463-485.

Pedretti, E. (1996). Learning about science, technology, and society (STS) through an action research project: Co-constructing an issues-based model for STS education. *School Science and Mathematics, 96*, 432-40.

Rolnick, M., Zwane, S., Staskun, M., Lotz, S., & Green, G. (2001). Improving pre-laboratory preparation of first-year university chemistry students. *International Journal of Science Education, 23,* 1053-1071.

Schön, D. (1990). *Educating the reflective practitioner: Toward a new design for teaching and learning in the professions.* San Francisco, CA: Jossy Bass Publisher.

Silverman, D. (2004). *Doing qualitative research: A practical handbook.* Thousand Oaks, CA: Sage Publications.

Solomon, J., Duveen, J., & Scot, L. (1992). Teaching about the nature of science through inquiry: Action research in the classroom. *Journal of Research in Science Teaching, 29,* 409-421.

Spiegel, S. (Ed.). (1995). *Perspectives from teachers' classrooms. Action research. Science FEAT (Science for Early Adolescence Teachers)*. Tallahassee, FL: SERVE, Math/Science Consortium.

Staten, M. E. (1998). *Action research study: A framework to help move teachers toward an inquiry-based science teaching approach.* Milwaukee, WI: Milwaukee Public Schools.

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research. Grounded theory procedures and techniques*. Newbury Park, CA: Sage Publications.

Towns, M. H., Kreke, K., & Fields, A. (2000). An action research project: Student perspectives on small-group learning in chemistry. *Journal of Chemical Education, 77,* 111*.*

Walker, D.F. (1992). *Methodological issues in curriculum research.* In P. W. Jackson (Ed.), *Handbook of research on curriculum* (pp. 98-118). New York: Macmillan.

Waters-Adams, S., & Nias, J. (2003). Using action research as methodological tool: Understanding teachers' understanding of science. *Educational Action Research, 11,* 283-300.

Willison, J. (1999). Who writes the recipes in science? Possibilities from four years of action research with students and their scientific literacy. *Research in Science Education, 29,* 111-26.

Winter, R. (1989). *Learning from experience: Principles and practice in action research*. London: Falmer Press.

Young, R.E. (1990). *A critical theory of education: Habermas and our children's future.* New York: Teachers College Press.

10

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 (Fetterman, 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.

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,[2] 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

Anderson, G. L. (1989). Critical ethnography in education: Origins, current status, and new directions. *Review of Educational Research, 59*, 249-270.

Atkinson, P. (1988). Ethnomethodology: A critical review. *Annual Review of Sociology, 14*, 441-465.

Barton, A. (2001). Science education in urban settings: Seeking new ways of praxis through critical ethnography. *Journal of Research in Science Teaching, 38*, 899-917.

Benson, D., & Hughes, J. A. (1983). *The perspective of ethnomethodology*. New York: Longman.

Bhattacharyya, G. (2004). *A recovering organic chemist's attempts at self-realization: How students learn to solve organic synthesis problems*. Unpublished doctoral dissertation, Purdue University.

Bhattacharyya, G., & Bodner, G. M. (2005). "It gets me to the product": How students propose organic mechanisms. *Journal of Chemical Education, 82*, 1402-1407.

Bleicher, R. E., Tobin, K. G., & McRobbie, C. J. (2003). Opportunities to talk science in a high school chemistry classroom. *Research in Science Education, 33*, 319-339.

Bodner, G. M. (1986). Constructivism: A theory of knowledge. *Journal of Chemical Education, 63*, 873-877.

Bowen, G. M., Roth, W., & McGinn, M. K. (1999). Interpretation of graphs by university biology students and practicing scientists: Towards a social practice view of scientific representation practices. *Journal of Research in Science Teaching, 36*, 1020-1043.

Brandt, D. (1992). The cognitive as the social: An ethnomethodological approach to writing process research. *Written Communication, 9*, 315-355.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*, 42.

Calimsiz, S. (2003). *How undergraduates solve organic synthesis problems. A problem-solving model approach.* Unpublished master's thesis, Purdue University.

Cobb, P. (1994). Where is the mind? Constructivist and sociocultural perspectives on mathematical development. *Educational Researcher, 23*, 13-20.

Crawford, T. (2005). What counts as knowing: Constructing a communicative repertoire for student demonstration of knowledge in science. *Journal of Research in Science Teaching, 42*, 139-165.

Crawford, T., Kelly, G. J., & Brown, C. (2000). Ways of knowing beyond facts and laws of science: An ethnographic investigation of student engagement in scientific practices. *Journal of Research in Science Teaching, 37*, 237-258.

Darby, L. (2005). Science students' perceptions of engaging pedagogy. *Research in Science Education, 35*, 425-445.

Fetterman, D. M. (1989). *Ethnography step by step*. Newbury Park, CA: Sage.

Garfinkel, H. (1967). *Studies in ethnomethodology*. Englewood Cliffs, NJ: Prentice-Hall.

Hayes, M. T., & Deyhle, D. (2001). Constructing difference: A comparative study of elementary science curriculum differentiation. *Science Education, 85*, 239-262.

Herbert, S. (2000). For ethnography. *Progress in Human Geography, 24*, 550-568.

Kelly, G. J., & Crawford, T. (1997). An ethnographic investigation of the discourse practices of school science. *Science Education, 81*, 533-559.

Leiter, K. (1980). *A primer on ethnomethodology*. New York: Oxford University Press.

McGinnis, J. R., & Simmons, P. (1999). Teachers' perspectives of teaching science-technology-society in local cultures: A sociocultural analysis. *Science Education, 83*, 179-211.

Mead, M. (1928). *Coming of age in Samoa: A psychological study of primitive youth for western civilization*. New York: Blue Ribbon Books.

Patton, M. Q. (1990). *Qualitative evaluation and research methods* (2nd ed.). Newbury Park, CA: Sage.

Roth, W., Bowen, G. M., & McGinn, M. K. (1999). Differences in graph-related practices between high school biology textbooks and scientific ecology journals. *Journal of Research in Science Teaching, 36*, 977-1019.

Samarapungavan, A., Westby, E. L., & Bodner, G. M., (2006). Contextual epistemic development in science: A comparison of chemistry students and research chemists. *Science Education, 90*, 468-495.

Schön, D. A. (1987). *Educating the reflective practitioner: Toward a new design for teaching and learning in the professions*. San Francisco: Jossey-Bass.

Seiler, G. (2001). Reversing the "standard" direction: Science emerging from the lives of African American students. *Journal of Research in Science Teaching, 38*, 1000-1014.

Sharrock, W. (1989). Ethnomethodology. *British Journal of Sociology, 40*, 657-677.

Spencer, J. (2001). Ethnography after post-modernism. In P. A. Atkinson, A. J. Coffey, S. Delamont, J. Lofland, & L. H. Lofland (Eds.). *Handbook of ethnography* (pp. 443 - 452). Thousand Oaks, CA: Sage.

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research. Grounded theory procedures and techniques*. Newbury Park, CA: Sage Publications.

11

Situated Cognition

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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"?

- 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

Anderson, J. R., Reder, L. M., & Simon, H. A. (1996). Situated learning and education. *Educational Researcher, 25,* 5-11.

Bianchini, J. A. (1997). Where knowledge construction, equity, and context intersect: Student learning of science in small groups. *Journal of Research in Science Teaching, 34,* 1039-1065.

Bredo, E. (1994). Reconstructing educational psychology: Situated cognition and Deweyian pragmatism. *Educational Psychologist, 29,* 23-35.

Brickhouse, N. W. (2001). Embodying science: A feminist perspective on learning. *Journal of Research in Science Teaching, 38,* 282-295.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18,* 32-42.

Case, J., & Jawitz, J. (2004). Using situated cognition theory in researching student experience of the workplace. *Journal of Research in Science Teaching, 41,* 415-431.

Clancey, W. J. (1993). Situated action: A neuropsychological interpretation response to Vera and Simon. *Cognitive Science, 17,* 87-116.

Clancey, W. J. (1994) Situated cognition: How representations are created and given meaning. In R. Lewis & P. Mendelsohn (Eds.), *Lessons from Learning* (pp. 231-242). Amsterdam: North-Holland.

Clancey, W. J. (1995) A tutorial on situated learning. In J. Self (Ed.), *Proceedings of the International Conference on Computers and Education* (pp. 49-70). Charlottesville, VA: AACE.

Dewey, J. (1963). *Experience and education*. New York: Collier Books.

Engestrom, Y., & Cole, M. (1997). Situated cognition in search of an agenda. In D. Kirshner & J. A. Whitson (Eds.), *Situated cognition: Social, semiotic, and psychological perspectives* (pp. 301-309). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Gee, J. P. (1997). Thinking, learning, and reading: The situated sociocultural mind. In D. Kirshner & J. A. Whitson (Eds.), *Situated cognition: Social, semiotic, and psychological perspectives* (pp. 235-259). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Greeno, J. G. (1994). Gibson's affordances. *Psychological Review, 101,* 336-342.

Greeno, J. G. (1997). Response: On claims that answer the wrong questions. *Educational Researcher, 26,* 5-17.

Greeno, J. G. (1998). The situativity of knowing, learning, and research. *American Psychologist, 53*, 5-26.

Greeno, J. G., & Moore, J. L. (1993). Situativity and symbols: Response to Vera and Simon. *Cognitive Science, 17,* 49-59.

Griffin, M. M. (1995). You can't get there from here: Situated learning, transfer, and map skills. *Contemporary Educational Psychology, 20,* 65-87.

Hung, D. W. L., & Chen, D.-T. (2001). Situated cognition, Vygotskian thought and learning from the communities of practice perspective: Implications for the design of web-based e-learning. *Education Media International, 38(1).*

Kirshner, D., & Whitson, J. A. (1997). Editors' introduction. In D. Kirshner & J. A. Whitson (Eds.), *Situated cognition: Social, semiotic, and psychological perspectives* (pp. 1-16). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Lave, J. (1993). The practice of learning. In S. Chaiklin & J. Lave (Eds.), *Understanding practice: Perspectives on activity and context* (pp. 3-32). Cambridge, UK: Cambridge University Press.

Lave, J. (1997). The culture of acquisition and the practice of understanding. In D. Kirshner & J. A. Whitson (Eds.), *Situated cognition: Social, semiotic, and psychological perspectives* (pp. 17-35). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

Osterlind, K. (2005). Concept formation in environmental education: 14-year olds' work on the intensified greenhouse effect and the depletion of the ozone layer. *International Journal of Science Education, 8,* 891-908.

Rodriguez, A. J. (1998). Strategies for counterresistance: Toward sociotransformative constructivism and learning to teach science for diversity and for understanding. *Journal of Research in Science Teaching, 35,* 589-622.

Rogoff, B. (1984). Introduction: Thinking and learning in social context. In B. Rogoff & J. Lave (Eds.), *Everyday cognition: Its development in social context* (pp. 1-8). Cambridge, MA: Harvard University Press.

Roschelle, J., & Clancey, W. J. (1992). Learning as social and neural. *Educational Psychologist, 27,* 435-453.

Roth, W.-M. (1996). Knowledge diffusion in a grade 4-5 classroom during a unit on civil engineering: An analysis of a classroom community in terms of its changing resources and practices. *Cognition and Instruction, 14,* 179-220.

Roth, W.-M., & McGinn, M. K. (1998). Knowing, researching, and reporting science education: Lessons from science and technology studies. *Journal of Research in Science Teaching, 35,* 213-235.

Suchman, L. (1993). Response to Vera and Simon's situated action: A symbolic interpretation. *Cognitive Science, 17,* 71-75.

Vera, A. H., & Simon, H. A. (1993). Situated action: A symbolic interpretation. *Cognitive Science, 17,* 7-48.

Walkerdine, V. (1997). Redefining the subject in situated cognition theory. In D. Kirshner & J. A. Whitson (Eds.), *Situated cognition: Social, semiotic, and psychological perspectives* (pp. 57-70). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Wilson, B. G., & Myers, K. M. (1999). Situated cognition in theoretical and practical context. Retrieved March 18, 2006, from http://carbon.cudenver.edu/~bwilson/SitCog.html

Wolfson, L., & Willinsky, J. (1998). What service learning can learn from situated learning. *Michigan Journal of Community Service Learning, 5,* 22-31.

Young, M. F., Kulikowich, J. M., & Barab, S. A. (1997). The unit of analysis for situated assessment. *Instructional Science, 25,* 133-150.

12

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 interpretation (Patton, 1990). 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

Data Source	Collection Plan
Semi-structured interviews — includes both prepared questions and questions that arise during the interviewing process to acquire information from the respondent. The interview process is like a conversation. Questions are asked when the interviewer feels it is appropriate to ask them. **Use in the theoretical framework of a community of practice:** To understand the individual's point of view (contribution) rather than make generalizations about the behavior of the group.	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: • Describe, in your own words, the problem your group was solving. • What did you know about this problem before starting the process of solving it? • What do you know now? Be as neutral as possible when asking probing questions: "Tell me more" or "Can you be more specific?" Video- and/or audio-tape interviews for transcription and coding later.
Observations and field notes — methods of collecting data simply by watching what people do. Field notes are the comments written to record what was observed. **Use in the theoretical framework of a community of practice:** To look for patterns in behaviors and interactions among group members and to abstract similarities and differences.	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 though 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

Reference	**Research Questions/Purpose**
Johnson, 2001	Can communities of practice in their true definition be established, maintained, and supported in an online environment?
McGinn & Roth, 1999	How can science education be a starting point for trajectories of legitimate peripheral participation in science-related discourses and practices?
O'Neill, 2001	Does student involvement with online mentors influence the ways in which they use the customary "tools of argument" in a genre of scientific writing?
Pea, 1993	How is a conceptual change in scientific thinking achieved through meaning negotiation and appropriation?
Rickey & Stacy, 2000	What is the role of community in promoting metacognition in science education?
Rogers, 2000	How can we create learning environments and experiences that bring our learners together to form learning communities?
Rosebery et al., 1992	To what extent do students appropriate scientific ways of knowing and reasoning as a result of their participation in collaborative scientific inquiry?
Roth et al., 1999	How is content and form of classroom discourse influenced by different combinations of artifacts?
Singer et al., 2000	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?
Sweeney & Paradis, 2004	To what extent does a laboratory model serve as an effective means of enculturation for prospective science teachers?

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:

Bakhtin, M. (1981). *The dialogic imagination: Four essays* (C. Emerson & M. Holquist, Trans.). Austin: University of Texas Press (Orginal work published in 1975).

Bandura, A. (1977). *Social learning theory*. New York: General Learning Press.

Barab, S.A., & Duffy, T. (2000). From practice fields to communities of practice. In D. Jonassen & S. Land (Eds.), *Theoretical foundations of learning environments* (pp. 25-56). Mahwah, NJ: Lawrence Earlbaum Associates.

Bielaczyc, K., & Collins, A. (1999). Learning communities in the classrooms: A reconceptualization of educational practice. In C. Reigeluth (Ed.), *Instructional-design theories and models.* (Vol. 2, pp. 169-292). Mahwah, NJ: Lawrence Erlbaum Associates.

Brown, J. S, Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, *18*, 32-42.

Brown, A. L., Metz, K. E., & Campione, J. C. (1996). Social interaction and individual understanding in a community of learners. The influence of Piaget and Vygotsky. In A. Tryphon & J. Voneche (Eds.), *Piaget-Vygotsky: The social genius of thought* (pp. 145-170). New York, NY: Psychology Press

Brown, A., & Palincsar, A. M. (1989). Guided, cooperative learning and individual knowledge acquisition. In L. B. Resnick (Ed.), *Cognition and instruction: Issues and agendas* (pp. 393-451). Hillsdale, NJ: Lawrence Erlbaum Associates.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches* (2^{nd} ed.). Thousand Oaks, CA: Sage.

Dufresne, R. J., Gerace, W. J., Hardiman, P. T., & Mestre, J. P. (1992). Constraining novices to perform expertlike problem analyses: Effects on schema acquisition. *The Journal of the Learning Sciences*, *2*, 307-331.

Edelson, D., Pea, R., & Gomez, L. (1996). Constructivism in the collaboratory. In B. G. Wilson (Ed.), *Constructivist learning environments: Case studies in instructional design* (pp. 151-164). Englewood Cliffs, NJ: Educational Technology Publications.

Ertmer, P. A., & Russell, J. D. (1995). Using case studies to enhance instructional design education. *Educational Technology*, *35*, 23-31.

Gardner, H. (1983) *Frames of mind: The theory of multiple intelligences*. New York: Basic Books.

Glesne, C. (1998). *Becoming qualitative researchers: An introduction* (2nd ed.). New York: Allyn & Bacon.

Greeno, J. G. (1977). Process of understanding in problem solving. In N.J. Castellan, D. B. Pisoni, & G. R. Potts (Eds.), *Cognitive theory* (Vol. 2, pp. 43-48). Hillsdale, NJ: Erlbaum.

Hollway, W., & Jefferson, T. (1997). Eliciting narrative through the in-depth interview. *Qualitative Inquiry*, *3*, 53-70.

Johnson, C. M. (2001). A survey of current research on online communities of practice. *Internet and Higher Education*, *4*, 45-60.

Jonassen, D. (1999). Designing constructivist learning environments. In C. M. Reigeluth (Ed.), *Instructional design theories and models* (Vol. 2, pp. 215-239). Mahwah, NJ: Lawrence Erlbaum Associates.

Jonassen, D. (2001). Can you train employees to solve problems? *Performance Improvement*, *40*, 16-22.

Jonassen, D. (2004). *Learning to solve problems: An instructional design guide*. San Francisco, CA: Pfeiffer.

Jonassen, D., & Henning, P. (1999). Mental models: Knowledge in the head and knowledge in the world. *Educational Technology*, (May-June), 37-42.

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The Journal of the Learning Sciences*, *4*, 39-103.

Kelly, A., & Lesh, R. (Eds.). (2000). *Handbook of research design in mathematics and science education*. Mahwah, NJ: Lawrence Erlbaum Associates.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

Lesh, R. (2002). Research design in mathematics education: Focusing on design experiments. In L. English (Ed.), *International handbook of research design in mathematics education* (pp. 27-51). Mahwah, NJ: Lawrence Erlbaum Associates.

Lesh, R., & Doerr, H. (2003). *Beyond constructivism: A models & modeling perspective on mathematics teaching, learning, and problems solving*. Mahwah, NJ: Lawrence Erlbaum Associates.

Lesh, R., & Lehrer, L. (2003). Models and modeling perspectives on the development of students and teachers. *Mathematical Thinking and Learning*, *5*, 109-129.

Lewis, C., Watson, M., & Schaps, E. (1999). Recapturing education's full mission: Educating for social, ethical, and intellectual development. In C. Reigeluth (Ed.), *Instructional-design theories and models: A new paradigm of instructional theory* (Vol. 2, pp. 511-539). Mahwah, NJ: Lawrence Erlbaum Associates.

McGinn, M. K., & Roth, W. H. (1999). Preparing students for competent scientific practice: Implications of recent research in science and technology. *Educational Researcher*, *28*, 14-24.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Thousand Oaks, CA: Sage.

O'Neill, D. K. (2001). Knowing when you've brought them in: Scientific genre knowledge and communities of practice. *The Journal of the Learning Sciences*, *10*, 223-264.

Palincsar, A. S., Magnusson, S. J., Marano, N., Ford, D., & Brown, N. (1998). Designing a community of practice: Principles and practices of the CiSML community. *Teaching and Teacher Education*, *14*, 5-19.

Palloff, R., & Pratt, K. (1999). *Building learning communities in cyberspace: effective strategies for the online classroom*. San Francisco, CA: Jossey-Bass.

Patton, M. Q. (1990). *Qualitative research and evaluation methods* (2nd ed.). Thousand Oaks, CA: Sage.

Payne, J. W. (1994). Thinking-aloud: Insights into information processing. *Psychological Science*, *5*, 241-248.

Pea, R. D. (1993). Learning scientific concepts through material and social activities: Conversational analysis meets conceptual change. *Educational Psychologist*, *28*, 265-277.

Polanyi, M. (1976). Tacit knowing. In M. Marx & F. Goodson (Eds.), *Theories in contemporary psychology* (pp. 330-344). New York: Macmillan.

Resnick, L. B. (1987). Learning in school and out. *Educational Researcher*, *16*, 13-20.

Rickey, D., & Stacy, A. M. (2000). The role of metacognition in learning chemistry. *Journal of Chemical Education*, *77*, 915-920.

Rogers, J. (2000). Communities of practice: A framework for fostering coherence in virtual learning communities. *Educational Technology & Society*, *3*, 384-392.

Roschelle, J. (1992). Learning by collaborating: Convergent conceptual change. *The Journal of the Learning Sciences*, *2*, 235-276

Rosebery, A. S., Warren, B., & Conant, F. R. (1992). Appropriate scientific discourse: Findings from language minority classrooms. *The Journal of the Learning Sciences*, *2*, 61-94.

Roth, W-M., McGinn, M. K., Woszczyna, C., & Boutonné, S. (1999). Differential participation during science conversations: The interaction of focal artifacts, social configurations, and physical arrangements. *The Journal of the Learning Sciences*, *8*, 293-347.

Roth, W-M., & Roychoudhury, A. (1992). The social construction of scientific concepts or the concept map as conscription device and tool for social thinking in high school science. *Science Education*, *76*, 531-557.

Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *The Journal of the Learning Sciences*, *3*, 265-283.

Schon, D. A. (1983). *The reflective practitioner*. New York: Basic Books.

Simon, H. A. (1979). Information processing models of cognition. *Annual Review of Psychology*, 30, 363-396.

Singer, J., Marx, R. W., Krajcik, J., & Chambers, J. C. (2000). Constructing extended inquiry projects: Curriculum materials for science education reform. *Educational Psychologist*, *35*, 165-178.

Soden, R., & Halliday, J. (2000). Rethinking vocational education: a case study in care. *International Journal of Lifelong Education*, *19*, 172-182

Stake, R. (2000). Case studies. In N. K. Denzin and Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 134-164). Thousand Oaks, CA: Sage.

Strauss, B., & Corbin, J. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (2nd ed.). Thousand Oaks, CA: Sage.

Suchman, L. A., & Trigg, R. H. (1991). Understanding practice: Video as a medium for reflection and design. In J. Greenbaum & M. Kyng (Eds.), *Design at work: Cooperative design of computer systems* (pp. 65-89). Hillsdale, NJ: Lawrence Erlbaum Associates.

Surowiecki, J. (2004). T*he wisdom of crowds: Why the many are smarter than the few and how collective wisdom shapes business, economies, societies and nations*. New York, NY: Doubleday.

Sweeney, A. E., & Paradis, J. A. (2004). Developing a laboratory model for the professional preparation of future science teachers: A situated cognition perspective. *Research in Science Education*, *34*, 195-219.

Voss, J. F., & Post, T. A. (1988). On the solving of ill-structured problems. In M. T. H. Chi, R. Glasser, & M. J. Farr (Eds.), *The nature of expertise* (pp. 261-285). Hillsdale, NJ: Lawrence Erlbaum Associates

Vygotsky, L. S. (1978). *Mind in society*. Cambridge, MA: Harvard Press.

Vygotsky, L.S. (1986). *Thought and language*. Cambridge, MA: The MIT Press.

Wagner, R. K. (1987). Tacit knowledge in everyday intelligent behavior. *Journal of Personality and Social Psychology*, *52*, 1236-1247.

Wagner, R. K., & Sternberg, R. J. (1985). Practical intelligence in real-world pursuits: The role of tacit knowledge. *Journal of Personality and Social Psychology*, *48*, 436-458.

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identit*y. Cambridge, UK: Cambridge University Press.

Wenger, E. (2000). Communities of practice and social learning systems. *Organization*, *7*, 225-246.

Wenger, E., McDermott, R., & Snyder, W. M. (2002). *A guide to managing knowledge: Cultivating communities of practice*. Cambridge, MA: Harvard University Press.

Wilson, B. G. (1995). Situated instructional design: Blurring the distinctions between theory and practice, design and implementation, curriculum and instruction. In M. Simonson (Ed.), *Proceedings of selected research and development presentations*. Washington, DC: Association for Educational Communications and Technology. Retrieved March 25, 2006 from: http://www.cudenver.edu/~bwilson

Yin, R. (1994). *Case study research: Design and methods* (2^{nd} ed.) Thousand Oaks, CA: Sage.

13

Telling the Whole Story via Narrative Analysis

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Biographies

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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:

1. Teaching Philosophies and Indiana's Standards: Neutral to Contradictory Relationships

    a. Suburban's biology teachers
    b. Rural's science teachers
    c. Chemistry, physics, and earth science teachers
    d. Urban's biology teachers

2. Students and Administration: One Distinction and One Pattern

    a. Urban High School
    b. Suburban High School
    c. Rural High School

3. Visions of Standards and the Nature of Compromise
    a. Teachers willing to compromise
    b. Teachers reluctant to compromise
    c. Teachers' recommendations for changing Indiana's science standards

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. A*ffective* 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.

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

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy.* New York: Oxford University Press.

Calabrese Barton, A. (2000). Autobiography in science education: Greater objectivity through local knowledge. *Research in Science Education, 30*, 23-42.

Clandinin, D. J., & Connelly, F. M. (2000). *Narrative inquiry: Experience and story in qualitative research.* San Francisco: Jossey-Bass.

Conle, C. (1997). Community, reflection, and the shared governance of schools. *Teaching and Teacher Education, 13,* 137-152.

Conle, C. (2000). Narrative inquiry: Research tool and medium for professional development. *European Journal of Teacher Education, 23,* 49-63.

Conle, C. (2001). The rationality of narrative inquiry in research and professional development. *European Journal of Teacher Education, 24,* 21-33.

Conle, C. (2003). An anatomy of narrative curricula. *Educational Researcher, 32,* 3-15.

Connelly, F. M., & Clandinin, D. J. (1986). On narrative method, personal philosophies, and narrative unities in the study of teaching. *Journal of Research in Science Teaching, 23*,293-310.

Dewey, J. (1938). *Experience and Education*. New York: Collier Books.

Doyle, W. (1997). Heard any good stories lately? A critique of the critics of narrative in educational research. *Teaching and Teacher Education, 13,* 93-99.

Elbaz-Luwisch, F. (1997). Narrative research: Political issues and implications. *Teaching and Teacher Education, 13*, 75-83.

Fenstermacher, G. D. (1997). On narrative. *Teaching and Teacher Education, 13*, 119-124.

Fenstermacher, G. D. (2002). A commentary on research that serves teacher education. *Journal of Teacher Education, 53,* 242-247.

Ferguson, R. L. (2003). *Investigating chemistry students' understanding of arrow-pushing formalism*. Unpublished doctoral dissertation, Purdue University.

Geelan, D. R. (1997). Weaving narrative nets to capture school science classrooms. *Research in Science Education, 27*, 553-563.

Goodson, I. F. (1997). Representing teachers. *Teaching and Teacher Education, 13*, 111-117.

Indiana Department of Education. (2003). *Indiana's Academic Standards.* Retrieved October 1, 2003 from http://www.doe.state.in.us/standards

Lincoln, Y. S. & Guba, E. G. (1985). *Naturalistic inquiry*. Thousand Oaks, CA: Sage.

Moss, P. A. (1994). Can there be validity without reliability? *Educational Researcher, 23,* 5-12.

Orgill, M. (2003). *Playing with a double-edged sword: Analogies in biochemistry*. Unpublished doctoral dissertation, Purdue University.

Patton, M. Q. (2002). *Qualitative research and evaluation methods.* Thousand Oaks, CA: Sage.

Polkinghorne, D. E. (1988). *Narrative knowing and the human sciences*. Albany, NY: State University of New York Press.

Polkinghorne, D. E. (1995). Narrative configuration in qualitative analysis. In J.A. Hatch and R. Wisniewski (Eds.). *Life history and narrative* (pp. 5-23). Washington D.C.: The Falmer Press.

Roth, W. M. (2000). Autobiography and science education: An introduction. *Research in Science Education, 30*, 1-12.

Segal, G. (1999, April). *Self study on the road to reform in teacher education: Obstructions, detours, and ringroads*. Paper presented at the American Educational Research Association, Montreal, Canada.

Shane, J. W. (2005). *Indiana high school science teachers' beliefs about the intended and actual impacts of standards-based reforms*. Unpublished doctoral dissertation, Purdue University.

Shapiro, B., & Melrose, S. (1998, February). *A research approach to bring student views into the creation of professional development experiences*. Paper presented at the International Consortium for Research in Science and Mathematics Education, Port of Spain, Trinidad and Tobago.

Tobin, K. (2000). Becoming an urban science educator. *Research in Science Education, 30,* 89-106.