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Methodology and location in the context of qualitative data and theoretical frameworks in geoscience education research

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ABSTRACT

Successful and rigorous qualitative research requires careful planning of purpose, methods, and theoretical frameworks. The qualitative researcher must locate the study in time, space, and culture, and must also locate herself or himself in the study. This is in order to thoroughly and publicly explore his or her purpose, role, and potential biases. Through this process, the researcher defines the ways in which these and other factors inform the research. Finally, the qualitative researcher must take thought of methodology—as opposed to method—and must understand the difference between the two.

In this paper, I review basic principles of qualitative inquiry with regard to the nature of qualitative data and theoretical frameworks. I then explore the issues of location and methodology as applied to qualitative inquiry in geoscience education research through examples relevant to the discipline. I describe the process of locating the study, and the ways in which the researcher defines his or her place therein. I then discuss the differences between method and methodology. Finally, I review four specific methodologies, including hermeneutics, phenomenology, ethnography, and policy analysis.

INTRODUCTION

Geoscience education can be defined as the scholarship of teaching and learning applied to the geosciences. The scholarship of geoscience teaching includes the study of teaching innovations, evolving classroom practices, field skills acquisition, and educational policy, to name a few items. Some examples of learner-focused scholarship include their alternative conceptions of Earth processes, their cognitive and meta-cognitive processes, and the affective factors that shape their learning. The examples I have listed here are quantitatively observable or measurable either directly, or as a function of their impact upon teachers, students, and/or an educational setting. These measurable parameters can be student outcomes (how much/how well did they learn?), analyses of variance between outcomes of two teaching

techniques, or identification of systematic patterns in student misconceptions. Even policy analysis lends itself to quantitative inquiry. For example, how does a high-stakes test in a public school system affect geoscience teaching in terms of student outcomes, numbers of misconceptions, or enrollments in postsecondary geoscience courses? These kinds of quantitative inquiries are fundamentally empirical, and firmly rooted in a hypothesis-driven, positivistic tradition. The instrumentation associated with these measurements are usually in the form of questionnaires, surveys, concept inventories, and pre- and post-tests.

Survey instruments and concept inventories can and do yield extensive and useful data, but they have inherent limitations. Most of the time, quantitatively oriented researchers can safely ignore these limitations, because numerical methods are appropriate for their research questions. The first limitation of instruments and

inventories is that responses are generally constrained to prewritten options. In choosing between A, B, C, and D, the respondent may wish for an E to select, or may feel that a mix of A and C are most appropriate. The second limitation is the inherent difficulty for the researcher in quantifying open-ended questions, especially where a “correct” answer does not exist. A third limitation is that instrument data compose a snapshot of an end condition. While surveys and inventories yield an understanding of a particular perceived truth, it is much more difficult to figure out how the person *constructed* that truth by using a survey or inventory. Furthermore, the instrument does not allow you to see this construction happen in real time. This is because personal truths are constructed through lived experiences, and these both resist quantitative study. Quantitative inquiry can tell a researcher *what* and *how much* of something happens, but the question of *why* is problematic. In pursuit of this line of inquiry, a researcher might find herself awash in information about her students’ attitudes, perceptions, lived experiences, values, and memories. She recognizes these as qualitative data in the form of communicated truths: that is, words, stories, and descriptions, and sometimes nonverbal expressions. These data are not subject to validity tests or manipulation by experiment. In order to extract meaning from these data, the researcher must turn to qualitative inquiry.

Many geoscientists are skeptical of non-numerical modes of inquiry. These concerns are fueled in part by a lack of familiarity with qualitative methods. Another issue is the fact that qualitative inquiry is generally not conducted within a framework of “scientific” empiricism. Experimental and control groups are not established; norm- or criterion-referenced metrics are not collected; dependent and independent variables are not identified. Furthermore, reality itself takes on a more nuanced meaning. Geoscientists are accustomed to making our findings and observations correspond to reality. For example, an observed formation has a measurable thickness; its rocks have certain characteristics observable by others; those rocks in turn represent a particular environment. We might argue over details, but we are likely to assume that only one realistic interpretation exists, which is best articulated by the most thorough observations, the most logical arguments, and the most replicable experiments. By contrast, the qualitative researcher embraces the notion of multiple realities. This is largely because of the nature of the data we work with. As scientists, we understand our world through the data we amass. An examination of the contrasts of “reality” in the context of “data” is a good conceptual starting place for scientists unfamiliar with qualitative inquiry.

A PRIMER ON QUALITATIVE DATA

In scientific research, data are *collected*, because they exist independent of the scientist. For example, we say strikes and dips are collected because the rocks had an orientation before the geologist arrived, and continue to be oriented after she or he leaves the field. The data exist, and the geologist goes and gets them. Qualitative data are *generated* because they do not exist until

the researcher goes after them. For example, asking a geology student to describe her experiences mapping with and without a global positioning system (GPS) unit is an example of generating data because (1) it is possible she did not consciously compare those experiences before she was asked; (2) her responses will be different depending on how she is asked and who is asking; and (3) her responses will vary depending upon the mapping situation she is in. Other reasons likely exist. In short, qualitative data have a tendency to be iteratively variable.

I must make an important aside here: not all non-numerical data are qualitative. For example, when documenting the luster of, say, the mineral galena, we describe it as “metallic.” It is true that this is not a number. However, it is possible to generate consensus, even among large numbers of geologists, that the luster of galena is metallic. This physical property is not iterative, and it exists independent of the observer. Luster does not depend upon the observer as much as it does on the mineral’s composition and other consistent, physical properties. So in this case, rather than being “qualitative,” that is, a communicated truth from a social actor based on lived experience, this datum is “nonmetric.” Other examples of nonmetric, geological data types include grain sorting and angularity, and relative bedding thickness, i.e., not expressed in units but as either “thinly bedded” or “thickly bedded.”

So what are qualitative data, and what makes them resistant to empirical manipulation? Qualitative data can be thought of as “ontological objects.” “Ontology” as I use it is synonymous with “metaphysics”; that is, the study of reality and being, and the things that constitute the world (Schwandt, 2001). This definition is not limited to material objects but also includes items from the “mental life” of those being studied. In the science education literature, ontology refers to how people ascribe meaning to phenomena (Chi et al., 1994; Libarkin and Kurdziel, 2006). In terms of mental life, ontological objects include observed behaviors, responses to verbal questions, nonverbal cues (e.g., body language), individual choices, student preconceptions or alternate conceptions (Libarkin, 2005), the ways in which students cope with and process novel field spaces (Orion, 1993), their previously lived experiences, and how they respond to stimuli. Ontological objects like these are in the form of communicated truths (Gadamer, 1975), from participant to researcher, not objective truths, such as the dip of a package of rocks, or the composition of those rocks. Rocks are physical objects, subject to third-party verification and validity analysis. Ontological objects in qualitative inquiry do not correspond with a single reality, but exist within multiple realities. The researcher uses them to assemble mental models (e.g., Brodaric et al., 2004). One can argue that these models represent objective reality, but in truth they should be considered a snapshot of one single reality among many. Models of teaching and learning processes may have wide applicability and general application, but they could just as easily fail to accommodate a given situation or set of learners, where reality may be different.

Ontological objects are real to those who hold and live them, but they are not subject to verification. For example, a student in

my class might arrive with a concept of plate tectonics wherein solid plates float on top of a homogeneous, completely liquid mantle. The mantle has been established to be much more complex than this simple representation, so his conception is “wrong” (“alternate”). His conceptualization may be faulty, but nevertheless it is what he presents to me, so therefore it exists. I can add it to my data pool, along with other ontologies from other learners, if these objects are the focus of my research.

Another issue that may confront the geoscientist unfamiliar with qualitative inquiry consists of distinguishing between qualitative data and anecdotes. In quantitative inquiry, we occasionally obtain information that we do not intend to quantify. Depending on the researcher’s intent, this information may be anecdotal, or it may in fact be a pool of generated qualitative data. For example, teaching evaluations often have quantitative and qualitative components. Students respond to a questionnaire containing ordinal items such as, “Rate the instructor’s ability to motivate you (on a scale of 1 to 5).” Institutions compile descriptive statistics, and a score is produced for each question. Students are also given the opportunity to write open-ended comments, such as, “What did you like best/least about this course?” These comments are frequently not scored against any rubric, but are simply aggregated and sent back to the instructor. If the institution bases merit and promotion solely on the numerical results, then the student comments are not important to that process, and, in that context, they are anecdotes. Furthermore, the comments may have been influenced by external factors, such as the difficulty of the upcoming final exam, or the donuts the instructor brought in for his class.

On the other hand, the student comments may yield patterns upon close inspection. This pattern-identification is systematic, but it is not necessarily repeatable; different workers might produce different interpretations. This makes the process iterative in a manner dependent upon the situation and the investigator, and therefore is not “scientific” in the way we practice traditional geoscientific investigations. For example, the students may be struggling with the course management software; the instructor’s approach to collaborative learning may need adjustment; the instructor may have displayed cultural insensitivity in his interactions with students. If the instructor systematically analyzes the comments he receives and acts on them, they are no longer anecdotes: they are data. This is especially true if a large percentage of students chose, on the quantitative portion, to score him arbitrarily (picking “all threes,” or “all fives,” to finish the survey faster). He could have high quantitative scores, but still see a need for improvement yielded by the comments. Systematic analysis and action are what mark the difference between anecdotes and qualitative data. While it could be argued that these data exist independent of the instructor, the bottom line is that they did not exist until the students were asked to contribute them. This is why qualitative data such as these are different in nature from quantitative items like strike and dip.

Yet another point of contention for geoscientists who are new to working with qualitative data is the issue of how much to collect. A striking contrast between quantitative and qualitative

research is that in the former, a large population is sampled, while the latter extracts meaning from a much smaller pool of participants. The meanings parsed via qualitative inquiry concerning the “how” and “why” of teaching and learning are often much deeper and more fully developed than in quantitative approaches. The purposes of sampling in numerical analysis are to mathematically and statistically extrapolate results from the sampled population to an entire population. The rigor of the extrapolation is directly proportional to the amount of sampling. However, the qualitative researcher is not interested in representing a population (Mason, 2002), but rather illustrating a process, documenting events, or understanding specific ontological realities. These require not a representative sampling, but rather a purposive or theoretical strategy (Schwandt, 2001). Purposive sampling is guided by the question of relevance to the phenomenon being studied. For example, a qualitative researcher studying how field students use GPS technology would sample students in a single field course that uses such technology. The researcher would not sample a larger pool that includes students who are not mapping with GPS, even if the available population (n) is small. This small group may or may not be demographically or cognitively representative of all geology students; however, they are the group in the field interacting with the technology. They have the highest relevance to the question of how students use, depend on, and conceptualize GPS technology. Documenting and understanding what happens with these students is critical to understanding the phenomenon.

Another factor that reduces sample size is that of data saturation (Mason, 2002). Saturation takes place when enough data have been generated so that the researcher has a picture of what is going on, and any further generation would result in the data repeating themselves. For example, a researcher examining barriers to understanding the concept of geologic time could interview students. Through the course of the interviews, ten students express a dissonance between geologic time scales and their religious beliefs. The researcher interviews three more, and all three express the same dissonance. The researcher could interview 87 more students, or eight more, and expect the theme of dissonance to recur. However, it is safe for the researcher to conclude that she or he has a reasonable picture that “religious dissonance” impacts student conception of geologic time. This dissonance is an ontological object, an emergent theme expressed by the participants as a group. What the researcher does with this theme depends on his or her chosen theoretical framework.

THEORETICAL FRAMEWORKS: A SELECTIVE REVIEW

Scientific inquiry in the geosciences is conducted wholly within the realm of mechanistic, positivistic logical empiricism (Nagel, 1961). The “laws” of physics and chemistry underlie every Earth process, and those processes are investigated through hypothesis, experiment, observation, and subsequent hypothesis revision/rejection. Quantitative inquiry in geoscience education

research also lies entirely within the realm of logical empiricism. Relationships are parsed, correlations discovered, and inferences made according to the rules and assumptions contained within mathematical, statistical, and psychological approaches. As such, geoscientific and quantitative educational research is informed by only one theoretical foundation, that of logical empiricism, i.e., the scientific method.

An inquiry guided by empiricism is feasible in qualitative inquiry, if the data are somehow quantifiable (so-called “mixed methods”), or if they lend themselves to experimental manipulation. Ontological objects (e.g., lived experiences, communicated truths, attitudes) do not readily lend themselves to empirical study. The scientific method is not a suitable theoretical foundation for working with most qualitative data types; however, qualitative inquiry can be *informed* by logical empiricism. In my own research, I have alternately operated within two different frameworks, those of grounded theory and critical theory. The former is, in part, informed by the scientific method. The latter has a long history in the social sciences, but has only recently emerged in science education research.

Grounded Theory

Grounded theory is a data-driven approach to understanding a central phenomenon (Creswell, 1998). The outcome of a grounded theory study is a model, or some other theoretical construct, applicable to multiple settings. Ontological objects are constantly compared and analyzed for concept indicators (Glaser and Strauss, 1965, 1967; Strauss, 1987). Concept indicators can be thought of as data categories or “flags.” The researcher may establish the concept indicators in advance of analysis, depending on the problem being considered and his or her theoretical perspectives. In this situation, data are sorted into categories, for example, high-visual penetrative ability (VPA) or low-VPA (Alles and Riggs, this volume). Alternatively, concept indicators may arise inductively during observation/analysis. The framework of grounded theory is familiar to scientists: pattern recognition, consistency across different settings, visual models of processes, and unifying explanations of phenomena. In establishing models, researchers look for discounting or disconfirming evidence (e.g., Morrow and Smith, 1995). Grounded theory studies typically have a more scientific and objective language and feel (Creswell, 1998). Grounded theory is an appropriate framework for modeling teaching and learning processes. Kusunick (2002) applied a grounded theory framework in her work to outline a specific process (model) for how students come to understand sedimentary rock-forming processes. She articulated a common set of conceptual blocks that students navigate during their learning process. Alles and Riggs (this volume) work in a grounded theory framework in their model for the development of three-dimensional visualization skills among students.

Some workers (e.g., Creswell, 1998; Willis, 2007) classify grounded theory not as a guiding framework, but rather as a methodology. They consider grounded theory to be any set of proce-

dures for constructing models that are based on data. However, I cast it here as a theoretical framework in the context of geoscience education research. This is because one purpose of this paper is to acquaint geoscientists with specific elements of qualitative inquiry. It is my assumption that many readers are unfamiliar with the territory. Because of the more “scientific” feel of grounded theory, it serves as a useful conceptual bridge between the more familiar theoretical framework of logical empiricism and other, less familiar frameworks such as critical theory.

Grounded theory is suitable for analysis of policy, especially in historical context. Those workers exploring patterns and consistencies in alternative conceptions are served by a grounded theory approach as well. To a point: Workers seeking to document situated power relationships, or document a lived experience will find grounded theory a limiting framework. Additionally, qualitative data that are site-specific and/or iteratively complex resist grounded theory analysis. In these cases, critical theory may be an appropriate framework.

Critical Theory

Critical theorists are researchers whose work is intended to be transformational (affecting change), liberationist (breaking down barriers and promoting freedom from literal and figurative oppression), and deconstructive (identifying and breaking down power relationships). These workers address social and educational problems such as systemic oppression and racism (e.g., Freire, 2000; Gould, 1993; Haymes, 1995), and sex and gender inequities (e.g., Christ, 1979; Barton, 1998). Critical theorists view science as a major tool in the construction of social realities (Kvale, 1995). Physical scientists seek to understand the workings of natural systems, and critical theorists seek to ensure that “Nature” is not pitted against “Man” in an adversarial relationship. Critical theory is counter to the use of physical science for dominion or oppression. An example of this is found in the work of Stephen Jay Gould (1993), who analyzed the nineteenth-century practice of craniometry, and the perversion of Darwin’s theory of evolution by Victorian society. Gould (1993) deconstructed the Victorian application of evolution to justify British conquest and oppression of African and Asian peoples. As Gould points out, the Victorians felt that evolution resulted in an ultimately superior human phenotype, i.e., Caucasians, which gave the Europeans license for conquest. Craniometry was selectively applied to assert that non-Europeans had smaller cranial capacity, and therefore lower intelligence, and could be conquered (or domesticated or civilized) much like any nonhuman species (Gould, 1993). Gould was a noted paleontologist, and a critical theorist as well.

Feminist inquiry in science is rooted in critical theory. Barton (1998) presented a comprehensive history of the development of three waves of feminist science, beginning in the 1960s. The three waves evolved from liberationists attacking equity issues within the patriarchal scientific institution, to exploring multiple perspectives on the nature of science and ways of knowing, to challenging how science is positioned as a school subject (Barton, 1998).

Ostensibly, feminism works for the liberation and advancement of women, but true feminism and feminist science visualizes a (scientific) world that is inclusive (e.g., Mayberry and Rees, 1996) and does not speak a hegemonic (i.e., aggressive, colonialistic) language (e.g., Summa, 1995). This is a world in which social and gender realities are not merely relevant, but must play a central role in how scientists construct their worldviews (Harding, 1991; Nairn, 1996). As such, feminist theory has given rise to other critical-theoretical frameworks such as queer theory and ecofeminism. Queer theory challenges notions of social and scientific categorization of people (Sullivan, 2003), especially with regard to sexuality and sexual identification (e.g., Nairn, 2003). Ecofeminism synthesizes critical theory, feminist theory, and multiculturalism (Schwartz, 1999). It is concerned with the treatment of women, as well as nature, at the hand of patriarchal western science (Christ, 1979; Gadon, 1989; Ruether, 1992; Schwartz, 1999). Ecofeminists view Earth and nature not as passive entities that exist for the benefit of [Man], but rather Nature is cast as benevolent maternal figure and caretaker, and holds the ultimate power over the planet, in contrast to human dominion and exploitation (Feig, 2004). The Gaia hypothesis (Lovelock, 1972) is a central theme of ecofeminism. Critical theory is largely informed by postmodernism, which itself can be labeled a framework (e.g., Creswell, 1998). However, I have treated critical theory in such a manner as to “bundle” it with postmodernism.

Grounded theory and critical theory are two of many guiding frameworks for the qualitative researcher, informing his or her approach. Another approach is that of symbolic interactionism. This framework is based on the notion that human behavior is predicated on the identification of people and objects as symbols with attendant meanings (Blumer, 1986). Social interaction is interpreted as entirely symbolic, and researchers interpret the deeper meanings of the symbols. This approach is not common in geoscience education research; much of our work is grounded in behavioral-psychology approaches (e.g., Arthurs, this volume; Libarkin, 2005; Petcovic and Libarkin, 2007). Indeed, behaviorism is an empirical outlook that assumes rules and metrics for human behavior (Skinner, 1953). Because the behaviorist approach is dominant in the geoscience education literature, I do not provide a comprehensive discussion of it here.

It is important to understand that theoretical frameworks themselves do not define the purpose of a qualitative study. Understanding the purpose of a qualitative study, either as its producer or consumer, lies in understanding the study’s elements of location. Locating the study and the researcher, and exploring the roles of the researcher reveal a great deal about the researcher’s purpose and potential biases as well as what informs, or drives, the research.

LOCATING THE STUDY AND THE RESEARCHER

Geoscientists typically think about “location” as a physical parameter. Geologic investigations are located in a particular terrain or part of a state or province. Physical location is also impor-

tant to qualitative inquiry, but this parameter takes on additional meaning. The study itself has a temporal location in multiple spaces, and the researcher has a location within the study.

Locating the Study in Time, Space, and Culture

Geoscience education research can focus on the present, it can be a historical investigation of some process or policy, or it can be predictive, leading to a model. The researcher must locate the study temporally in order to define the context of his or her work. Is the research intended to support a cognitive model of student learning, focused on future events and phenomena? Is the study a snapshot in time of a phenomenon? Does the study examine a phenomenon from a longitudinal perspective? Spatially, geoscience education research can take place in a classroom, in the field, “on the street,” and in cyberspace. The less obvious factor is the notion of “cultural space.”

We tend to equate culture with ethnicity, with a social “otherness” that emerges when contrasted with our own cultural identity as, for example, Americans, Britons, Anglos, Hispanics, or scientists. The anthropologist Harry Wolcott (1990) defined the subjects of qualitative study as “culture sharing groups.” This definition does not focus on shared, inherent traits like ethnicity, but rather on patterns of observed behavior. For example, students in an introductory class express a culture; they share a set of similar experiences by virtue of their interaction with the instructor and with the course content; they take exams, participate in laboratory exercises, and attend field trips. Their culture-sharing group is independent of their ages, ethnicities, or other demographics. However, these demographics, together with their value systems, and political and religious positions inform and impinge upon the overall classroom culture.

This impingement compares well with what Vélez-Ibáñez (1997) defined as cultural “bumping.” This is the notion that human populations are never isolated enough to not interact with each other on some level and thus remain unchanged. In this context, Vélez-Ibáñez was concerned with the bumping and intercultural interactions between indigenous peoples, Hispanics, and Europeans in what eventually became the southwestern United States. However, analogs exist between these social actors and the subjects of qualitative inquiry in geoscience education. For example, a researcher might be interested in how science majors and nonscience majors learn in the collaborative setting of his class. These two groups have their own cultural spaces, which bump each other in the overall cultural space of the class. Because the researcher is conducting qualitative, intergroup comparisons, he must work to understand the two culture-sharing groups, and describe this understanding in his research. His study has a location in cultural space. Through documenting the cultural location of his study, the researcher outlines who is being studied and how they interact. This additional context benefits the consumers of his research.

Sometimes culture-sharing groups and their bumping are more ephemeral, and more subtly defined. For example, in my

own ethnographic research of field camp (Feig, 2010), I encountered the phenomenon of technology (GPS) dependence among the students. I interpreted these students in terms of cultural space as digital natives (Sheffield, 2007); they were comfortable with technology and never questioned it. However, the instructional staff of the field camp was, culturally (in the words of one student) “old-school” (Feig, 2010). The instructors valued non-technological approaches to solving field problems. “Bumping” happened as the two groups juxtaposed their unaligned values, decisions, and viewpoints in the field. In this situation, cultural bumping yielded significant insight to my observation of field learning. I also discovered different cultural spaces within the student group. For example, some students were risk-takers in the physical environment, while others were risk-averse. This latter group spent considerable time planning traverses to minimize, as much as they could, exceptionally rough terrain, steep ridgelines, and sheer drops. By contrast, members of the former group moved across the landscape with minimal thought to topography or even, in some cases, to personal safety. Cultural bumping took place when risk-avoiders were paired with risk-takers to map the area, and when avoiders encountered instructors who insisted they negotiate a particular topographic feature. Risk behavior is a cultural classification in this context, because responses to risk are classifiable as a set of common observed behaviors. In both of these examples, my “big-picture” insights and the themes that I identified were heavily dependent upon my understanding and descriptions of my study’s location in cultural space.

Qualitative inquiry requires the researcher to publicly address the question, “Who is being studied?” Another requisite question is, “Who is the researcher?” The answer to this question comes through the process of the researcher locating himself or herself in the study.

Locating the Researcher

In geological research, we are accustomed to assuming the role of a detached observer, as something of a disembodied eye, observing a single reality (Varela et al., 1991). We objectively collect data and make inferences about processes that operate independent of our thought or presence. It is possible to assume this role in educational research as well. Public policy, historical records, and aggregate test scores are examples of processes and data that exist independently of the researcher and can be studied objectively. This is not feasible when studying the ontological objects that are the subjects of qualitative inquiry. The role, purpose, potential bias, and background of the researcher each inform the generation of data and its subsequent interpretation. I provide three categorical examples of a researcher’s role and potential purposes: (1) the researcher-observer; (2) the researcher-participant; and (3) the action-researcher.

The researcher-observer generates data by both passive and active means. Passive means include detached observation of a classroom or field setting. Participant behavior is recorded by audio, video, or in the form of field notes. In this sense, the

researcher is “looking over the shoulder” (Wolcott, 2001, p. 117) of the participants. This role is useful for documenting student choices, how they cope with novel situations, or how they respond to a teaching innovation. Active observation encompasses passive methods, but is interactive in nature. An active observer engages participants either conversationally, or via interviews and focus groups. In this volume (Feig and Stokes, 2011), examples of studies in which the authors were located as researcher-observers include Clary and Wandersee, Ishikawa et al., and Stokes.

The researcher-participant is most commonly found generating data on his or her own classroom. This is the role assumed by those studying and documenting “best practices” in their own classroom and field-learning settings. For example, an instructor wants to understand the efficacy of a technological or pedagogical innovation beyond outcomes (quiz scores). A major purpose of this inquiry is to craft the innovation further, and to consider its application to future classes that she or he teaches. Additionally, the researcher may wish to share the innovation with the wider community. The *Journal of Geoscience Education* contains many examples of researcher-participant roles (e.g., Boundy and Condit, 2004; Basu and Middendorf, 2004; Earle, 2004), although the majority are quantitative inquiries. The researcher-participant observes his or her students engaged in or with the innovation, and may conduct interviews and focus groups. The instructor is not only a researcher, but is also a participant in the research, by virtue of (1) studying his or her own students, (2) having designed the innovation in question, and (3) using the results to improve and apply the innovation in future classes. Researcher-participant studies in this volume (Feig and Stokes, 2011) include Alles and Riggs, Arthurs, Arthurs and Marchitto, Atchison and Feig, Kortz et al., and Swenson and Kastens.

The action-researcher tackles educational questions in the context of social problems. An example of action-research is the work of Riggs et al. (2007) and Riggs (2005) in their efforts to address, respectively, increasing the participation of Native American students in the geosciences, and integrating geosciences and indigenous knowledge. The purposes of their research went beyond understanding phenomena of teaching and learning. Rather, they sought to address ostensible problems, such as broadening participation in Earth sciences, and incorporating multiple ways of knowing. Research based on service-learning and community-outreach efforts (e.g., Feig and Girón, 2001; Prakash and Richardson, 1999, respectively) is action-research. The action-researchers in the present volume (Feig and Stokes, 2011) are Williams and Semken.

A comprehensive statement of location made by the researcher is a public, transparent exploration of why the study was conducted, how the researcher fits into the study, and provides context in which to address potential bias. For example, by declaring a participant-observer role, the researcher has the opportunity to address the appropriateness of his or her methods, and how those methods may have influenced the data generation. The researcher-participant has the opportunity to address how she or he impacted student perceptions of and performance on a

teaching innovation. An action-researcher has the opportunity to provide the framework of the social problem in question. In all of these cases, an understanding of the researcher's location gives the consumers of the research insight into emergent themes and how the researcher interpreted those themes.

A qualitative study is enriched by an articulation of the temporal and cultural location of the study, as well as the researcher's location within it. Doing so answers questions about why the study was conducted, who was studied, and who was investigating, but what about the actual practice of conducting qualitative research? This is a question of methodology.

METHODOLOGY AS SEPARATE AND DISTINCT FROM METHOD

A researcher will make choices about methodology and method, in part, based on his or her ontological and epistemological frameworks. In empirical science, "method" describes how research is conducted. Electron microscopy, statistical analysis, and disaggregation of sediment are all methods of geoscientific inquiry. As geoscientists, we tend not to make a distinction between our methods and our methodologies. In fact, we occasionally use those terms interchangeably. However, it is possible to distinguish them in geoscientific research. Consider the how these concepts might differ from one another:

- (1) field methodology;
- (2) laboratory methodology;
- (3) mathematical modeling methodology.

The procedures (methods) used in the field differ from those used in the laboratory. They differ still from a mathematical modeling approach. For example, using a Jacob staff to measure section is a field method, but not something done in a laboratory. "Jaking" fits neither into laboratory nor mathematical methodologies. X-ray diffraction is a method used in the laboratory, but not in the field. This fits into the laboratory methodology.

One is hard pressed to find more than occasional instances in the literature where geologists have made the method–methodology distinction. It may be that many geoscientists would find it either artificial or useless, or both. However, this is not the case in qualitative inquiry. Observation, interviewing and conducting focus groups, comparing policy outcomes, and examining historical records are all examples of methods. Each one of these, however, can be applied across multiple methodologies. I discuss four examples of methodology with which I have experience as a qualitative researcher: hermeneutics, phenomenology, ethnography and policy analysis. Other valid methodologies exist, such as case study, phenomenography, narrative analysis, and biography. However, they are outside the scope of this paper.

Hermeneutics

A researcher-participant working in his or her own classroom moves multiple times between the roles of researcher and teacher. She or he is working with the intention of using the

research to improve his or her teaching. The data move from being generated in a research environment to being put into day-to-day practice. These movements are defined as hermeneutic (Balfour and Mesaros, 1994). A hermeneutic approach seeks to understand a larger process through the understanding of smaller parts of that process, which in turn requires an understanding of that greater process itself (Schwandt, 2001). This is not circular reasoning; it is a shifting of perspectives. To understand why a student thinks or says something about, say, plate tectonics, it is important to perceive that thought or statement from multiple perspectives. We want to know what the thought/statement says about the larger phenomenon of learning in general (e.g., alternative conceptions studies; Libarkin and Anderson, 2005). We try to "get in the student's head" to improve our understanding of learning, but we need to have an understanding of the larger process of learning in the geosciences in order to get into the student's head. This is an example of a hermeneutic process, and it is applied in Kortz (this volume). If this student is in our class, then we are both the practitioner (teacher) and the researcher. In the purest sense, hermeneutics is not really a self-contained methodology. Rather, it is best thought of as a modifier for other methodologies, such as phenomenology or ethnography. Phenomenology, for example, can be hermeneutic or not.

Phenomenology

A phenomenologist seeks to understand the "essence" of things such as the everyday lived experiences of people engaged in a particular activity or process, and the values that drive them (Feig, 2004). Phenomenology, therefore, is a highly descriptive process (Schwandt, 2001). The kinds of data common in phenomenological studies include personal accounts and narratives, non-verbal behaviors, interpersonal interactions, individual choices, strategies, and attitudes. The ontological objects in phenomenology include basic realities, people, people as social actors, emotion, memory, consciousness, understandings and interpretations, ideas and perceptions, attitudes, beliefs, and belief systems. These data and ontological properties form and reside in communicated truths. A phenomenological methodology is appropriate for those workers who are seeking an intimate understanding of how reality is constructed (e.g., alternative conceptions), how preconceptions are acted on, or how students cope with new situations, i.e., novel spaces (Orion, 1993). Often, phenomenology is combined with ethnography for a blended methodology (e.g., Feig, 2004, 2010).

Ethnography

Ethnography is the careful and thorough documentation and description of a culture-sharing group with the goal of understanding that group (Wolcott, 1990). This is accomplished through immersive observation. Ethnographic observation is the act of living and working among one's subjects for an extended period of time. How long that time should be has been the subject of some debate. Anthropologist Harry Wolcott (2001) suggests

a twelve-month minimum, while Margaret Mead (1970) argued for a far shorter period of time. Both workers ultimately agreed that the amount of time spent in the field should be enough to gain an intimate insight into the culture, persons, or processes being observed.

Ethnographers extract meaning by coding themes from interviews, conversations, and their own observations. These latter data are in the form of field notes. Ethnographic studies have a very different look and feel from other kinds of qualitative and quantitative studies. Data are typically excerpted rather than presented in full. The common format is that recommended by Wolcott (1994), which provides for a description, an analysis, and an interpretation. The description is essentially a narrated story, describing the events that contribute to a thematic understanding. The setting of those events is also described (e.g., Feig, 2010).

An ethnographic analysis constructs an argument out of raw data, such as student responses to the researcher's questions. Items that occur multiple times or are otherwise significant (meaningful) are "flagged" in the coding process. For further reference, Libarkin (2005) discussed qualitative analysis relevant to the geosciences, and the anthropologists Ryan and Bernard (2000, 2003) provided in-depth discussions on thematic analysis in ethnography. The interpretation portion of an ethnography asks the question, "What is to be made of the group being studied?" (Wolcott, 1994). This is where the ethnographer discusses the implications of emergent themes and places them in the larger world context of the phenomenon being studied. An example of the applications of ethnography to geoscience education problems is described in the place-based education research conducted by Semken (2005) and Semken and Butler Freeman (2008).

Policy Analysis

Policy analysis is the systematic investigation of the function of a set of rules, requirements, or norms. The major players are identified: the authors of the policy, those who it applies to, and those meant to enforce it (Anderson, 1996). Policy analysis examines the implied assumptions and values made by the authors of the policy. Winners and losers are identified, as well as unexpected outcomes (Anderson, 1996). The longitudinal effects of, and compliance with, a given policy are identified. Finally, the fate of the policy is explored, depending on whether it is continued or terminated. Topical examples of policy analysis studies include high-stakes testing in Texas public schools (McNeil, 2000), renewals of the Elementary and Secondary Education Act by Congress (e.g., Applegate, 2001), and ongoing educational reform (e.g., Geary and Groat, 1994).

SUMMARY

Qualitative inquiry is a powerful means for gaining deep insight into a process, event, or culture-sharing group. Qualitative study transcends the limitations of empiricism, the constraints of codified metric analysis, and the notion of a single, objective

reality. In geoscience education, qualitative inquiry allows for the analysis of such data as communicated truths about student conceptions; feelings and perceptions about teaching and learning; lived experiences in the classroom and field; and attitudes and beliefs. These data are ontological objects that resist empirical and numerical analysis.

Qualitative researchers may choose from multiple theoretical frameworks. Those who wish to model a teaching or learning process by generating qualitative data work from a grounded theory perspective. Those who wish to directly and publicly confront social or educational problems through their research work in a critical theory framework, and those who conduct mixed-methods studies blend empiricism into their theoretical approach.

The qualitative researcher claims a location in his or her research, which varies depending on his or her purpose. The location can be that of researcher-observer, researcher-participant, or action-researcher. The grounded theorist constructing a model is usually a researcher-observer or a researcher-participant. The critical theorist seeking to affect change is usually an action-researcher. These options have limited utility in hypothesis-driven, empirical study. I do not suggest that qualitative approaches are better or more valuable. Rather, they allow for the parsing of educational problems where multiple realities exist, the data cannot be manipulated, and/or a call for change is needed. Qualitative study is appropriate for those workers who move back and forth hermeneutically between roles, such as a teacher studying his or her own classroom.

Qualitative inquiry requires the researcher to distinguish between methodology and method. This distinction is less important in empirical research, but the qualitative worker must select a methodology with his or her purpose, location, and group to be studied in mind. The qualitative researcher who is seeking to document the essence of a phenomenon chooses phenomenology; for a detailed understanding of a culture-sharing group, ethnography is an appropriate methodology. Those workers who seek to understand the purpose, intent, and detailed impact of rules or procedures select policy analysis as their methodology. Each of these options allows the use of multiple methods, including document review, direct observation, and interviews.

Qualitative inquiry is unfamiliar territory to many geoscientists. The notion of multiple realities is daunting; the need to consider location is novel; and the nature and iterative variability of qualitative data are potentially intimidating. However, the richness of meaning that can be extracted from these data, together with the potential for real change and impact as a result are worth every effort.

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REFERENCES CITED

- Alles, M., and Riggs, E.M., 2011, this volume, Developing a process model for visual penetrative ability, *in* Feig, A.D., and Stokes, A., eds., *Qualitative Inquiry in Geoscience Education Research: Geological Society of America Special Paper 474*, doi:10.1130/2011.2474(06).
- Anderson, J., 1996, *Public Policy Making* (3rd ed.): New York, Houghton Mifflin College Division, 352 p.
- Applegate, D., 2001, Monkey business: The sense of the Senate: *Geotimes*, v. 46, p. 19–46.
- Arthurs, L., 2011, this volume, What college-level students think: Student alternate conceptions and their cognitive models of geoscience concepts, *in* Feig, A.D., and Stokes, A., eds., *Qualitative Inquiry in Geoscience Education Research: Geological Society of America Special Paper 474*, doi:10.1130/2011.2474(10).
- Arthurs, L., and Marchitto, T., 2011, this volume, Qualitative methods applied in the development of an introductory oceanography concept inventory survey, *in* Feig, A.D., and Stokes, A., eds., *Qualitative Inquiry in Geoscience Education Research: Geological Society of America Special Paper 474*, doi:10.1130/2011.2474(08).
- Atchison, C., and Feig, A.D., 2011, this volume, Theoretical perspectives on an investigation of constructing experience through alternative field-based learning environments for students with mobility impairments, *in* Feig, A.D., and Stokes, A., eds., *Qualitative Inquiry in Geoscience Education Research: Geological Society of America Special Paper 474*, doi:10.1130/2011.2474(02).
- Balfour, D., and Mesaros, W., 1994, Connecting the local narratives: Public administration as a hermeneutic science: *Public Administration Review*, v. 54, p. 559–564, doi:10.2307/976676.
- Barton, A., 1998, *Feminist Science Education*: New York, Teachers College Press, 155 p.
- Basu, A., and Middendorf, J., 2004, Demanding and enforcing high expectations in freshman courses: *Journal of Geoscience Education*, v. 52, p. 320–323.
- Blumer, H., 1986, *Symbolic Interactionism: Perspective and Method*: Berkeley, University of California Press, 208 p.
- Boundy, T., and Condit, C., 2004, Bringing the field into the classroom by using dynamic digital maps to engage undergraduate students in petrology research: *Journal of Geoscience Education*, v. 52, p. 313–319.
- Brodaric, B., Gahegan, M., and Harrap, R., 2004, The art and science of mapping: Computing geological categories from field data: *Computers & Geosciences*, v. 30, p. 719–740, doi:10.1016/j.cageo.2004.05.001.
- Chi, M., Slotta, J., and de Leeuw, N., 1994, From things to processes: A theory of conceptual change for learning science concepts: *Learning and Instruction*, v. 4, p. 27–43, doi:10.1016/0959-4752(94)90017-5.
- Christ, C., 1979, Why women need the Goddess: Phenomenological, psychological, and political reflections, *in* Plaskow, J., and Christ, C., eds., *Womanspirit Rising*: San Francisco, Harper & Row, p. 71–86.
- Clary, R.M., and Wandersee, J.H., 2011, this volume, Geobiological opportunities to learn at U.S. fossil parks, *in* Feig, A.D., and Stokes, A., eds., *Qualitative Inquiry in Geoscience Education Research: Geological Society of America Special Paper 474*, doi:10.1130/2011.2474(09).
- Creswell, J., 1998, *Qualitative Inquiry and Research Design: Choosing among Five Traditions*: Thousand Oaks, California, Sage Publications, 403 p.
- Earle, S., 2004, A simple paper model of a transform fault at a spreading ridge: *Journal of Geoscience Education*, v. 52, p. 391–392.
- Feig, A.D., 2004, Identifying Ecoliteracy in the El Paso Borderplex (Ed.D. thesis): El Paso, University of Texas, 144 p.
- Feig, A.D., 2010, Technology, accuracy and scientific thought in field camp: An ethnographic study: *Journal of Geoscience Education*, v. 58, p. 213–220.
- Feig, A.D., and Girón, H., 2001, Building community connections in the Earth science laboratory, *in* International Sun Conference on Teaching and Learning, 1st Annual Meeting, Abstracts: El Paso, Texas, p. 2.
- Feig, A.D., and Stokes, A., eds., 2011, *Qualitative Inquiry in Geoscience Education Research: Geological Society of America Special Paper 474*, p.
- Freire, P., 2000, *Pedagogy of the Oppressed*, 30th Anniversary Edition: New York, Continuum, 183 p.
- Gadamer, H.G., 1975, *Truth and Method* (G. Bardon and J. Cumming, trans.): New York, Seabury Press, 601 p.
- Gadon, E., 1989, *The Once and Future Goddess*: San Francisco, Harper and Rowe, 432 p.
- Geary, E., and Groat, C., 1994, Implementing science education reform: *Geotimes*, v. 39, p. 13–15.
- Glaser, B., and Strauss, A., 1965, *Awareness of Dying*: Chicago, Aldine, 305 p.
- Glaser, B., and Strauss, A., 1967, *The Discovery of Grounded Theory*: Chicago, Aldine, 271 p.
- Gould, S.J., 1993, American polygeny and craniometry before Darwin, *in* Harding, S., ed., *The “Racial” Economy of Science*: Bloomington, Indiana University Press, p. 77–91.
- Harding, S., 1991, *Whose Science? Whose Knowledge? Thinking from Women’s Lives*: Ithaca, New York, Cornell University Press, 319 p.
- Haymes, S., 1995, *Race, Culture, and the City*: Albany, New York, State University of New York Press, 167 p.
- Ishikawa, T., Barnston, A.G., Kastens, K.A., and Louchouart, P., 2011, this volume, Understanding, evaluation, and use of climate forecast data by environmental policy students, *in* Feig, A.D., and Stokes, A., eds., *Qualitative Inquiry in Geoscience Education Research: Geological Society of America Special Paper 474*, doi:10.1130/2011.2474(11).
- Kortz, K.M., Clark, S.K., Gray, K., Smay, J.J., Viveiros, B., and Steer, D., 2011, this volume, Counting tectonic plates: A mixed-methods study of college student conceptions of plates and boundaries, *in* Feig, A.D., and Stokes, A., eds., *Qualitative Inquiry in Geoscience Education Research: Geological Society of America Special Paper 474*, doi:10.1130/2011.2474(12).
- Kusnick, J., 2002, Growing pebbles and conceptual prisms: Understanding the source of student misconceptions about rock formation: *Journal of Geoscience Education*, v. 50, p. 31–39.
- Kvale, S., 1995, Themes of postmodernity, *in* Anderson, W., ed., *The Truth about the Truth*: New York, Penguin Putnam, p. 18–25.
- Libarkin, J., 2005, Conceptions, cognition, and change: Student thinking about the Earth: *Journal of Geoscience Education*, v. 54, p. 342.
- Libarkin, J., and Anderson, S., 2005, Assessment of learning in entry-level geoscience courses: Results from the geoscience concept inventory: *Journal of Geoscience Education*, v. 53, p. 394–401.
- Libarkin, J., and Kurdziel, J., 2006, Ontology and the teaching of earth system science: *Journal of Geoscience Education*, v. 54, p. 408–413.
- Lovelock, J., 1972, *Gaia: A New Look at Life on Earth*: Oxford, UK, Oxford University Press, 176 p.
- Mason, J., 2002, *Qualitative Researching*: London, Sage Publications, 223 p.
- Mayberry, M., and Rees, M., 1996, Feminist pedagogy and interdisciplinary science education: working for social and scientific transformation: *Geological Society of America Abstracts with Programs*, v. 28, no. 7, p. A-330.
- McNeil, L., 2000, *Contradictions of Reform: The Educational Costs of Standardization*: New York, Routledge, 256 p.
- Mead, M., 1970, The art and technology of fieldwork, *in* Naroll, R., and Cohen, R., eds., *Handbook of Method in Cultural Anthropology*: Garden City, New Jersey, Natural History Press, p. 426–265.
- Morrow, S., and Smith, M., 1995, Constructions of survival and coping by women who have survived childhood sexual abuse: *Journal of Counseling Psychology*, v. 42, p. 24–33, doi:10.1037/0022-0167.42.1.24.
- Nagel, E., 1961, *The Structure of Science: Problems in the Logic of Scientific Explanation*: London, Routledge Kegan Paul, 618 p.
- Nairn, K., 1996, Parties on geography field trips: Embodied fieldwork?: *New Zealand Women’s Studies Journal*, v. 12, p. 86–97.
- Nairn, K., 2003, What has the geography of sleeping arrangements got to do with the geography of our teaching spaces?: *Gender, Place and Culture*, v. 10, p. 67–81, doi:10.1080/0966369032000052667.
- Orion, N., 1993, A model for the development and implementation of field trips as an integral part of the science curriculum: *School Science and Mathematics*, v. 93, p. 325–331.
- Petcovic, H.L., and Libarkin, J.C., 2007, Research in science education: The expert–novice continuum: *Journal of Geoscience Education*, v. 55, p. 333–339.
- Prakash, M., and Richardson, H., 1999, From human waste to the gift of soil, *in* Smith, G., and Williams, D., eds., *Ecological Education in Action: On Weaving Education, Culture and the Environment*: New York, State University of New York Press, p. 65–78.
- Riggs, E.M., 2005, Field-based education and indigenous knowledge: Essential components of geoscience education for Native American communities: *Science Education*, v. 89, p. 296–313, doi:10.1002/sce.20032.
- Riggs, E., Robbins, E., and Darner, R., 2007, Sharing the land: Attracting Native American students to the geosciences—Special Edition on Broadening Participation in the Earth Sciences: *Journal of Geoscience Education*, v. 55, p. 478–485.

- Ruether, R., 1992, *Gaia and God: An Ecofeminist Theology of Earth-Healing*: San Francisco, HarperCollins, 320 p.
- Ryan, G., and Bernard, H.R., 2000, Data management and analysis methods, in Denzin, N., and Lincoln, Y., eds., *Handbook of Qualitative Research* (2nd ed.): Thousand Oaks, California, Sage Publications, 1065 p.
- Ryan, G., and Bernard, H.R., 2003, Techniques to identify themes: *Field Methods*, v. 15, p. 85–109, doi:10.1177/1525822X02239569.
- Schwandt, T.A., 2001, *Dictionary of Qualitative Inquiry*: Thousand Oaks, California, Sage Publications, 281 p.
- Schwartz, E., 1999, Exploring children's picture books through ecofeminist literacy, in Smith, G., and Williams, D., eds., *Ecological Education in Action: On Weaving Education, Culture and the Environment*: New York, State University of New York Press, 244 p.
- Semken, S., 2005, Sense of place and place-based introductory geoscience teaching for American Indian and Alaska Native undergraduates: *Journal of Geoscience Education*, v. 53, p. 149–157.
- Semken, S., and Butler Freeman, C., 2008, Sense of place in the practice and assessment of place-based science teaching: *Science Education*, v. 92, p. 1042–1057, doi:10.1002/sci.20279.
- Sheffield, C., 2007, Technology and the gifted adolescent: Higher order thinking, 21st century literacy, and the digital native: *Meridian: A Middle School Computer Technologies Journal*, v. 10, <http://www.ncsu.edu/meridian/sum2007/gifted/index.htm> (accessed 9 September 2009).
- Skinner, B.F., 1953, *Science and Human Behavior*: New York, The Free Press, 461 p.
- Stokes, A., 2011, this volume, A phenomenographic approach to investigating students' conceptions of geoscience as an academic discipline, in Feig, A.D., and Stokes, A., eds., *Qualitative Inquiry in Geoscience Education Research: Geological Society of America Special Paper 474*, doi:10.1130/2011.2474(03).
- Strauss, A., 1987, *Qualitative Analysis for Social Scientists*: Cambridge, UK, Cambridge University Press, 336 p.
- Sullivan, N., 2003, *A Critical Introduction to Queer Theory*: New York, New York University Press, 240 p.
- Summa, C., 1995, The language of geology: Can it change and should it change?: *Geological Society of America Abstracts with Programs*, v. 27, no. 6, p. A-148.
- Swenson, S., and Kastens, K., 2011, this volume, Student interpretation of a global elevation map: What it is, how it was made, and what it is useful for, in Feig, A.D., and Stokes, A., eds., *Qualitative Inquiry in Geoscience Education Research: Geological Society of America Special Paper 474*, doi:10.1130/2011.2474(13).
- Varela, F.J., Thompson, E., and Rosch, E., 1991, *The Embodied Mind: Cognitive Science and Human Experience*: Cambridge, Massachusetts Institute of Technology Press, 308 p.
- Vélez-Ibáñez, C., 1997, *Border Visions: Mexican Cultures of the Southwest United States*: Tucson, University of Arizona Press, 361 p.
- Williams, D., and Semken, S., 2011, this volume, Ethnographic methods in analysis of place-based geoscience curriculum and pedagogy, in Feig, A.D., and Stokes, A., eds., *Qualitative Inquiry in Geoscience Education Research: Geological Society of America Special Paper 474*, doi:10.1130/2011.2474(05).
- Willis, J., 2007, *Foundations of Qualitative Research*: Thousand Oaks, California, Sage Publications, 392 p.
- Wolcott, H., 1990, *Writing Up Qualitative Research*: Newbury Park, California, Sage Publishing, 96 p.
- Wolcott, H., 1994, *Transforming Qualitative Data: Description, Analysis and Interpretation*: Thousand Oaks, California, Sage Publishing, 440 p.
- Wolcott, H., 2001, *The Art of Fieldwork*: Walnut Creek, California, AltaMira Press, 285 p.

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