Integrating a Naturalistic Paradigm Into Research on Mathematics and Science Cognition and Learning

Judit N. Moschkovich

University of California–Santa Cruz

Mary E. Brenner

University of California–Santa Barbara

The fields of mathematics and science education no longer accept a model of the mathematics or science learner as an individual grappling with a body of predetermined concepts and facts. It is recognized that the learner is a member of multiple communities and that, within and through these communities, the content and meaning of mathematics or science are continually renegotiated as parts of the learning process. Thus in order to understand the individual’s thinking fully, it is necessary to analyze the individual’s home and community cultures (Abreu, 1995; Brenner, 1998a, 1998b) as well as the classroom cultures (Cobb & Bauersfeld, 1995) within which learning occurs. In fact, current models of mathematical problem solving include beliefs and practices that individuals develop through interaction with their physical and social environments as important aspects of cognition (Bishop, 1991; Schoenfeld, 1992). These new models of mathematics and science cognition call for new approaches to research. In this chapter, we discuss the approach we have used for two research projects that integrated a naturalistic paradigm into the study of mathematics cognition and learning.

We refer to this paradigm, derived from the social sciences that traditionally have studied communities, cultures, and social interactions, as the naturalistic research paradigm (Erlandson, Harris, Skipper, & Allen, 1993; Lincoln & Guba, 1985). Because we assume that the reader is more familiar with cognitive research approaches in mathematics and science
education, such as cognitive science (Schoenfeld, 1987a) or constructivism (Steffe & Gale, 1995), we focus on the naturalistic research paradigm. We review the main principles for using a naturalistic paradigm, describe two studies that used a spiraling design for integrating this paradigm with other research methods, and outline some standards of quality for naturalistic research studies. We are not proposing that the naturalistic paradigm is more advantageous than any other paradigm. Our claims are that it can be integrated into studies of cognition, that naturalistic and cognitive (or experimental) methods can be combined in complementary ways, and that this integration and combination can move mathematics and science education research forward. We present two research projects as examples of how this integration is possible and what it can contribute.

In the two studies in which we have used the naturalistic paradigm to examine mathematics cognition and learning, the paradigm from sociology and anthropology was integrated with cognitive science methodology in a spiraling design that combined naturalistic and cognitive science methods for collecting and analyzing data. These studies are not presented as exemplary in any sense but, rather, to provide a focus for dialogues about methodology in mathematics and science education research.

In this chapter and through the descriptions of these two studies, we address several questions that focus on naturalistic inquiry and how to include it in research on mathematics and science education:

- What principles guide research studies using a naturalistic paradigm?
- How can a naturalistic paradigm be combined with other research approaches to explore questions about mathematics cognition and learning?
- How can researchers use ethnographic methods to investigate aspects of mathematics cognition and learning?
- What are the standards for quality in naturalistic research?
The naturalistic paradigm that undergirds our work is an emergent paradigm about the nature of the research enterprise (Lincoln & Guba, 1985; Erlandson et al., 1993). This paradigm arose in contrast to positivistic traditions in which the scientific method was considered the route to discovering an objective reality. The naturalistic paradigm assumes that meaning is constructed by both participants and observers so that, in effect, there are multiple realities (Erlandson et al., 1993). Because these multiple versions of reality are shaped by both theoretical and value frameworks, it is not possible to achieve pure objectivity (Guba, 1990). The goal of the naturalistic research enterprise is, “to identify the variety of constructions that exist and bring them into as much consensus as possible” (Guba, 1990, p. 26). To fulfill this purpose, naturalistic research takes a holistic view in order to examine these various constructions in relation to each other as they interact in their own contexts. It should be noted that naturalistic research is not synonymous with qualitative research, although qualitative methods tend to be the preferred methods used in the naturalistic paradigm (Erlandson et al., 1993; Guba, 1993). A close examination of the assumptions underlying different qualitative traditions in educational research, such as those described by Jacob (1987), shows that the naturalistic paradigm is inherent to some qualitative traditions, but not all.

**PRINCIPLES OF NATURALISTIC RESEARCH STUDIES**

So far, we have used the term paradigm, rather than methodology, to emphasize that we are not referring to a collection of methods but to an epistemological stance. Although the term methodology is misunderstood sometimes to refer only to “methods,” theory and methods are intricately related, mutually constructive, and informing of each other. Methodology includes the underlying theoretical assumptions about cognition and learning: what cognition and learning are; when and where cognition and learning occur; and how to document, describe, and explain them. In the rest of this chapter, we use the terms paradigm and methodology interchangeably, assume that both of these terms refer to theory and methods together, and

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1. Although more recently it has been called the constructivist paradigm by some of its main proponents (e.g., Guba, 1990), we prefer to use the term naturalistic in order to distinguish it from cognitive constructivism, which term is used by many educational researchers (Steffe & Gale, 1995).
assume that integrating a naturalistic paradigm into research involves using both methods and theory.

A naturalistic paradigm is not defined by the methods used or the place where data are collected but, more important, by a theoretical stance and a set of research principles. The theoretical stance can be summarized as the assumption that meaning is socially constructed and negotiated in practice. The research principles include considering multiple viewpoints, studying cognition in context, and connecting theory generation and verification. This stance and these principles do not exist on their own; they are tied complexly to several disciplines and traditions and draw meaning from these disciplines. The naturalistic methods we mention are couched within the practices of an academic discipline also and take their meaning from these practices.\(^2\)

The three basic research principles that we have followed when integrating a naturalistic paradigm into the study of mathematics cognition are given next. These principles derive in large part from ethnography, a methodology (not a collection of methods) connected closely to the theoretical principles of anthropology, such as the centrality of the concept of culture (Spindler & Spindler, 1987).

**Principle 1: It Is Essential to Consider Multiple Points of View of Events**

A naturalistic research paradigm provides both theoretical and methodological leverage for capturing multiple points of view of an event. There are many advantages to this for researchers who accept constructive processes that begin from a learner’s existing base of knowledge. In some cognitive research for educational purposes, there has been a traditional assumption that there is only one correct way to do mathematics or science and that there are optimal cognitive structures for learners’ knowledge. Some examples of research epitomizing this assumption most strongly include work using the expert–novice paradigm (Larkin et al., 1980), the work on misconceptions (for reviews, see Confrey, 1990; Driver & Easley, 1983; L. McDermott, 1984), bugs (J. S. Brown & Burton, 1978; J. S. Brown & VanLehn, 1980; Burton, 1982), errors (Matz, 1982), and ideal task analysis (L. Resnick & Ford, 1981). This assumption results in portraits of a learner’s knowledge that emphasize its relative accuracy or

\(^2\)See Jacob (1987), for a detailed analysis of qualitative traditions and their relationships to academic disciplines.
completeness when it is compared with an ideal model held by an expert. But this often unexamined assumption can lead researchers to miss the unexpected structure of novices' knowledge, the alternative understandings held by learners (Confrey, 1990), or the potential for progress in students' initial conceptions (Moschovkovich, 1992, 1999). A naturalistic paradigm provides a road map for understanding learners in their own terms and for highlighting the potential in what they know, rather than only comparing their knowledge to that of an expert.

From anthropology and sociology come notions of relativity that acknowledge and honor the knowledge of the people we study (Spindler & Spindler, 1987; Spradley, 1979). A relativistic stance in research means that we try to understand the knowledge of others in their own terms as much as possible prior to comparing it to other knowledge systems, including those of experts. Cognitive anthropology (Spradley, 1980; Werner & Schoepfle, 1987) and grounded theory (B. G. Glaser & A. L. Strauss, 1967) prescribe specific research techniques that enable the systematic elicitation of participants' knowledge, although each of these methodologies has its own set of assumptions about the nature of knowledge that may have different utility for any given research agenda in education.

Thus, relativism allows us to move from deficiency models of students to exploring their potential for progress, a move that is especially relevant to research with minority students. Closely aligned to notions of relativity is the recognition that culture plays a role in learning. The notion of culture is central in moving from deficiency models of students to exploring and defining culturally relevant pedagogy. The continuing failure to meet the needs of diverse students adequately points to the need for an infusion of fresh ideas for working with learners from different cultural backgrounds.

In a naturalistic paradigm, the point of view of the researcher becomes explicit. Because many forms of naturalistic research utilize the individual researcher as a tool in the data collection process, recent standards for data collection (Emerson, Fretz, & Shaw, 1995; Lincoln & Guba, 1985) dictate that researchers set down their own reactions to the events being recorded and analyzed. Thus, the researcher becomes a variable to be described in the

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3 Here we are not referring to culture as a factor or a variable for understanding students' performance (such as socioeconomic status, ethnicity, or gender) but to the concept of culture: the assumption that everyone has a culture and that this culture plays a role in cognition and learning.
research report. Rather than aspiring to perfect objectivity, a naturalistic methodology
prescribes a controlled and acknowledged subjectivity.

Principle 2: It Is Useful to Connect Theory Verification and Theory Generation

In addition to verifying or extending existing theoretical frameworks, research in mathematics
and science education needs to generate new theories grounded in data. Combining the
verification and generation of theories is most likely to move the field forward for two
reasons. Verifying existing theories builds on previous work and makes connections to
theories outside mathematics and science cognition. Building on previous work prevents the
reinvention of the wheel that may exist already. Connecting to other areas prevents theories of
cognition in mathematics and science from becoming isolated from theories in other domains.

As we show in our descriptions of two projects, a naturalistic research paradigm can be
used for generating and verifying both substantive and formal theory (LeCompte & Preissle,
1993). Substantive theory provides explanations for a circumscribed area of inquiry such as
linear functions, proportions, or metacognition. In contrast, formal theory is an interlocking
set of assumptions, concepts, and propositions that frame the research enterprise. This set of
assumptions typically derives from specific disciplinary traditions such as sociolinguistics or
structuralist sociology (Jacob, 1987; LeCompte & Preissle, 1993). Mathematics and science
education can benefit from using not only the techniques of other social sciences but also the
formal theories. In fact, to use the methods appropriately, it is necessary to acknowledge and
understand the theories underlying these methods. In a later section, we discuss ethnography in
more detail in order to illustrate the relationship between ethnographic methods and theory.

Principle 3: It Is Important to Study Cognitive Activity in Context

Research on mathematics and science cognition needs to pay particular attention to context.
We would like to make an explicit distinction between setting and context.4 We use the term

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4These definitions are parallel to, but different, from Lave's definitions of arena, setting, and
context. In particular, Lave used the term arena to refer to what we call setting, and the term
setting in a different sense than we intend, defining setting as the "repeatedly experienced,
personally ordered and edited version" (Lave, 1988, p. 151) of an arena. We use context in the
same sense that Lave did, to refer not to a single entity, such as a place, but to "an
identifiable, durable framework for activity, with properties that transcend the experience of
setting to refer to the physical and social environment. We use the term context to refer to the relationship between a setting and how participants interpret the setting, including the meaning of practices. Thus, a description of a setting might include what objects, people, and activities are present. A description of a context would need to delve more deeply into the different meanings that a setting and the practices taking place in a setting have for different participants.

Studying cognitive activity in context means not only considering the place where the activity occurs, but also considering how context, the meaning that the place and the practices have for the participants, is socially constructed. It is not possible to neutralize the "distracting" effects of contextual variables as early "think-aloud" studies tried to do (Schoenfeld, 1985). Rather, cognition and its context constitute aspects of the same phenomenon. As Lave and Wenger (1991) pointed out, "learners inevitably participate in communities of practitioners and that the mastery of knowledge and skill requires newcomers to move toward full participation in the sociocultural practices of a community" (p. 29). This notion of situated learning means that it is not sufficient to describe the setting in which learning takes place (classrooms, stores, homes); rather, learning and cognition need to be described within the larger set of practices that happen to occur in particular physical and social settings.

One way to address the importance of context is to study cognition in the settings in which it naturally and regularly occurs without intervention. Of course, naturalistic research methods were developed to study behavior within such "natural" settings and here they have much to offer educational research. However, because the mathematics content in which we are individuals, exist prior to them, and are entirely beyond their control. On the other hand, context is experienced differently by different individuals" (Lave, 1988, p. 151).

Although we could define a "natural" setting as one in which a cognitive phenomenon occurs regularly without intervention, in using a naturalistic paradigm, it is more important to consider and describe in detail the characteristics of the setting and how they might impact cognition and learning in that setting than to decide whether one setting is more or less "natural" than another.
most interested may not always be visible in these “natural” settings.\textsuperscript{6} Researchers may need to combine data from a “natural” setting and a more structured situation that includes an intervention, a quasi-experiment, or a design experiment (Brown, 1992). Nonetheless, to understand the process of learning from the naturalistic research stance, it is essential to include at least some data from a natural setting, such as a classroom or other complex setting, in the research design. The descriptions of the two studies that follow exemplify a design for doing this.

**A DESIGN FOR INTEGRATING A NATURALISTIC PARADIGM INTO THE STUDY OF COGNITION**

This account of a spiraling design which we have followed integrates a naturalistic paradigm into the study of cognition. This spiraling design combines central aspects of a naturalistic paradigm, such as ecological validity and an ethnographic stance, with some of the advantages of using a more cognitive approach, such as a focus on cognition, content, and individual performance.

We propose that research studies examining cognition and learning can integrate a naturalistic paradigm by spiraling between the use of different naturalistic methods (e.g., natural observation and conversational interviews) and more cognitive-oriented methods (e.g., written tests, controlled experiments, quasi-experiments, and clinical interviews). These methods can be used in tandem with a cyclical reiterating movement through the different phases of project development (planning, data collection, analysis, and theory building). This spiraling design combines the linear structure of the traditional psychology experiment with the more circular research process usually described for qualitative research designs (Marshall & Rossman, 1995; Spradley, 1980).

As FIG. 17.1 illustrates, the typical phases of experimental research on cognition can be outlined as:

- Define a research question or a hypothesis.

\textsuperscript{6}In fact, Newman, Griffin, & M. Cole (1989) emphasized that even during carefully structured classroom lessons, sometimes problems get solved and yet the researcher cannot detect who did the cognitive work or how the work was accomplished.
FIG. 17.1. The four phases of experimental research.

In contrast, in a naturalistic study, each of these phases is revisited several times and each phase informs other phases, as FIG. 17.2 demonstrates.

FIG. 17.2. The cycle of naturalistic research.

A project can shift between these two models as needed to achieve optimal understanding of the cognitive process in question. The spiral shown in FIG. 17.3 combines cycling between the phases of a naturalistic research study with the linear phases of an experimental cognitive study.
FIG. 17.3. An example of a spiral design for research. The black dots indicate steps that might be carried out at each phase of the project.

When using this spiraling design, our suggestion to integrate a naturalistic paradigm does not imply abandoning experiments. Rather, researchers can consider experiments (or quasi-experiments) as one possible aspect of the research cycle and can design them to be as “ecologically valid” as possible. Ecological validity has been addressed in psychological studies before (Bronfenbrenner, 1977; M. Cole, Hood, & R. P. McDermott, 1978). Bronfenbrenner suggested that for a study to be considered ecologically valid it should be designed to fulfill the three conditions:

First, it must maintain the integrity of the real-life situations it is designed to investigate. Second, it must be faithful to the larger social and cultural contexts from which the subjects came. Third, the analysis must be consistent with the participants’ definition of the situation. (p. 35)

Cole, et al. (1978) recommended, specifically, that “the analysis of any behavior should begin with a descriptive analysis of at least one real world scene” (p. 4). Then, this descriptive analysis can inform the design of an experiment (or quasi-experiment) that preserves some aspects of the real-world setting while modifying others. We have followed this recommendation in our own research by starting a study with observations in a setting where cognitive phenomena occur regularly without intervention. To explore further the cognitive phenomena observed in the natural setting originally, we designed interviews, quasi-experiments, tests, interventions, and so on, that were based on those observations.

TWO STUDIES

In this section, we describe two studies that integrated a naturalistic paradigm into the study of mathematics cognition, focusing on how each study follows a spiraling design for the research cycle and exemplifies the principles proposed for using a naturalistic paradigm.
Making Sense of Linear Functions

The purposes of this study (Moschkovich, 1992, 1996, 1998, 1999) were to explore secondary students' conceptions of linear functions and to examine how these conceptions change. The model used for the design of the study was an anthropological one, following studies conducted in workplaces that integrated different data collection and analysis methods (Brenner, 1985; Lave, 1988; Scribner, 1984). Whereas these studies with a similar spiraling strategy had focused on mathematics cognition at work, this study focused on cognition in school. The project included the collection of data from two settings: classroom observations and videotaped discussions between pairs of students conducted outside classroom time. The data were examined by analyzing the field observations, responses to written assessments, and the protocols of the videotapes.

To integrate an ecological perspective into the study, the research started with observations in a setting where students learned regularly about linear functions: two ninth-grade algebra classrooms. Students were observed working in groups or with a teacher during two curricular units, one covering linear functions and the other quadratic functions. Each unit lasted approximately 8 weeks, and classroom observations were conducted for every lesson in each unit. The researcher also participated in several tutoring sessions after school where students discussed their homework assignments. Whole-class discussions and one student group were audiotaped during 10 lessons in one classroom. Students also were videotaped while they worked on the computer during one lesson. Ten pairs of students from the two classrooms observed volunteered to complete written assessments and to participate in discussion sessions. During the discussion sessions, pairs of students were videotaped while exploring linear functions with a peer, using graphing software and problems designed by the researcher.

7 This setting can be considered “natural” in that the daily classroom practices were occurring regularly with little or no intervention from the researcher. The important questions are not whether classrooms, in general, are natural settings or how one classroom might be a more natural setting than another. For example, it is possible to use a naturalistic research paradigm to conduct research in a classroom with an instructional intervention, without needing to worry about whether this is a more or less natural setting. Instead, it is most important to consider and describe in detail the characteristics of the setting and how they might impact cognition and learning.
This study reflects a strategy that spirals between different methods in both the design and analysis phases of the study. The cycle of data collection began by observing students in a natural setting, the classroom, making conjectures based on these observations, and then addressing these conjectures directly in the design of the written assessments and the problems for the peer discussion sessions. Starting the research cycle with a natural setting was important for establishing the ecological validity of the student conceptions that were observed. Inherent to this spiraling strategy is triangulation through using different sources of data and methods of analysis. Conjectures based on field observations were corroborated through the analysis of written and videotaped data for individual students. For example, during the classroom observations the researcher noted that some students were using the $x$-intercept to generate equations of the form $y = mx + b$ and that some students were having difficulty describing lines on the computer screen. These two working hypotheses, which emerged from the analysis of the fieldwork, were verified and refined through the quantitative analysis of the written assessments and the protocol analysis of the videotapes. Thus, the central arguments were developed through the "constant comparative method" (B. G. Glaser & A. L. Strauss, 1967) across settings, data sources, and case studies of pairs of students.

A central objective of the study was to consider multiple points of view, especially the points of view of the students. The goal was to describe how the students approached the connection between lines and equations (Moschkovich, 1992). One technique for maintaining this focus on the students' perspectives was to take special notice of those of their actions or statements that seemed at odds with the researcher's understanding of lines and their equations. The researcher then constructed hypotheses about the students' points of view, based on these initial observations. These hypotheses were addressed more explicitly and in more detail in the written assessments and discussion problems. For example, several of the discussion problems targeted the students' use of the $x$-intercept. Throughout the analysis, an attempt was made to maintain at least two concurrent perspectives of the subject matter: the researcher's perspective, informed by training in mathematics and science, and the students' perspectives, as they were reflected in their conversations about lines and equations.

The study also aimed at verifying and generating theories. Two goals here were to corroborate previous laboratory case study data on student conceptions in this domain, such as their focus on the $x$-intercept for equations of the form $y = mx + b$ (Goldenberg, 1988; Schoenfeld, J. P. Smith, & Arcavi, 1993), and to extend these findings to a classroom setting. However, new themes, such as the students' use of descriptive terms and the negotiation of the
meaning of these terms (Moschkovich, 1996), arose from the field observations and the analysis of the videotapes.

This study explored cognitive activity in both a naturally occurring setting, a classroom, and in a setting not occurring naturally but constructed specifically for the research study, the peer discussion sessions. The classroom observations served several methodological purposes. First, these observations informed the analysis of the videotaped peer discussions. Instead of conjecturing or wondering what the students' classroom experiences had been, the researcher had detailed data on their experiences with linear functions. Second, the students' classroom activities were used as a model for the design of the peer discussion sessions. Although the discussion sessions were more structured than the classroom group work and constituted a short instructional intervention, in order to maintain as much ecological validity as possible, the discussion sessions were devised to resemble classroom group work as much as possible. For example, the directions for the students were similar to those given to them in the classroom and the structure of the discussions was taken from a model for classroom science discussions (Hatano, 1988; Inagaki, 1981). However, because one of the goals was to document conversations between peers, the researcher intervened as little as possible during the discussion sessions, in contrast to the classroom setting where the teacher was a resource for students.

One reason for conducting the peer discussion sessions was that this setting provided "quieter" data than a classroom, both in terms of the noise level in a classroom and the factors that can be controlled there. Students chose their partner for the discussion sessions, instead of being assigned to a group randomly, as was the case in the classroom. Students worked with a peer of their choice (they were instructed to pick a peer of the same gender), the social situation that has been suggested as being optimal for collaboration (Azmitia & Perlmutter, 1989). Also, during the discussion sessions, the students worked on problems designed to address particular conceptions more specifically than their classroom activities did and they completed written assessments that addressed the conceptions targeted in the discussion problems.

Several results from this study have some ecological validity for students in reform-oriented mathematics classrooms, are grounded in data, and have both verified and generated theories. Students' use of the x-intercept was documented in the classroom work, in their answers to the written assessments, and in their discussions with a peer (Moschkovich, 1992, 1999). The protocol analysis of the videotapes was used to describe the nature and
transformation of this conception and to develop a theoretical framework for the transformation of students’ conceptions (Moschkovich, 1998, 1999). The analysis also described how students negotiated descriptions of lines, especially the meaning of the term steeper (Moschkovich, 1996).

Hawaiian Children’s Understanding of Money

Anthropologists have developed a theory of culture conflict that has been used to analyze and change classroom practices that have prevented the academic achievement of children from nonmainstream cultures. Most of the research has been done in the area of instructional methods (Au & Mason, 1981; C. Jordan, 1985) and literacy (Heath, 1983). The theory states that there are key differences between schools and homes that block children from participating in school activities effectively, whereas other differences do not seem to make a difference. In addition, comparisons of home and school can enable content from children’s everyday life to be integrated successfully into classroom lessons for enhanced learning of the regular curriculum (Brenner, 1989, 1998a).

This study (Brenner, 1998a, 1998b) was conducted to determine if differences existed between the ways in which Native Hawaiian children learned about mathematics at home and the ways in which it was taught at school, and if such differences had any importance for their learning school curricula. Although culturally compatible instructional methods had been adopted by teachers, including cooperative peer work and altered discourse styles, Native Hawaiians continued to underachieve in mathematics in both research classrooms and in the entire school system (Hannahs, 1983; U.S. Congressional Senate Committee on Indian Affairs, 1994). The topic of money was chosen because children from ages 4 to 8 have a large interest in it and they learn about it both in and out of school. Not only is money a topic in its own right in early elementary mathematics curricula, it is used as a model for place value concepts and often in applications such as word problems.

A multifaceted research design was employed (Brenner, 1989, 1998b). Children were studied in three settings—stores, homes, and schools. Nonparticipant observation was used in stores on a regular basis for 6 months to determine what kind of shopping children do, what kinds of money they use, and how they interact with peers and shopkeepers while they are shopping. The researcher chose to begin the study with observations of children engaged in shopping because of the desire to overcome assumptions about children’s use of money. As a newcomer to the Hawaiian Islands and as an adult who grew up in an era when penny candy really cost a penny, the researcher had reason to expect that her childhood shopping
experiences would differ from those of Native Hawaiian children. In addition, the researcher wanted to observe the shopping routines used by children because prior studies had shown that the mathematical skills used in shopping are shaped strongly by other factors operating in particular settings such as who is present and what goals are being fulfilled (Lave, 1988; Saxe, 1991). Because the research focus was on the early elementary years, it was believed that the children would be unable to explain their shopping in an adequate level of detail. Nor were the questions that would elicit the best information from the children known beforehand. Werner and Schoepfle (1987) emphasized the importance in ethnography of negotiating culturally relevant questions: "Just because another group speaks some variety of English does not mean that we are capable of asking significant questions" (p. 321). The observations were begun before the first interviews and continued for another 2 to 3 months after the first round of interviews was completed. In this way the observations helped to shape the interview questions, and continuing observations cross-validated what the children said in interviews, an example of how the research spiral builds on different research approaches. In addition, it was important to spread the shopping observations over a period of time in order to capture variations in children's routines, which are influenced by the school year and summer vacation.

Children's money experiences at home were studied in two ways. A sample of six families was visited weekly for a year. The researcher functioned as a participant observer with the target child in each family, shopping and playing games that involved money with the child, whereas another interviewer interacted with the parents. The parents in these families were interviewed regularly. A larger sample of 100 families was surveyed to determine the money and shopping practices of children in kindergarten through Grade 3. Through this component of the study, it was possible to ascertain which kinds of money and shopping knowledge were transmitted and valued by parents and how shopping experiences fit into children's everyday lives. The survey also enabled an assessment to be made of whether observations in stores and observations in six homes were characteristic of a larger sample of Native Hawaiian children.

The school environment for money was studied by following a cohort of 24 children from the beginning of kindergarten through the end of second grade. The same children were interviewed about money three times over this period of time, they were observed regularly in their classrooms, and all school materials dealing with money (textbook lessons, worksheets, etc.) were catalogued, including tests that contained questions on money. By combining the
data from these various sources, it was possible to trace the longitudinal development of knowledge about money for this sample of children in relation to both school instruction and their shopping practices outside school.

Cognitive models were developed from the data to show what children needed to know about money outside school in order to be competent shoppers, what they actually knew about money at ages 4 to 8, and what model of knowledge about money was taught by the school for this same age range. Key differences were described in what the children knew at each age and what the school expected them to know, thus confirming that there is a difference in the knowledge learned at home and at school by Native Hawaiian children in this aspect of mathematical information. The interviews with the children and the analysis of their school work showed that these differences were important because they caused a negative effect on some children’s motivation and blocked comprehension of some aspects of their school curriculum. Not all children showed this pattern. About 25% of the children had no spending money and little shopping experience, as reported both by the children during interviews and by their parents on the survey. These children showed a growth of knowledge that conformed more closely to what was taught in school. Studies of children from other ethnic groups (Abreu 1995; Guberman, 1992; Nunes, Schliemann, & Carraher, 1993; Saxe, 1991), as well as informal observations in non-Hawaiian neighborhoods, revealed that the Native Hawaiian children’s shopping patterns and knowledge of money were distinctive from those of many other groups of children.

Observing children in their natural settings of stores and homes turned out to be the key to understanding children’s behavior during interviews and in school. For instance, the children in kindergarten appeared not to know anything about money because, on the school’s test, they were unable to identify pennies, nickels, and dimes. However, a more open-ended interview and simulated shopping tasks revealed that the children knew the value of a quarter and a dollar and could use these denominations accurately for making purchases. A review of the data from the shopping observations confirmed that children seldom used anything but quarters or dollars for making purchases. Furthermore, although the school organized lessons about money around pennies, the children organized their knowledge of money with quarters as the central value.

This study demonstrates how naturalistic methods can be combined with the kinds of methods used more typically in cognitive studies (clinical interviews and task simulations) to explore the utility of a formal theory from anthropology (culture conflict theory) for studying
how mathematics is learned as well as to develop a substantive theory about children's understanding of the domain of money. At the formal theory level, this study was one of the first to substantiate a difference between children's everyday mathematical knowledge and their school mathematical knowledge, including verification that the children recognized and were affected by this difference. At the level of substantive theory, the researcher was able to develop models of mathematical knowledge about money that were informative for teachers of Native Hawaiian children, but whose generalizability to other populations requires further research. Although only the research methods used to examine the differences between school knowledge and everyday knowledge about money for Native Hawaiian children have been described, in subsequent studies, some teachers and the researcher designed new mathematics activities that built more directly from children's everyday mathematical experiences (Brenner, 1998a). The effectiveness of these interventions provided further verification that conflicts between everyday practices and school practices were a source of difficulty for some children.

The inclusion of both observations and interviews was planned from the beginning of the study. The researcher did not believe that she could understand children's everyday knowledge of money without including multiple methodologies. In line with the basic assumptions of the naturalistic paradigm, it was assumed that children's knowledge of money was constructed from their experiences or lack of experiences with shopping and the use of money. Therefore, it was important to obtain information about these experiences, and, in this instance, the children were not able to tell us about them directly. The observations also permitted the elimination of some rival hypotheses about the nature of children's understanding of money. The initial evidence from classroom observations that kindergarten children did not know about pennies, nickels, and dimes had several possible explanations. It was reasonable to suggest either that children just beginning kindergarten did not have the underlying knowledge of numbers in order to be able to understand the quantities represented by the coins or that they had trouble understanding that five pennies were the same as a nickel in value because of undeveloped concepts about part–whole relations. Alternatively, it was possible to hypothesize that they had not done any shopping and, therefore, were simply unfamiliar with money in general. However, the initial observations showed that many young children do go shopping, but not with pennies, nickels, and dimes. In the observations, it was noticed that children used quarters and dollars almost exclusively. So the interviews with the kindergarten children were extended to include these denominations and they were asked about the relation between them. Other questions to test children's numerical skills were incorporated too, and,
generally, it was found that they understood number concepts well enough to understand the values of pennies, nickels, and dimes. Without the observations, these kinds of questions would not have been included in a clinical interview with children beginning kindergarten.

The inclusion of multiple methods can entail significant additional expenditures of time and money on the part of researchers. However, this was not a significant issue in this study. The initial study was planned to cover a full year, so the use of multiple methods did not prolong its duration of the study because the researcher alternated between methods over the course of the year. Because the observations of children took place after school in either homes or public shopping areas, it was possible to interview them and to observe them in classrooms during the school day and to carry out other parts of the research in complementary times in the afternoons and evenings. In addition, colleagues collaborated in collecting data from the home study, enabling other important issues about the home experiences of young Native Hawaiian children to be addressed (Levin, Brenner, & McClellan, 1993).

ETHNOGRAPHY AND ETHNOGRAPHIC METHODS

The naturalistic paradigm reflected in the two studies described previously relies largely on an ethnographic stance toward research. Using this ethnographic stance to study cognition means more than borrowing methods; it means integrating theories and methods. In this section, we use ethnography to illustrate the distinction between methods and methodology and to discuss important issues that need consideration when using ethnographic methods. A similar discussion could be held for grounded theory, case studies, discourse analysis, and other methodologies from anthropology, sociology, or linguistics.

A number of authors have differentiated using ethnographic methods from the goal of writing an ethnography. An ethnography involves much more than using ethnographic methods such as participant observation, taking field notes, or conducting interviews. A true ethnography is a long-term project, involves participant observation as well as other methods, and aims to describe the participants' perspectives (Emerson et al., 1995; Glesne & Peshkin, 1992; Shimahara, 1988; Spradley, 1979, 1980). Ethnography is a methodology that is intricately related to the theoretical principles of anthropology, such as the centrality of the concept of culture (Spindler & Spindler, 1987). In the words of these two educational anthropologists:
Many people, who are quite innocent of anthropology as a discipline and who have only vague notions of cultural process, claim to be doing ethnography. We have nothing against anyone doing qualitative, field site evaluation, participant or nonparticipant observation, descriptive journalism, or anything else if it is well done. It will produce some tangible result and may be useful, but it should not be called ethnography unless it is, and it is not ethnography unless it uses some model of cultural process in both the gathering and interpretation of data. (p. 151)

Although not every naturalistic study is an ethnography, ethnographic methods can be integrated into a research study that may not be a full ethnography. One of the central goals of using ethnographic methods is to identify the issues for the participants (Malinowski, 1922; Spradley, 1979). However, ethnographic methods also help the analyst to raise issues that the participants may not have been aware of themselves. For example, in uncovering the mathematics that is involved in candy selling in the streets, one main goal was to describe events from the point of view of the participants. However, another aim was to describe the mathematical principles underlying the selling activities, even if the participants themselves might not identify these mathematical principles (Nunes et al., 1993; Saxe, 1991).

In using ethnographic methods to study learning in classrooms, it is important to keep in mind that we are conducting observations not only across cultures, but also across ages and educational experiences. One criterion in anthropology for how well one understands the participants in a study is being able to act like them (Goodenough, 1956; Shimahara, 1988). When one is observing students who are younger and have less schooling, it is perhaps less important to be able to act like them and more important to remain aware of how one’s experience can affect the research. Eckert (1989) provided a number of observations that are pertinent to mathematics and science education researchers, based on her ethnographic research in a high school:

Doing ethnography in one’s own culture brings obvious problems and an American doing ethnography in an American high school certainly stretches the limits of the ethnographic method. My challenge in doing this work was not to pretend to be a complete outsider to the community, but to assess the real nature of my status. (p. 26)

There is no special way to deal with the potential interference of personal experience. My responsibility as an ethnographer was not to forget my own
story, but to know it well and to refer to it constantly to make sure that it
was not blinding me to what I saw or focusing my attention on only some
of what I saw. Careful articulation of my previous beliefs about school and
adolescence was interleaved with a constant questioning of every observation
and every interpretation. (p. 27)

When using ethnographic methods, researchers need to be aware of the difference between
conducting short-term (a few weeks) and long-term observations (a few months). In
ethnographic work, it takes time to be admitted into a community:

In the end, the challenges and responsibilities of doing participant
observation in an American high school are not very different than those
facing an ethnographer working in any other culture or age group. I was an
outsider trying to get to know and understand a community. I needed to gain
the confidence and trust of the members of the community so that they
would allow me access to their activities and knowledge, and I needed to
become sufficiently part of the local woodwork to be able to observe
activities without producing a distraction. (p. 25)

Another important distinction between using ethnographic methods and doing an
ethnography is in the different ways to collect data when using ethnographic methods. There is
a difference between what people say they do (self-reports), what people are observed doing
(observation), or what the researcher concludes from participation in an activity (participant
observation). There is also a difference between being a “participant-observer” and an
“observing participant.” A participant-observer observes and participates in activities without
being identified as belonging to one of the social categories of the community being observed.
On the other hand, an observing participant, such as a teacher-researcher, is a part of the
classroom community. This distinction, however, is not a dichotomy. A researcher can engage
in a spectrum of activities that ranges from the first, observing and participating while not
belonging to the community, to the second, belonging to a community and observing one’s
own activity as well as those of others.

One important aspect of using ethnographic methods is knowing the purpose of different
note-taking techniques (Emerson et al., 1995). A researcher can jot down observations online,
write low-inference descriptions, or make analytical, methodological, or personal memos.
Each type of note has different implications for analysis. In analytical memos, inferences are
made beyond low-inference description. For instance, questions or curricular reflections are
noted and hypotheses are made. In writing methodological memos the researcher might consider what to do next and how to do it. And, last, in writing personal memos the researcher records feelings, impressions, and reactions that may or may not become a part of the research analysis. However, these personal memos can become part of the audit trail that helps to establish the overall quality of a study as explained later.

We also would like to point to the connection between using ethnographic methods and collecting video data. Video data can be collected concurrently with ethnographic observations or without any ethnographic observations. Conducting observations while being present physically provides a researcher with multiple impressions that may not be reproduced by reading someone else’s field notes or watching a tape of activities in a classroom the analyst has not visited. We are not suggesting that researchers only analyze tapes of activities in classrooms where they have conducted observations personally. Instead, we suggest that researchers consider and describe the methods used to collect and analyze their data, including whether observations and field notes were collected while videotapes were made and whether the videotaping or observations were conducted by the analyst or another researcher. In this way, we can specify and discuss the advantages and disadvantages of each situation.

The last aspect of ethnographic methods that we would like to address is transcription. Transcripts and tapes are not equivalent, nor are all transcripts alike (Kvale, 1996). The act of transcribing is an interpretive act. The choice of a system of transcription conventions reflects the analyst’s theoretical stance, analytical focus, and relationship to the audience (Linde, 1993; Ochs, 1979). When transcribing tapes it is important to be explicit about how and why certain aspects of the data were not included in the transcripts and why others were. For example, gestures, expressions, and tone of voice usually help the analyst interpret utterances on a videotape in a way that needs to be communicated in a transcript.

**STANDARDS OF QUALITY FOR NATURALISTIC RESEARCH STUDIES**

The methods and assumptions used in naturalistic research raise serious questions about the rigor and objectivity of data collected within this paradigm. For instance, the issue of subjectivity is often raised about naturalistic research. Because researchers working within a naturalistic paradigm assume that there are multiple constructions of reality, they also assume that any descriptions of these constructions will have subjective overtones. At the same time,
naturalistic researchers are sensitive to issues of how the characteristics and beliefs of individual researchers can bias results. Another important concern is that of reactivity to the researcher. Because naturalistic researchers observe people as they are engaged in their everyday activities and even participate in these activities at times, there is a chance that their presence changes these activities. Naturalistic research designs can incorporate safeguards for these threats to the validity of research results. Another issue brought up frequently about naturalistic studies is the possibility of generalizing beyond the people studied because samples are often small or specific to particular settings. One of the basic assumptions of naturalistic research states that the highest priority is given to understanding and theorizing adequately about the particular research context in the form of substantive theory before the relevance of the findings is discussed for other groups or contexts (Erlandson et al., 1993). However, there are techniques that enable researchers to assess the transferability, if not the actual generalizability, of results. In this section, we discuss specific ways that naturalistic research addresses the issues of bias, reactivity, and generalizability.

Because naturalistic research methods derive from particular disciplinary traditions, the standards for judging the adequacy of research using these methods should derive from these traditions too. Although there is consensus that naturalistic research requires a redefinition of the traditional research concepts of validity, reliability, and generalizability, researchers have not reached consensus yet about the nature of this redefinition (for discussions of the issues involved, see Firestone, 1993; LeCompte & Preissle, 1993). We have chosen to follow the recommendations of Lincoln and Guba (1985) and Erlandson et al. (1993) by calling the qualities that establish the credibility of a study its trustworthiness. By using a different term such as trustworthiness, we stress that distinct sets of standards and strategies are appropriate for judging naturalistic research.

Despite clear differences in traditional and naturalistic approaches to defining the quality of a research project, at the heart of most research is the need to establish the systematicity, rigor and believability of its results. Lincoln and Guba (1985) identified four dimensions that frame the concern for quality in both traditions: (a) truth value, (b) applicability, (c) consistency, and (d) neutrality.

As Table 17.1 displays, we consider each of these in turn by comparing briefly the traditional and naturalistic definitions with examples of specific strategies that can be used within a naturalistic paradigm. The strategies included here are by no means exhaustive. Further strategies and variations have been described in LeCompte and Preissle (1993),

TABLE 17.1

<table>
<thead>
<tr>
<th>Dimension of Quality</th>
<th>Traditional term</th>
<th>Naturalistic term</th>
<th>Sample strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truth value</td>
<td>Internal validity</td>
<td>Credibility</td>
<td>Prolonged engagement, Persistent observation, Triangulation, Member checking, Thick description, Purposeful sampling</td>
</tr>
<tr>
<td>Applicability</td>
<td>External validity, Generalizability</td>
<td>Transferability, Analytical generalizability</td>
<td>Multisite designs, Critical case selection, Audit trail, Multiple researchers, Participant research assistants, Recording devices, Audit trail, Researcher's role defined</td>
</tr>
<tr>
<td>Consistency</td>
<td>Reliability</td>
<td>Dependability</td>
<td></td>
</tr>
<tr>
<td>Neutrality</td>
<td>Objectivity</td>
<td>Confirmability</td>
<td></td>
</tr>
</tbody>
</table>

Note. The sources of the terms and strategies are Erlandson, Harris, Skipper, and Allen (1993), Firestone (1993), LeCompte and Preissle (1993), and Lincoln and Guba (1985).

Truth Value

The truth value of traditional research is addressed as internal validity, that is, the real relationship between accurately identified variables. In the trustworthiness approach, truth value is defined as credibility: In other words, how well do the results capture the constructs used by the participants in a context and the particular dynamics of that context. Several research strategies are used to assure that the basic database is adequate for capturing the major features of the phenomenon under study. Prolonged engagement (see Table 17.1) means that the researcher spends enough time in the context to eliminate or control distortions in the data that might occur because of unusual or atypical events, including the presence of the researcher herself. Prolonged engagement is the naturalistic researcher's strongest defense against reactivity. People have trouble maintaining atypical or ideal patterns of behavior over extended
periods. In addition, everyday activities tend to be very robust. As Jean Lave put it (Lave & Kvale, 1995):

There are common practices in American life that I dislike very much and if, just by being a participant-observer, I could change them, I would certainly do so. It turns out not to be easy to change social formations, or communities, or peoples' ways of life. In fact, it is very difficult. (p. 226)

In traditional ethnographic studies, a period of fieldwork usually lasts at least a year so as to allow the researcher adequate time to learn the culture and to see a full cycle of events. Frequently, the cycles of activity in contexts relevant to science and mathematics education will differ from this. For the study about linear functions (Moschkovich, 1992), one such cycle was the approximately 8 weeks taken to cover a curriculum unit. The researcher spent two of these cycles with each of her study classrooms in order to observe all of the instruction that had direct relevance to linear functions. For the money study (Brenner, 1989, 1998b), the observations in stores spanned 6 months and covered several distinct cycles that influenced children's spending—the school year/summer cycle and the monthly cycle in which there is more money to spend at the beginning of the month when paychecks and food stamps arrive.

Spending an extended period of time also gives the participants the opportunity to become accustomed to the researcher's presence. For example, at the beginning of data collection for the money study, the researcher was asked frequently by children who she was and why she was "hanging around." After a few weeks these questions seldom arose or the children told their friends, "She's somebody's mom" or, "She's looking at how kids spend money."

Another concern about credibility that arises in naturalistic research is deciding how much information is enough. The answer from the perspective of prolonged engagement is that enough time has been spent in a context when recurrent patterns become clear and fewer new types of data are being collected. Credibility is also enhanced by the use of persistent observation. This entails taking an analytical view of the data, looking for important patterns, and then seeking out further information that confirms or contradicts the emerging understanding of the researcher. The use of persistent observation ensures that the researcher achieves adequate depth in the most important aspect of the phenomenon under study.

In the linear functions study (Moschkovich, 1999), the researcher initially noticed and documented students' use of the \( x\)-intercept and their difficulties in describing graphs and in resolving disagreements during the classroom observations. A special effort was made to collect a substantial body of examples confirming or contradicting these initial themes, as
well as other themes that emerged during the analysis of the videotapes. The discussion problems were designed to explore the initial themes further and the videotapes of the discussion sessions were analyzed by focusing on both initial and emergent themes.

In the case of the money study (Brenner, 1989, 1998b), the researcher noticed after a few weeks of observation that there were not many observations about the use of pennies. This became increasingly important as a research theme when she discovered during interviews that the kindergarten children had trouble identifying pennies and said consistently that they were "junk" and not money. To explore this theme, over a period of months the researcher included observations that focused on the coins and bills used by the children and the kind of change given to them by the storekeepers. These observations generated several hundred accurate records of the actual money used that confirmed that, indeed, the children seldom used pennies and never received them as change. The researcher also began to record the prices of the items that children bought most frequently and discovered that they were priced so that pennies were unnecessary. For instance, cheap candies were always two for 5¢ and storekeepers would not sell one piece for 3¢.

Triangulation, the use of multiple sources of data, is the best known of the techniques for establishing credibility. In the linear functions study (Moschkovich, 1992, 1996, 1998, 1999), written test results were used to corroborate some of the conclusions from the analysis of the peer discussions. In addition, the researcher compared students' discussions across her two research sites: the classroom and the peer discussions. Student conceptions documented in both settings, such as the use of the x-intercept, confirmed the robust nature of these conceptions. Student conceptions and descriptions were observed to be similar in both the classrooms and in the discussion sessions organized by the researcher. This confirmed the transferability of the analysis of the students' conceptions and their use of language; that is, it was not particular to one context only. The observation of these conceptions in the classroom established that they were not an artifact of the observer's influence as students carried out tasks designed by the researcher. During the money study (Brenner, 1998b), the researcher cross-checked the results from the interviews with the results from the tests that teachers gave as a regular part of their instruction. For instance, it was surprising that a comparison of interview data from the beginning and the end of the kindergarten year did not show much improvement in the children's knowledge of coins, even though they had covered a unit on money in class. The teacher's records showed that their test scores at the end of this unit were
correspondingly low, confirming that this result was not an artifact of an interviewing technique or reflective of a bias brought to the interview session.

Another control for research bias is member checking, a technique in which the researcher's constructed understanding of the research results is presented to the informants for comment and revision. At its simplest, this can entail asking the informants to review interview transcripts for accuracy and completeness or to provide commentary on raw data such as a videotape. More complex variations consist of asking the informants to comment on drafts of final reports or subjecting tentative conclusions to the systematic scrutiny of the participants. This latter approach was taken by J. W. Wilson (1994) in her study of motivating and nonmotivating instructional activities. After three months of participant observation during which she lived the life of a sixth-grade student (at least during school hours!), Wilson interviewed every student in the class to confirm that the activities she had identified as salient by personal experience during her participant observation were seen as such by a majority of the students. During the money study, the initial draft of the school's model of knowledge about money was shown to the teachers for comment and confirmation. Although it was not included in the textbook materials explicitly, it seemed that the students were expected to know by the second grade that a dollar is made up of 100¢. The teachers agreed that, even though it was not in the textbook, this knowledge was a part of what the students should learn in school and they intended to include it in their lectures to the class.

Applicability

Applicability is the dimension of quality that ascertains that the results of a study are relevant to a different or larger context. This may be the dimension of quality that differs most radically between the traditional and the naturalistic paradigms. In the traditional framework, this is called external validity or generalizability. The goal is to establish that the results obtained hold, regardless of the specific sample or context, most often with reference to a larger population. From the point of view of trustworthiness, this is referred to as transferability. Because understanding the context is one of the principles guiding naturalistic research, naturalistic researchers do not always try to establish how well their results will apply to other contexts. Some naturalistic researchers assert that it is not the researcher's task to suggest how the results may be relevant to others; rather, it is the reader's task to determine what is relevant from a study to a context of interest (Lincoln & Guba, 1985).

Two strategies are suggested for optimizing transferability, from the perspective of both the researcher and the reader, with particular reference to allowing the reader to make judgments
about transferability. The first is the use of thick description in which the context and the dynamics within the context are detailed thoroughly. In our studies, this included collecting both specifications of the participants with the usual demographics (e.g., age, ethnicity, and socioeconomic status) and the more particularistic details of a unique physical location. For instance, in the full report of the linear functions study (Moschkovich, 1992), the curriculum units and the problems that the students worked on each day were included to, "illustrate that the exercises the students worked on were reasonably good tasks to try, and thus the student difficulties discussed later . . . were not the result of a poor curriculum" (p. 46). In the money study, the researcher (Brenner, 1989, 1998b) provided a description of the food trucks (manapua trucks), snack shops (crackseed stores), and neighborhood stores that constituted the main settings for the children’s independent shopping because they are particular to Hawaii in some ways and perhaps relevant only to certain other kinds of urban neighborhoods.

The second strategy for supporting transferability is purposeful sampling in which sites and informants are included in a study in order to choose optimally informative sources of information rather than to represent a larger population randomly. Patton (1990) described 16 purposeful, sampling strategies that can be used to choose a sample that is most likely to elucidate the questions driving the research. The researcher is responsible for describing the procedures used to choose a sample and the rationale behind it. Some naturalistic researchers advocate sampling for maximum variability, whereas others explicitly choose limited variability in order to highlight other aspects of the context. Multisite designs, such as those described later are used by some researchers to control for irrelevant aspects of particular contexts. Other researchers are interested in what makes some events or sites unusual and will use critical case selection to assure that they capture the phenomenon of interest, particularly when it is somewhat rare.

In the linear functions study (Moschkovich, 1992), the two classrooms were chosen purposely to represent reform curriculum and exemplary teaching. The students’ groups observed in the classroom were selected because they were composed of average-achieving students. Although the students who participated in the discussion sessions were volunteers, they turned out to be mostly average students, with only two low achievers, as determined by their course grades and evaluation by the teacher. After ascertaining the achievement levels of the volunteer students, the researcher deliberately approached two students identified as high achievers in order to round out the sample. In the money study (Brenner, 1989, 1998b), three distinct kinds of stores were included in the sample to ensure that the shopping routines
identified were not results of the products sold (prepared food, toys, groceries) or idiosyncratic routines set up by a few storekeepers. In addition, businesses in lower socioeconomic neighborhoods were chosen because the research was part of a project intended to improve instructional methods for poorer Native Hawaiian children who are more at risk for school failure.

Consistency

The third dimension from Lincoln and Guba’s (1985) approach is that of consistency, which stipulates that under the same circumstances, the same results should be found. In traditional designs, this is called reliability; in the naturalistic paradigm, it is labeled dependability. Once again, these techniques can be seen as ways to minimize researcher bias and/or to assess the amount of researcher bias. The overall dependability of a researcher’s project can be established by an audit trail in which the process of the research is documented in such a manner that it can be scrutinized by others outside of the project. In the linear functions study (Moschkovich, 1992), the researcher kept records according to university human subject standards. For the money study (Brenner, 1998b), the researcher was required to submit annual reports on the details of the research and to archive the originals of all data (field notes, interview tapes, test forms) as forms of institutional as well as individual accountability. The use of multiple researchers also can provide corroboration when observations are compared in a process somewhat like measuring interrater reliability. In the linear functions study (Moschkovich, 1992), the researcher was supervised by senior investigators, shared data with other researchers, and conducted some of the analysis in the context of a research group. In the home study component of the money study (Levin, et al., 1993), the researcher was one member of a three-person team that shared the task of home visits for a year. In addition to pooling their field notes and interview transcripts, the researchers also read each other’s materials as a cross-check for the themes that were thought to be occurring across households and to confirm that their methods were consistent over time.

The help of participant research assistants (i.e., “natives” of the location) can serve as a check on the subjective meanings of the events occurring at a site, thus addressing one of the basic principles of naturalistic research. In the money study (Brenner, 1989, 1998b; Levin, et al., 1993), one of the members of the home study team was Native Hawaiian and a mother. She was able to provide useful insights about patterns of behavior that were observed in some homes. Also, using recording devices (e.g., videocameras and audio taperecorders) can aid the researcher in achieving and proving the dependability of certain kinds of data, particularly in
classrooms where recording may be relatively nondisruptive. However, an overreliance on recording devices can introduce or mask some threats to dependability because their use depends upon repeated judgments by the researcher of when and what to record.

Neutrality

The last dimension addresses the neutrality of the research, namely, how the biases of the researcher are dealt with throughout the research process. In traditional approaches, this is called objectivity; in the naturalistic paradigm it is referred to as confirmability. One clear difference between traditional and naturalistic research is that naturalistic researchers do not seek to distance themselves from the research participants; rather they immerse themselves in the lives of the participants.

The audit trail is useful for establishing the confirmability of a research project because it allows both the data and assertions based on the data to be traced to their origin over the course of a project. Naturalistic researchers readily admit that it is impossible to eliminate completely the effects of the observers when using methods such as participant observation and intensive interviewing. Thus, it becomes important to describe the researcher’s role in the research context. This entails describing personal attributes such as ethnicity or the ability to participate in the discourse of a site (this can mean speaking Spanish or talking about mathematics), how one obtained access to the site, and the reactions of the participants to the researcher. For example, in the money study (Brenner, 1998b), the researcher was construed to have quite different roles depending on the particular context. When the researcher was observing at food trucks at public parks, the children assumed that she was someone’s mother because local adults regularly spent time at these places. In contrast, in the small neighborhood stores, it was not normal for people to spend time while not actively shopping and the researcher was asked on a number of occasions if she was the store detective.

Because the spiral design that we propose for research allows for emergent research questions, new strategies for trustworthiness may need to be incorporated as new questions emerge. For instance, it may be necessary to add new cases to a study, thus shifting the nature of the purposeful sampling, or new ways of triangulation may emerge over the course of a study. These new and developing strategies used in a spiraling design research project would need to be described and carried out in a principled way.

Any one research project is limited to including only some of these specific strategies for establishing trustworthiness. However, it is essential to consider how to incorporate some of these strategies into the initial design of the research, especially the documentation underlying
the audit trail. We feel that the spiral design proposed offers increased opportunities for assessing the trustworthiness of results through its combination of multiple research methods. Further, triangulation of the results of data collected from multiple sources is a principled and integral aspect of the spiral research design.

LEARNING TO USE A NATURALISTIC PARADIGM

The principles and standards for using a naturalistic paradigm discussed in this chapter were developed in several disciplines. Learning to use these principles involved participating in a community of researchers who were engaged in research practices reflecting these principles. The two authors of this chapter have different trajectories of participation. One was trained in anthropology and has conducted traditional fieldwork in other countries. The other was trained as a natural scientist originally and then as an educational researcher (in part by the second author). Nevertheless, both authors learned similar skills through their participation and collaboration with other researchers involved in the daily practice of conducting research. These skills involve not only explicit aspects of sound research practice but also implicit knowledge such as rules of thumb and how to decide what constitutes a good research problem or question.

Mathematics and science education are drawing on several academic disciplines to develop methodologies for research. Participating in interdisciplinary collaborative work and staying connected with the fields that generated these methods (sociology, anthropology, linguistics, etc.) either through reading texts, attending conferences, or talking with colleagues are crucial aspects of learning to include a naturalistic paradigm in cognitive research.

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Rutgers University
Richard A. Lesh
Purdue University

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