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## **Progressing through the Haze in Science and Mathematics Education Research: Contemporary Use of Spradley's Qualitative Inquiry in Two Case Studies**

Jean S. Lee, PhD  
Assistant Professor, University of Indianapolis  
Indianapolis, IN, USA

Vanashri Nargund-Joshi  
Research Associate, Indiana University  
Bloomington, USA

Barbara Dennis, PhD  
Associate Professor, Indiana University  
Bloomington, USA

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### **Abstract**

Spradley's developmental research sequence (DRS) has been used primarily for ethnographic studies. However, this ethnographic tool has been employed in case studies without an examination of the merits of its modification. In this article the authors discuss how adapting analytical steps of DRS to case studies can be methodologically advantageous. They found that transforming Spradley's ethnographic approach rendered it useful for articulating implicit conceptualizations in case studies, one from science education and the other from mathematics education. Investigating this issue will necessarily involve looking closely at the substantive aspects of the case studies themselves. Findings from the case studies and results from the methodological investigation are reported along with suggestions for future research.

**Keywords:** Spradley, developmental research sequence, concepts, beliefs, zero

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## **Introduction**

In our work we examine the use of Spradley's developmental research sequence (DRS) in mathematics and science education research. Only a few of the publications in these two fields that actually use Spradley's (1979, 1980) DRS<sup>1</sup> are devoted to methodological questions themselves (Appleton & Kindt, 2002; Eisenhart, 1988; Kelly, Chen, & Crawford, 1998; Morey & Luthans, 1984). Situated among these, this paper is unique because we have used two qualitative case studies (one from within the field of mathematics education and the other from within the field of science education) to examine the methodological merits, limitations, and possibilities of adapting Spradley's detailed ethnographic interview analysis (commonly referred to as the developmental research sequence, or DRS) for the purpose of understanding participant subject-specific conceptualizations.

The two case studies drawn on for this inquiry both serve to illuminate the tacit math or science concepts held by individuals. Spradley's DRS was specifically developed to articulate cultural, semantic knowledge shared by a community of participants. Our adapted use of it rendered it capable of articulating the implicit conceptualizations of individual participants. Transforming Spradley's DRS involved (a) shifting its unit of analysis from the culture to the individual and (b) linking the semantic strategies of DRS to their implicit pragmatic structures. Such innovations contribute, in a practical way, to the methodological critique of traditional positivist and postpositivist distinctions between culture/person and semantics/pragmatics. The paucity of literature on methodological innovations in science and mathematics education in general, and this specific set of innovations in particular, indicate a place for the kind of dialogue this paper seeks to promote. Any such dialogue offers math and science education researchers the opportunity to progress through a haze of qualitative decisions with respect to theory and analysis. Furthermore, the paper should inspire creative and transformative methodological practices in the fields of math and science education research. The research question addressed through this dual-case study design is methodological, exploratory, and descriptive: what are the merits, limitations, and possibilities of using an adapted version of Spradley's DRS? Answering this question will necessarily involve looking closely at the substantive aspects of the case studies themselves.

Spradley's DRS fits comfortably within the qualitative research tradition known as cognitive anthropology (Jacob, 1988). Cognitive anthropologists aim to describe culture in nonmaterialist terms (Jacob, 1988) by explicating participant's cultural categories with little influence from the researcher. According to Jacob, "cognitive anthropologists have traditionally focused on understanding the cognitive organization of cultural knowledge through the study of semantic systems, with a consequent emphasis on the relationships among words" (p. 22). Moreover, Tyler (1969) stated, "Cognitive anthropologists [believe] that most of the cultural knowledge of a group is reflected in its language—specifically its semantics" (as cited in Jacob, 1988, p. 23). Formal analysis in the semantics can be generated through, most prominently, Spradley's DRS.

Spradley's DRS (1979, 1980) includes four analytic processes: domain, taxonomic, componential, and thematic. The first analytic step, domain analysis, involves identifying the semantic relationships salient to the participants talk and activities. Researchers look for connections, patterns, and themes within the domains as well as between the domains and then search for included terms that fit the given semantic relationships. Taxonomic analysis takes the researcher deeper into those structures to developing a hierarchy of terms associated with each of the cover terms for the identified domains. This affords researchers a more in-depth examination of the domains. Implied in the analysis of semantic and taxonomical relations are a set of differences or contrasts—terms that lie just outside the domains and taxonomies, marking the

boundaries between what has been included and what is necessarily excluded. Researchers get at these terms through componential analysis. Such an analysis can reveal contradictions and tensions between individuals and the cultures within which they are acting. Last, there are a variety of ways to move from these three preliminary forms of analyses into a thematic analysis which attends to cultural patterns implicit in the naturally occurring semantics of one's participant communities. The major themes are further synthesized within and across the data to illustrate important, and often contrasting, aspects of the cultural milieu.

### **Review of pertinent literature**

Various studies employ DRS in a cursory fashion. For example, Steele (1997) employed DRS to understand the mathematical culture of a fourth-grade class and how the teacher used a socio-cultural approach to teach mathematics. The researcher finds two themes but does not elaborate on the analytical procedures of DRS. Other researchers have employed all four analytical steps to Spradley's DRS but do not provide details of each step carried out during analysis process (e.g., Carlone, 2004; Steele, 1997). Furthermore, some researchers discuss in detail how each DRS step was employed but do not share the strengths or challenges to the process of employing these analytical steps (e.g., Carlone & Johnson, 2007; Johanning, 2000). Of course, in papers reporting on substantive findings, it is not uncommon for the methodological details to be left out, but such details promote scholarly efforts.

Still other studies selectively use parts of DRS. Johanning (2000) used domain and taxonomic analyses to understand middle school students' approach to solve nonroutine problems. Johanning reported on the domain and taxonomic analyses so that relevant information becomes apparent. Borko and Livingston (1989) have employed domain, taxonomic, and componential analysis to investigate the nature of pedagogical expertise by comparing the planning, teaching, and postlesson reflections of three mathematics student teachers with their cooperating teachers. Although these researchers describe how they used each analytical step and provide examples of each step, a rationale for the analytic steps they choose to employ are not provided.

Several studies combine Spradley's DRS with another form of data analysis but do not discuss the methodological underpinnings of using Spradley in their innovative form. Knuth (2002) has combined Spradley's analytical tool (domain analysis) with another method to identify the nature of what the teachers seemed to believe constitutes proof in mathematics. Before Knuth conducted domain analysis, he used a deductive approach and used researcher-generated external codes that were identified prior to data collection. Knuth then supplemented the codes with a more inductive approach by using DRS. Despite this innovative use of DRS, he did not justify or defend how data analysis in this fashion is appropriate. Appleton and Kindt (2002) produced case summaries and used a coding system based on conceptual themes in their attempt to investigate the influence of different aspects on beginning elementary school teachers' transition to full time science teachers. In their analysis, they compared the coding system of Minichiello, Aroni, Timewell, and Alexander (1990) with domain analysis of Spradley but did not actually employ DRS in the analysis. In these two studies the researchers do not justify their reasons for innovation: combining Spradley's DRS with another method of analysis or opting for similar analytical steps of DRS.

Few common themes can be drawn after reviewing these studies. First, a majority of studies have used Spradley's analytical tools to analyze discourse. These studies used discourse as a gate to understand participants' actions. Second, these researchers employed Spradley's analytical or observational tools with other analytical methods (e.g., Appleton & Kindt, 2002; Knuth, 2002) but did not supply reasons underlying their innovations. Third, a majority of studies have not

mentioned a rationale for choosing Spradley's analytical techniques. Last, most studies have failed to mention strengths and weaknesses of each analytical step. Researchers have not expressed limitations of implementing DRS while analyzing data. In short, researchers have not been self-conscious in using DRS. In this paper we investigate if Spradley's four analytical steps can be employed on case studies while reflecting how this analytical tool is equally useful for understanding participants' conceptions.

Through our research question we intend to explore the potential for an adapted version of DRS to contribute to the substantive literature in mathematics and science education through the use of two case studies that each examines a mainstream interest in their respective fields. In the first case study, Nargund-Joshi interrogated Indian secondary science teachers' beliefs about teaching and learning (other qualitative studies in math and science education that use Spradley's DRS to analyze teacher conceptualizations include Carlone, 2004; Kelly, Chen, et al., 1998; Knuth, 2002; Lloyd, 1999; Steele, 1997, 2001). In the second case study, Lee explored elementary students' conceptions of "zero" (other qualitative studies in science and math education that use Spradley's DRS to analyze student conceptualizations include Johanning, 2000; Zeidler, Walker, Ackett, & Simmons, 2002).

Overall, there are three main criticisms of DRS. First, cognitive approaches in general, and Spradley's DRS specifically, assume that the researcher can take a noninvolved perspective in the data analysis process (Jacob, 1988). Since the 1990s, the legitimacy of this claim has been called into question (Korth, 2003), and consequently, the use of methodologies purporting that assumption has been abandoned by many qualitative researchers (Denzin & Lincoln, 2008). A critical perspective (Carspecken, 1996; Habermas, 1984) makes it possible to forge a connection between the third-person attitudes that are privileged in cognitive anthropology and the critical orientations that reflectively employ standpoints the researcher might engage in dialoguing with the data. It is this dialogic perspective that best demonstrates a shift from the positivist/postpositivist views of knowledge for which Spradley's DRS has been criticized and the principles involved in resituating this approach. If we think of the research process as an opportunity to engage people in dialogue, a dialogue through which researchers owe their allegiance to understanding the participants (Carspecken, 1996; Korth, 2003), it is possible to use tools such as DRS to better understand the language and culture of participants while admitting that all such tools will require the interpretive engagement of researchers. According to both Habermas (1984) and Carspecken (1996), this interpretive engagement must not overpower the meaning that participants bring to the research and must, in fact, privilege it. Spradley's DRS provides a mechanism for describing and articulating the language and culture of participants in a way that is anchored in their own self-expressions and experiences. Third-person, objectivating cultural perspectives need not be tethered to positivist epistemological accounts. As Habermas has argued, an objective account is part of the larger set of perspectives through which the lives of participants can be understood. Habermas's critical theory (1984) and Carspecken's critical ethnographic methods (1996) are inclusive of these perspectives without being limited to them. The intersubjective epistemology of Habermas's critical theory calls for the researcher to be involved with the objective, subjective, and normative perspectives of participants. Hence, all claims about a group that might be produced as findings are always contextualized as part of a research dialogue, which inevitably, whether implicitly or explicitly, include the researcher. The present study invokes this critical theoretical perspective as a modification to the more traditional way in which Spradley's work has been employed.

A second and related criticism is that Spradley does not adequately theorize the distinction between individual and culture, a distinction his methodology relies on. In other words, Spradley assumes that culture is manifested in the minds of individuals rather than as something external to

individuals (is mentalistic as opposed to materialistic), yet he does not, according to his critics, explain the link between these two. The mentalistic connection between the individual and the culture is just taken for granted. Giddens's (1990) theory of structuration addresses the social science problem of dichotomizing structure and agency, which is at the heart of the distinction between individual and culture. Giddens identified this as an unresolved tension in social theory. Social theorists tend to emphasize either a culture-deterministic view or an individual-autonomy view using one to explain the other. According to Giddens, social science cannot rest content on explanations that are solely derived from either the macro (cultural) or micro (individual) level. An account of human activity that perpetuates a dualism between culture (structure, in Giddens's terms) and individuals (agency in Giddens's terms) is inadequate.

Cognitive anthropologists responded to the structure-agency problem by forging a mentalistic definition of culture, which basically argued that culture existed as mental phenomena (structures) within individuals. To this way of thinking, individuals are basically a manifestation of their culture. This account of the link between individuals and culture leaves much unaddressed and has been found to be undertheorized by critics. For example, this view does not adequately explain how cultures change through critique. Giddens (1990) offered a different solution. His theory of structuration suggests that "structure [culture] enters simultaneously into the constitution of the agent [individual] and social practices, and 'exists' in the generation moments of this constitution" (p. 5). He takes up the insights from cognitive anthropology by pointing to how it is that culture can be found, in part, within the mind of the individual members, but he does not rest content with that one-sided description of culture. He further proposes that cultural stocks of knowledge which might be mentally inhabited in persons have the potential of being reflected upon and summoned in discourse. Thus, "all actors have some degree of *discursive penetration* of the social systems to whose constitution they contribute" (p. 5).

Giddens (1990) famously wrote that "structure is both the medium and the outcome of the reproduction of social practice" (p. 5). If Giddens's ideas are used to situate Spradley's DRS in a more thorough and compelling description of the relationship between the individual and culture, critical potential of the analysis is reaped where before it might have been overlooked. This is because as individuals draw on culture to express their experiences, they can also be provided with opportunities to reflect on those expressions and discursively attend to what might have heretofore been taken for granted as stocks of knowledge. Structuration theory also provides a way of thinking of the relationship between culture and the individual as recursive—mutually constitutive, which in turn gives reason to interpret the findings from DRS in a recursive manner. Our inquiry uses Giddens's theory to innovate DRS. Specifically, the study of individual conceptualizations is interpreted as a recursive expression of both individuals and culture.

A third criticism involves skepticism that an analysis of semantics is capable of providing rich enough access to the culture coupled with the concern that semantic theories of meaning are inadequate for explaining human communicative competence. "Semantic structures are instantiated through culturally distinctive uses of words and phrases whose meaning depends on relations to other categories through relations of opposition, contrast, similarity, analogy, metaphor and homology" (Carspecken, 2008, p. 743). Pragmatic structures are implicit whereas semantic structures are explicit. Pragmatic structures involve the ways in which the words are enacted. Carspecken drew on Brandom (1998) and Habermas (1984, 1987) to explain precisely how semantics are always embedded in, presuppose, and indicate pragmatic structures. Using a theory of inferentialism, Carspecken argued that the terms of a culture are always understood within their pragmatic context which is implicitly coupled with their semantics. Inferentialist theories like those of Habermas, Carspecken, and Brandom provide adequate justification for using analytic methods which afford a deep and thorough explication of the semantic practices of

a community as a window into further explicating the pragmatic aspects. Thus, the concern that semantics alone will not suffice is both acknowledged and resolved. Although we are using DRS, the present study assumes a pragmatic approach to the semantic footprints of cultural meaning.

The innovations that are explored in this paper are attempts to rescue Spradley's DRS from these three concerns. There is potential in this because Spradley's analysis provides one of the more comprehensive set of strategies for understanding the linguistic attributes of participants' lived and talked about experiences. The specific innovations involve two main shifts; namely, shifting the focus of analysis from cultures to individuals and broadening the semantic focus to include pragmatics. These innovations have both theoretical and practical complications. The innovations themselves are carried out through the conduct of two case studies and must therefore be considered, in part, through their distinct situations. Thus, in the methods section of the paper, the case studies are described separately except with respect to their parallel use of DRS. In the results section, the findings of the case studies will be presented followed by the findings related to the two methodological questions to which this paper is devoted. The discussion and limitations sections will focus entirely on the methodological issues central to this paper. Ultimately, the paper contributes to invigorating a methodological dialogue regarding the use of qualitative methods in science and mathematics education research by examining innovations in DRS. Because there are few examples in the mathematics and science education literature where analytic approaches in qualitative inquiry are interrogated, this paper benefits the literature by addressing this gap and by advancing social science conversations on qualitative analysis through mathematics and science education case studies.

## **Methods**

The two qualitative case studies presented here examine the methodological merits, limitations, and possibilities of adapting Spradley's DRS detailed ethnographic interview analysis for the purpose of articulating and understanding participant subject-specific conceptualizations. As noted earlier, the first case study is descriptive, and the researcher looks at Indian physics teachers' conceptualizations of science teaching and learning. The second study is an exploratory examination of fifth grade students' conceptualizations of zero in a mathematics class in a large southern U.S. city. In both studies the researchers use analysis elements from Spradley's DRS (domain, taxonomic, componential, and thematic) with the theoretical innovations described above. They used analytic procedures from Spradley's DRS to articulate the observable semantic structures, reconstruct the implicit pragmatic structures, and from there identify individual conceptualizations. In our cases, these analytic techniques revealed complexities in the ways in which (a) science teachers' beliefs and enactments affected their science teaching and learning and (b) fifth graders perceived the number zero.

### **Two case studies using Spradley**

The studies overlap in important ways. The foci of the studies, conceptualizations and their underlying beliefs, are not directly observable (Pajares, 1992) and must be reconstructed from what is observable. In both studies the researchers explore conceptualizations by shifting their unit of analysis from culture to the individual. Specifically, the studies used all analytic procedures from Spradley's DRS to move from the explicit semantic structures to the more implicit structures and concepts presupposed through the semantics. Following Giddens (1990), the analysis assumes a connection between the social structures and those which similarly serve as medium for individual action and understanding.

Validity for both case studies was established using standard validity techniques for qualitative research (Carspecken, 1996). Specifically, both researchers used recording devices, peer debriefing, and negative case analyses. In addition, Nargund-Joshi obtained member checks and employed a triangulated data collection strategy. The methodological details of each of the case studies are briefly described in order to provide readers with the necessary context relevant to the methodological findings.

### **Case study 1: Indian teachers' conceptualizations of science learning and teaching**

Nargund-Joshi's research questions guided her in conducting a descriptive case study: (a) What are secondary science teachers' beliefs/conceptualizations about the teaching and learning science? (b) To what extent are the teachers' beliefs/conceptualizations about teaching and learning of science consistent with their classroom instruction? Her focus was on the physics teaching/learning in one particular school in India. This school was using project-based learning, an exceptional case in Indian education.

#### *Participants and site selection*

The study took place in the western part of India in an urban school setting. The school selected for study was identified as the first day-boarding school in the city. Furthermore, teachers at the school applied a project-based learning approach. Project-based learning is an unusual approach to find in Indian schools, and thus it was suspected that the traditional cultural notions of teaching and learning in India might be in flux at this school. Both of the teachers who were responsible for physics lectures and laboratories agreed to participate in the study. They both held masters' degrees in science areas. One teacher had a bachelor's degree in education, which is equivalent to teaching teacher's license in the United States.

#### *Data collection procedures*

Across a 6-week period, the two participants were interviewed three times and observed multiple times. Informed consent was obtained from both teachers prior to classroom observations and interviews. Interviews ranged from 35 to 60 minutes and were conducted at the school site at the teacher's convenience. Interviews were audio-recorded and later transcribed verbatim. Field notes were taken during classroom video recordings and later expanded to help the researcher understand teachers' beliefs and their teaching practices. Semistructured interview protocols were used with particular attention to asking about things that came up during the observations.

### **Case study 2: Students' understanding of zero**

Lee conducted an exploratory case study of fifth grade students' conceptualizations of zero in the context of mathematics instruction. In her study she explored the following substantive questions: (a) What are students' conceptualizations of the number zero? (b) How did they come to conceptualizing it? Her focus was in the context (case) of a fifth grade mathematics class.

#### *Participants and site selection*

The participants were studied indirectly in this case research. The case comprises 16 students in a fifth grade class in the southern part of the United States whose class was videotaped as part of a larger study conducted in a mathematics class during the 2005–2006 academic year. The class was located in an ethnically diverse urban math/science magnet school. Eighty five percent of the fifth graders at this school were at or above grade level proficiency based on the state

standardized test; the state average was 92%. The school population was 2,320 students, and 66.5% of these students were labeled as economically disadvantaged.

At the beginning of the 2005–2006 school year, the fifth graders in this class scored significantly below grade level proficiency on the state-mandated standardized test. However, by the end of the year, all students in this class scored proficient or above. There were two teachers in this classroom, a veteran teacher with 25 years of teaching experience and a mathematics education researcher studying children’s mathematical reasoning. Informed consent was obtained from both teachers and the parents of the students, and assent was obtained from the student participants.

#### *Data collection/selection procedures*

Videotapes were generated in the math class throughout the 2005–2006 school year. Lee reviewed all of those videotapes and developed an interest in how students talked about zero. She returned to the tapes and identified all instances where zero was explicitly mentioned. There were 10 video clips that centered on classroom discussions about zero. The discussions ranged in time frame from 5 to 40 minutes. All footage relevant to class discussions about zero were transcribed and compiled chronologically according to their corresponding dates of instruction. These were the events analyzed.

### **Analysis and results**

In this paper we are concerned with addressing the methodological question, What are the merits, limitations, and possibilities of using an adapted version of Spradley’s (1979, 1980) DRS? A discussion of the results requires us to look at the analysis process. In some cases, our analyses are embedded within our results. Both studies used all four analytical procedures of Spradley’s DRS.

In Nargund-Joshi’s study, different domains were identified in teachers’ beliefs about science teaching and learning. Excerpts from transcripts and observation field notes were compared to participants’ statements. One domain that emerged through this analysis was “Effective science learning.” The excerpt below demonstrates how teachers view effective science learning:

The students need to have hands on experience, that does exist in aims of the school . . . we are trying to make them aware of what is going on through activities. When they are doing activities they will learn better and the “Swadhyayshakti” is about discovering for oneself and then getting the inner strength. Discovering for oneself will come when they get their own experience.

Domain analysis in Lee’s study revealed how students were conceptualizing zero as an even or odd number. Many students conceptualized zero as needing to fit into an even/odd alternating patterns and the cover term that seemed most suitable for these utterances was “Alternating pattern of even/odd.” For example, one student demonstrated his thought process:

How can it be odd if when you count from 1 and not from 0? Like 0, 1, 2, 3, 4. From 1, it’s odd, even, odd. From 0, it couldn’t just be odd, odd, even, odd. It has to be even, odd, even, odd.

Similar statements were collected, and the corresponding semantic relationship identified these utterances as attributes or characteristics of the cover term.

By transforming the analysis so that its pragmatic underpinnings are more explicit, researchers were able to reconstruct the conceptualizing as presupposed communicatively. First of all, in

Lee's case study, the conceptualizing of zero by fifth graders was an interactive, dialogic accomplishment, and the mathematics interplay over time gave rise to the conceptualizing process. In fact, the taxonomic analysis was especially powerful because it uncovered how students in this class were conceptualizing zero as they were thinking about mathematics. Some students were basing their understanding of zero as either even or odd by the patterns they envisaged across various other numbers. Some students used deductive reasoning to obtain the generalization that zero was an even number. Other students used proof by contradiction to justify why zero was an even number. Hence, taxonomic analysis displayed students engaging in experiential rationale, observational rationale, generalizability, and proof by contradiction. Individual concepts were mapped out and not treated as fixed material objects but were instead grasped through the pragmatic structures made explicit through the semantics. Furthermore, this transformation demonstrates the success of using Spradley's DRS on smaller, more focused sets of data: looking deeply into one or two people or the development of concepts, rather than having to work from an ethnographic data only.

The taxonomic analysis in Nargund-Joshi's study provided the means for understanding connections and relations between different domains and helped locate the relation between teachers' beliefs and actions. Both teachers mentioned different techniques and prerequisites for effective science learning. During classroom and lab observations as well as interviews, teachers mentioned the importance of an interactive environment for students' conceptual development. Teachers described science students' characteristics as "attentive, critical thinkers, asking questions." Teachers also mentioned instruction should be hands-on, more activities, something to show them, and learning by doing. These different attributes related to science learning and teaching can be put under the taxonomy of "effective science learning." Taxonomical analysis helped Nargund-Joshi see how teachers bring different components together to build effective science learning experience for her students.

From a practical perspective, applying the analysis to an understanding of individual conceptualizations made it possible to retain intra-individual tensions and contradictions in their conceptualizing. The findings do indicate that DRS worked well for mapping out the detailed individual conceptualizations inferred from close scrutiny of participants' semantic formulations. As can be seen particularly well with Nargund-Joshi's study, the complexities and subtleties of the teacher's individual conceptualizing is articulatable using an adapted version of Spradley's DRS. The componential analysis proved most useful for the study's substantive questions because it allowed Nargund-Joshi to locate contrasts in the way teachers expressed their beliefs about the teaching/learning process and the way they enacted that process as evidenced by interviews and observations respectively. Articulating the conceptualizations the teachers held with respect to teaching and learning was most insightfully revealed through this contrast. The contrast was mainly found between teachers' beliefs about science learning and teaching and how they actually taught in the class: though teachers believed that hands on activities are necessary to create effective science learning environment, both taught science in a lecture-driven fashion; both believed that best learning of scientific concepts happens through students doing activities or showing students something; teachers show simple demonstrations in the class mentioned in the textbook; and during laboratory sessions, students ought to perform experiments with predetermined protocols and produce known results. Hence, most of students' learning was not through a method of inquiry. Articulating the conceptualizations of teachers' beliefs about effective science learning and actual implementation in their instruction was most insightfully revealed through this contrast. Teachers' conceptualizing vividly illustrated the pragmatic complications of their work as physics teachers. There were contradictions in the way they talked and enacted their teaching, and those contradictions were evidenced through the disjuncture between pragmatic roles and the semantic descriptions they presented.

During the componential analysis in Lee’s study, the researcher found students referring to zero being even, odd, neither, or both. For example, an even number requires parity. Thus, 6 is an even number because it has two pairs of 3s. Some students referred to zero having a pair because it has two pairs of zeros, whereas others did not think zero had parity because zero was not a number. Claims that zero is an even number were compared to arguments of zero is an odd number. The componential stage of analysis became a medium through which Lee drew out misconceptions students had about zero being even/odd.

In summary, the first four strategies of DRS worked well to articulate the tacit conceptualizations implicit in the talk and action investigated through both case studies. Nargund-Joshi was able to articulate the implicit conceptualizations of science teaching by exploring the semantic expressions offered by the teachers as they described their work. These conceptualizations evidenced thematic complications which produced an unstable picture of the dual roles of transformational and traditional teaching. Figure 1 describes the process of developing one of Nargund-Joshi’s theme called Effective Science Learning, to best display how DRS was applied to the entirety of her study.

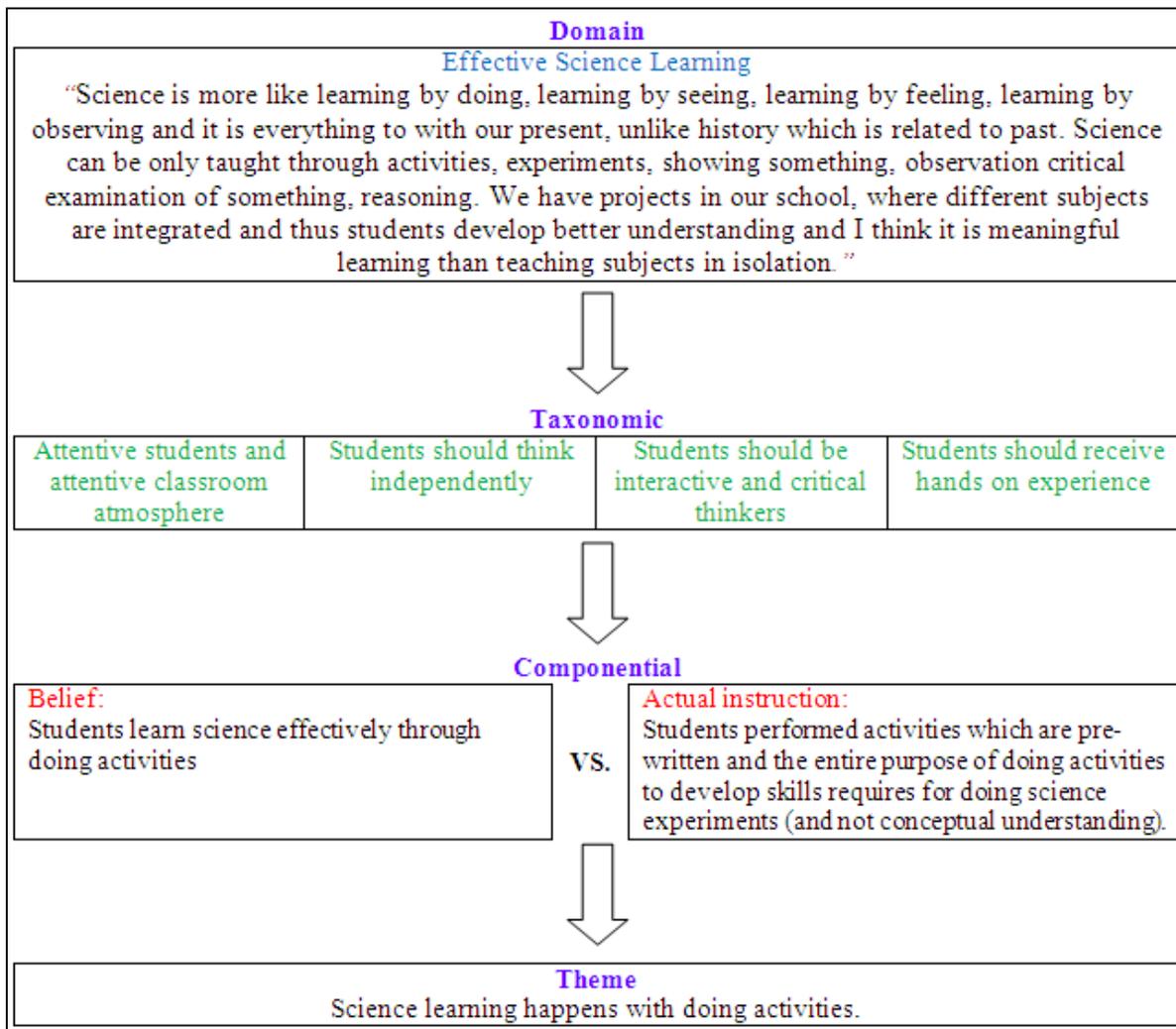


Figure 1: Case Study 1—Creation of one theme for Indian teachers’ conceptualizations of science learning and teaching

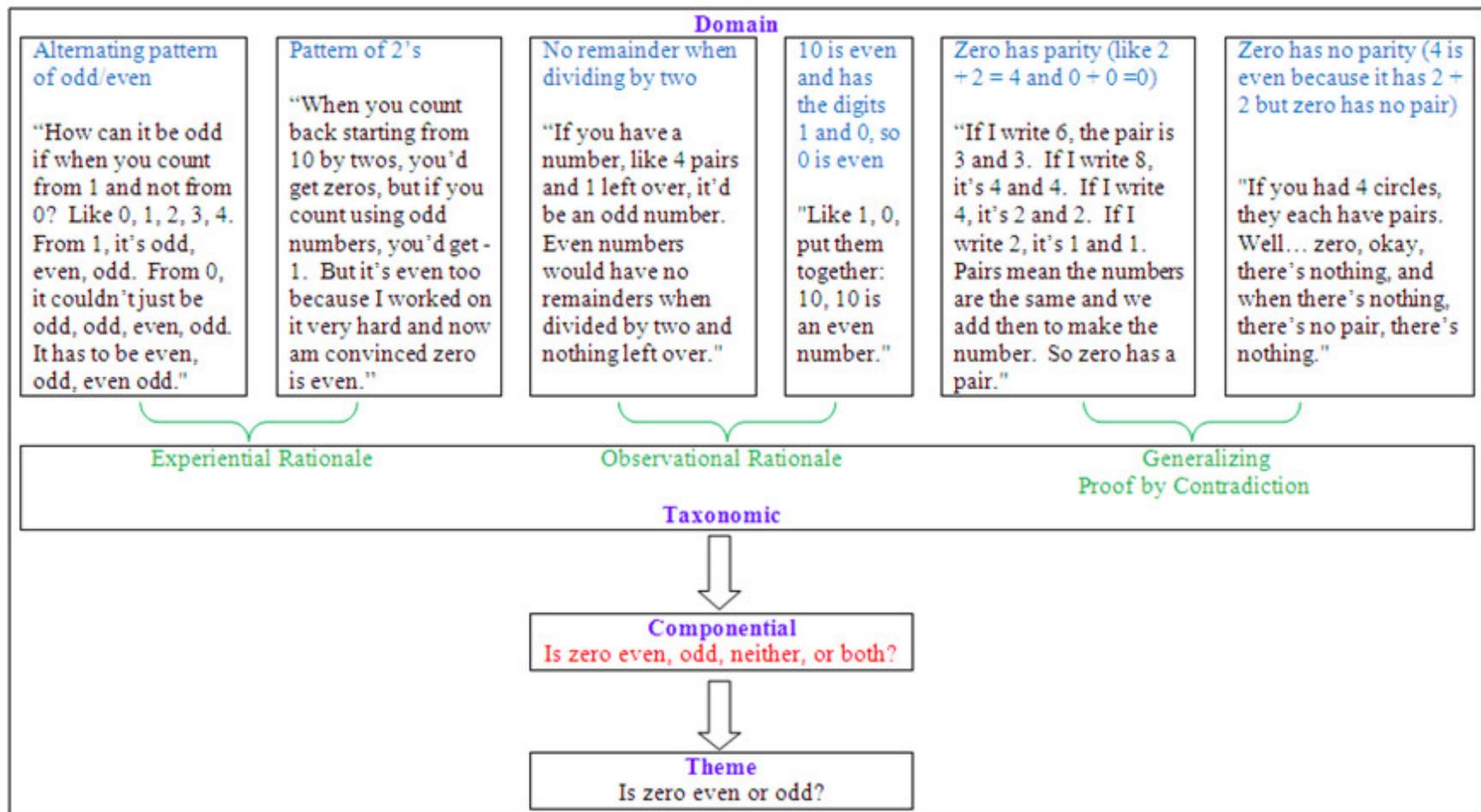


Figure 2: Case Study 2—Creation of one theme for students' understanding of zero

Likewise, Lee’s study demonstrated that even though students’ math concepts can be particularly difficult to articulate, Spradley’s analytical procedures made it possible to explicate students’ implicit conceptualizations of “zero”. Six thematic conceptualizations of “zero” were articulated. For the purpose of this paper Figure 2 describes, in depth, the process of developing one of these themes (the conceptualization of zero as a debatably even or odd number) to best display how DRS was applied to the entire study.

The approach contributes to the math and science educational research by probing deeply into the way semantic representations indicate how participants are thinking. In Table 1 we have summarized the findings from both case studies according to the analytic strategy involved.

	<i>Study 1: Indian teachers’ beliefs about science learning and teaching</i>	<i>Study 2: Students’ understanding of zero</i>
Domain analysis: A search for the larger units of cultural knowledge.	Identified domains: Capable teachers/ Ability of teachers Attributes of good science students Classroom environment Attributes of good school Definition of intelligent student Effective way of teaching science	Time constraint Work pressure Fear from higher authority Resource limitation Teaching preparation
Taxonomic analysis: A search for internal structure of domains that leads to identifying contrasting sets.	Located contrasts in and relationships between teachers’ beliefs and actions. Generated a concept map of teacher thinking.	Alternating pattern of odd/even Pattern of 2’s No remainder when dividing by two. 10 is even and has the digits 1 and 0, so 0 is even Zero has parity (like $2 + 2 = 4$ and $0 + 0 = 0$ ) Zero has no parity (4 is even because it has $2 + 2$ but zero has no pair)
Componential analysis: Process of searching for contrasts, sorting them out, grouping some together as dimensions of the contrast, and entering all this information onto a paradigm.	Best science learning happens through doing activities or showing them something. Teachers use the textbook to show simple demonstrations to the class. Students perform experiments with pre-determined protocol and produce known results in lab experiments.	Even Odd Neither even nor odd Both even and odd
Cultural themes: A search for the relationships among domains and how they are linked to the culture as a whole.	Attentive, interactive students are good in science. Role of the science teacher is facilitator. Learning happens with doing activities. Learning is essential because it is connected to our life. Continuous assessment is accomplished with testing. Teaching constrained by time and limited resources. Heavy reliance on textbooks and structured answers. Role of secondary science is to prepare for 10th grade exam. Labs and lectures are not synchronized.	Even or odd Place value holder Algebraic equations of zero As a number Starting point in measurement Dividing positives from negatives

Table 1: Case study substantive findings. The highlighted boxes were the most powerful analytic instruments for each study.

### **Limitations**

In this paper we have reported on an exploratory inquiry into the use of Spradley's DRS through two case studies whose interests were in individual conceptualizations. Limitations and implications for future research can be articulated. Several limitations must be claimed. Firstly, it was a very labor intensive process. Other methods might prove just as effective without the practical or theoretical labor. More ought to be done to determine this. Moreover, conducting DRS is a lengthy and time-consuming process. The analytic method does not easily mark its own end; in other words, it is difficult to know when to stop analyzing the data. Second, the analysis was limited to only four DRS strategies. DRS consists of 10 steps, the first six steps being data collection and the later four steps being analytical tools. In this paper, we have discussed the advantages of using only four analytical tools rather than the entire DRS. Third, the innovations to Spradley's DRS employed here might not meet with his approval. For example, DRS was used at the micro-level rather than at the macro-level as Spradley had intended. As with all case studies, there are no grounds for generalizing to other populations, but this was not part of the scope of the inquiry. Instead, the paper purports to address methodological questions through example. Nevertheless, more examples would be needed to demonstrate the merits and limitations of the proposed innovations.

### **Discussion: Reflection and future research**

In this paper we have explored how modifications of Spradley's DRS benefited two case studies. Using analytical steps of DRS helped unearth science teachers' beliefs about teaching and learning and students' conceptions of the number zero. All four steps of analysis aided in reaching themes, but taxonomic and componential analyses were particularly powerful tools for these two case studies. These two analyses helped researchers see internal connections within domains and ultimately understand teachers' tacit beliefs and students' engagement in mathematics. Nargund-Joshi aimed to compare teachers' expressed beliefs and which beliefs actually become expressed in their teaching. To understand this critical point, componential analysis was very helpful. Lee's goal was to seek students' conceptualization of the number zero and how it came about. Taxonomic analysis helped uncover the ways in which students were justifying why zero was even or odd. Beliefs and concepts can be inferred through individuals' actions and words. Spradley's analytical tools helped to develop an understanding of teachers' beliefs and students' conception of zero. Although the analytical steps of DRS are very powerful tools to understanding deep conceptualizations of participants, the entire process is not entirely data driven. Domains are put into taxonomies by the researcher, and though analytical steps are time consuming, one must keep in mind one's research questions to decide how and where to stop data analysis.

The innovations provide answers to the criticisms of traditional DRS. It was innovative to apply Spradley's ethnographic methods to an understanding of individuals because DRS was originally intended to produce findings about the macro-culture. It was found that the same techniques that work to articulate tacit assumptions of a culture do so, in large part, because those assumptions are made transparent across individuals. It was possible to apply analogous procedures to examine intra-individual thoughts: the tacit conceptualizations underlying individual talk and action. Moreover, the interactive nature of semantics was made visible through the analysis as it moved from explicit semantics to implicit pragmatic relations. The relations assessed through DRS are understandable only on pragmatic terms. This made it possible to locate the process in a broader theory of communication. These results counter contemporary criticisms of DRS and suggest its viability for studies of conceptualization.

More important, our findings suggest that a transformed DRS makes contributions not only to the methodological literature but to the substantive literature as well. Methodologically, the findings provide alternative responses to the criticisms of DRS. The methodological findings also contribute to the methodological critique of traditional distinctions between culture/person and semantics/pragmatics. The paucity of literature on methodological innovations, in general, and this specific way of innovating, in particular, indicates a place for the kind of dialogue our paper might inspire.

It would be good to engage in future research with additional case studies or small scale micro-level studies to test out the validity of the innovative applications. Continued interest in conceptualizations might be explored across the full range of analytic strategies available in Spradley's DRS. Similarly, it would be important to pursue the theoretical underpinnings which make the methodological innovations sensible. Lastly, and perhaps most importantly, future research needs to inspire critical, methodological dialogue for qualitative researchers working in mathematics and science education scholarship—raising questions, augmenting theory, and problematizing taken-for-granted assumptions about inquiry in math and science education research.

The theoretical explanation for the individual-culture link appears to hold from our data. Further analysis of the cultural maps with respect to the topics at hand would bear this out more completely. Thus, it would be recommended that future studies include embedded case studies within the same cultural milieu in order to more directly explore this connection. Structural elements of the conceptual apparatuses embedded in semantics of a shared cultural milieu (as evidenced through Lee's study) revealed the mathematical reasoning of individuals, but in the context of a micro-cultural classroom space. The interactive nature of the conceptual webs stands at the analytic nexus between individual and culture. Getting at this, again, without having to do it ethnographically is a benefit. Our study indicates that various types of data, perhaps data situated outside of mathematics and science education could be analyzed using Spradley's DRS.

### Notes

1. Unless otherwise specified, references are to Spradley (1979, 1980).

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