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Inside the Black Box: Revealing the Process in Applying a Grounded Theory Analysis

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Qualitative research methods have long set an example of rich description, in which data and researchers' hermeneutics work together to inform readers of findings in specific contexts. Among published works, insight into the analytical process is most often represented in the form of methodological propositions or research results. This paper presents a third type of qualitative report, one in which the researcher's process of coding, finding themes, and arriving at findings is the focus. Grounded theory analysis methods were applied to the interpretation of a single interview. The resulting document provides a narrative of the process one researcher followed when attempting to apply recommended methodological procedures to a single interview, providing a peek inside the black box of analysis often left unopened in final reports. Key Words: Analysis, Grounded Theory, Process, Methods, Data Representation, Teaching.

As I have taught courses on qualitative inquiry, I often use two kinds of texts to teach analytical methodology: (a) original writings proposing new methods, and (b) studies that utilize those methods. The former helps me to explain the rationale and philosophy behind the methods, and the latter helps students to see the results of using a particular approach. My experience has demonstrated that most of these latter studies deservedly focus on context, findings, and discussion. Though researchers seem to agree on the importance of getting the methods *right* in a study (Berg, 2007; Denzin & Lincoln, 2005; Merriam, 1998; Patton, 2002), application of qualitative analytical methods seldom receive the type of attention in published articles that one might give in a traditional dissertation. Original papers proposing methods certainly give this sort of attention to detail of process, but such manuscripts are necessarily devoid of the rich context present in a research study, making it difficult to see the situational constraints and considerations of implementing a specific analysis. Yet, the problem, as Tracy (2010) recently pointed out, "research on learning...demonstrates that novices and advanced beginners in any craft...rely heavily on rule-based structures to learn" (p. 838). The purpose of this paper is to demonstrate how to conduct a specific qualitative analysis in the context of a single study. Specifically, this article focuses on a generic grounded theory analysis, as outlined by Glaser and Strauss (1967), Strauss and Corbin (1990), and Charmaz (2002).

The data collected for this study were not originally intended to be used in a grounded theory analysis. A critical eye will quickly reveal that there are problems with such an approach. First, because of the way qualitative data are often collected, the analytical method used actually influences data collection. Thus, applying an analysis post-hoc may violate epistemological and methodological assumptions. Second, as rich as the data may be, they may be insufficient for satisfying the concerns or recommendations of a particular approach, such as Spradley's (1980), which requires researchers to return to the studied environment after initial analysis and ask clarifying questions of participants. Despite these valid concerns, my students have found it useful to be able to see how a particular analytical approach is carried out within the specific context of a study. It is equally beneficial to reveal the oft-hidden thinking behind one's analytical procedures.

The significance of this paper is in shifting the focus on providing rich data explaining how I applied recommended procedures in the context of a study through a grounded theoretical analysis, rather than the implications of the study itself (though I personally think the implications of the example study are intriguing, too). I first provide a brief discussion of grounded theory and its theoretical and methodological considerations. Based in this literature, I then present the step-by-step process I conducted to use grounded theory in analyzing a single interview. This analysis is followed by a discussion of the findings and how I refined them. Finally, the article concludes with personal insights and concerns over using a grounded theoretical approach to data analysis.

To better understand grounded theory, the following section briefly discusses its roots and theoretical assumptions. This is followed by practical recommendations for analytic procedures.

Grounded Theory

> "Theory must fit the situation being researched, and work when put into use."
>
> (Glaser & Strauss, 1967, p. 3)

Glaser and Strauss (1967) invented *grounded theory* a theoretical approach that systematically bases itself on the empirical world in order to find emerging theories that can then be applied for interpretation. This does not mean that grounded theory is to be used for testing theories. It seeks to explain and predict what is taking place (Dey, 1999). At the time of its conception, this set grounded theory apart from other qualitative approaches in that its goal was not merely to describe. Rather, grounded theory seeks to literally ground the research in the data in a way that any theory produced is readily verifiable. Thus, grounded theory is often seen as a favorable alternative for those who want to get close to the data and yet remain objective and apart at the same time (Patton, 2002).

Different theorists outline specific procedures for researchers to pass through to ensure that the theory emerges from the data and not from preconceived notions or an *a priori* framework (Strauss & Corbin, 1990). This study relied most heavily on those proposed by Strauss and Corbin (1990, 1998) and Charmaz (2002). Accordingly, grounded theory begins at ground zero. Charmaz (2002) proposes that, "researchers cannot know exactly what the most significant social and social psychological processes are" (pp. 675-676). Because of this, many grounded theorists believe that it is distracting and possibly harmful to conduct extensive reviews of the literature before beginning to collect and analyze data. Analyses of the data are not a confirmation of prior literature, but rather, "an interplay between the researcher and the data" (Strauss & Corbin, 1998, p. 13). This idea of interplay is an important aspect of grounded theory, as manifest by the concept of *theoretical sampling* (Glaser & Strauss, 1967), the idea that researchers choose participants who meet increasingly specific criteria as research evolves. Analysis and data collection occur simultaneously and coordinate one with the other.

Concepts are the building blocks of grounded theory. Researchers look for phenomena, "central ideas in the data represented as concepts" (Dey, 1999, p. 101) that answer the question, *what is going on here* (Charmaz, 2002)? They do this by analyzing the processes that make up key events in a contextualized experience. The result is a substantive theory (Glaser & Strauss, 1967), a theory applicable to more than just a crowd of a few, but not so grand that it can be applied independent of a specific and similar context. This leads to the realization that, grounded though the theory might be, all grounded theories are "provisional and contingent, never complete" (Pidgeon & Henwood, 1995, p. 638). Grounded theorists constantly recognize that conceptual categorization requires creativity (Patton, 2002). Therefore, while the substantive theories generated are applicable to a specific and real life context, one must always bear in mind that they are an abstraction of reality. Like a copy made from a copy machine, it resembles the real world, but may not be a perfect reproduction. Each copy produces the same picture, but may be missing different elements. However, the unmistakable picture of what is happening is apparent across all the copies.

Methodological Considerations—Constantly Comparing

Grounded theory takes researchers through a series of steps that leaves them constantly comparing data with other data and the emerging concepts. Strauss and Corbin (1990) refer to the first stage of analysis as open coding. Coding is open because "to uncover, name, and develop concepts, we must open up the text and expose the thoughts, ideas, and meanings contained therein" (p. 102). The idea of open coding is once again tied to the notion of grounded-ness, of letting concepts emerge from the data instead of force-fitting the data to an *a priori* theory. Strauss and Corbin suggest different levels of open coding, but recommend the most arduous for beginners, so they can create a habit of describing what they see while staying close to the data. Open coding can be conducted line by line, by statement, or by entire section. There are important questions to ask about the codes one generates even at this level, though. Mainly, *what is going on here* (Charmaz, 2002)? Strauss and Corbin note that by asking this and other sensitizing questions, researchers can bring out the implicit distinctions that cause people to name something one way or the other. They give the example of a researcher grouping kites, birds and planes as things that fly. While classifying all of these as things that fly (an explicit distinction), it is important to note that the implicit feature, or property, that makes them all fit into this category is the action taken with regards to the classified object. While Strauss and Corbin only point at the implicit nature of action occurring at the property level, Charmaz recommends that researchers initially code their data using action verbs. She gives examples such as, "meeting resistance, trying to establish entitlement, recounting the events, learning the facts, etc." (p. 685).

Memoing. True to the notion that analysis is an evolving process, a researcher should not wait until after all the data are initially coded to begin noting interesting discrepancies, concepts, or anomalies. Indeed, one of the most useful (for me) strategies employed in the grounded theory methodology is the use of *memos*. Memos are unconstrained musings on what is happening. Unlike categories, they are not limited to thinking about one thing or another, but are textual representations of the questions researchers begin to ask themselves as they analyze the data (Pidgeon & Henwood, 1995). Memos may be used to elaborate on concepts, vocabulary, *in vivo* codes (i.e., "catch phrases" embedded in the data), or connections among concepts. Failure to write a memo, or at least jot down emerging ideas, may cause a researcher to lose an idea, or an idea to lose its shine by being poorly elaborated on later due to the lackluster quality of human memory (Miller, 1956). Thus, as systematic as grounded theory is, it is important to remember that it is not a lock-step research methodology in which a researcher can only move on to the next stage after successfully completing a prior one. Interestingly, Pidgeon and Henwood (1995) suggest that "conducting memoing and open coding as parallel cognitive operations allows sensitivities to existing literature and theory to be combined with a commitment to grounding in data" (p. 638). In fact, memoing is a process that should parallel all other grounded theory methods throughout the process. Pidgeon and Henwood further recommend that the final analysis is nothing more than an elaboration of refined memos throughout the entire process.

Classification. Following initial open coding stages is the process of classifying concepts. Strauss and Corbin (1990) point out that this is as much a matter of management as anything else. Through classifying differing and similar concepts, categories are formed and a researcher can further his/her own understanding of the concepts involved. Nonetheless, the authors point out that, "the nature or essence of an object does not reside mysteriously within the object itself but is dependent upon how it is defined" (Strauss & Corbin, 1990, p. 104). For example, in the case of post-programmatic experiences of professional development (the context of the present study), I might label the Internet as a resource for teaching, whereas, for a commercial company, the Internet might be considered a venue for propaganda. Although this seemingly arbitrary difference might initially cause one to discredit its validity, the difference actually serves to validate the idea of groundedness in generating a substantive theory grounded in contextualized, empirical situations. This speaks to the side of the grounded theory that allows, or even obligates, the researcher to get down and dirty with the data. Without such familiarity, one cannot have the closeness required to open the data up (Strauss & Corbin, 1990), find the sensitizing concepts (Charmaz, 2002), and conduct the theoretical sampling (Glaser & Strauss, 1967) necessary to reach saturation (Pidgeon & Henwood, 1995).

Categorization, properties, and dimensions. After continuously comparing data, one is led to *categorization* (Strauss & Corbin, 1990), the process of grouping classifications. Due to the fact that categorization is a step in almost all qualitative analytical methods, it is perhaps best to focus on how grounded theorists verify and microanalyze their categories and subcategories through properties and dimensions. Once a researcher has identified important categories, it is important that s/he distinguish these by actually defining the *properties* (p. 123) of that category by answering questions such as, "what are the characteristics of items that fit that categorization?" Or, "what attributes are specific to this one concept?" While properties answer such descriptive questions, *dimensions* (p. 69) answer questions about the variance of such properties. For example, if pedagogy were a category for this study, a property of pedagogy might be "Use," defined as "the specific manner in which technology is used or integrated into the classroom." The dimensions of this category might be the extent to which technology is integrated or, in the subcategory of teacher-student interaction, the level of collaboration among instructor and pupil. Thus, dimensions measure, whereas properties describe.

Following this process, Strauss and Corbin (1990) recommend that researchers engage in what they term "Axial coding" (p. 96). This involves comparing the generated categories and concepts along several dimensions germane to most situations. These are (a) causal and intervening conditions, (b) context, (c) the phenomenon of interest, (d) action strategies, and (e) consequences. Strauss and Corbin argue that comparing concepts along these dimensions enables the researcher to identify key patterns and features of the concepts, further solidifying their understanding of these. Axial coding, however, has been one of the most contentious aspects of Grounded Theory analyses and may have been one of the key contributing factors to a rift between Glaser and Strauss. Charmaz (2006) explains that the reason many grounded theorists do not use axial coding is due to the fact that this type of coding to many researchers appears to be a rigid *a priori* framework, which seems to contradict the emergent nature of conducting an analysis grounded in the data. In this paper, I chose to adhere to Charmaz's conception and allow emergent themes to appear without the strict use of Strauss and Corbin's axial framework.

Finding patterns. However important and useful concepts of properties and dimensions may be, research best comes to fruition when the researcher finds the patterns created between them. "Patterns are formed when groups of properties align themselves along various dimensions" (Strauss & Corbin, 1990, p. 117). Pidgeon and Henwood remark that beginning researchers are adequately adept at making classifications, creating categories, pointing out properties and even delineating dimensions, but lament that where most novice researchers break down is in discovering the interplay among these. They lament this loss because the underlying connections form the base for finally generating a theory. Luckily, there are mechanisms to help researchers overcome this barrier and practice making connections. This can be done through the use of models (Strauss & Corbin, 1998), or a conditional matrix (Strauss & Corbin, 1990). Dey (1999) contends that "diagrammatic displays are not just a way of decorating our conclusions, they also provide a way of reaching them" (p. 192). Diagramming is not unique to grounded theory, but a general practice helpful to researchers, qualitative or quantitative. First, it offers a way to condense what are possibly pages of explanation into a simple figure. Second, if researchers cannot diagram an idea, there is a good chance they have not fully developed the connections among ideas in the first place. Thus, diagramming is the core process of microanalysis. It arises from and is followed by the interplay between the data and the researcher (Glaser & Strauss, 1967).

Grounded Theory Analysis of a Post-Professional Development Experience

To better understand the present context of the example study, it may help the reader to know my own relationship to the participants, context, and purpose of the study. I participated in a year-long professional development experience as one of several professional developers to help elementary school teachers learn to integrate technology and investigative approaches in mathematics. I spent time helping to both develop and to support teacher training. The professional development experience began with a week-long training during the summer, followed by once-a-month 60-minute workshops after school throughout the school year. In addition, I spent two to three days per week in the school for up to four hours at a time as on-call support to both plan and co-teach technology-integrated lessons with participants. The year following this professional development, I was curious as to which practices, if any, persisted from our training and factors helping or hindering the continuance of such practices. I then designed a study to interview teachers who adopted PD practices during training, as they were the most likely to have continued integrating technology in their mathematics lessons.

First, a word of caution: though I may have utilized grounded theory methods and procedures to code and analyze this interview, this was *not* a grounded theoretical study in the strictest sense. Due to the constraints of the study at the time, interviews were designed as an attempt to get time- and context-specific descriptions of activities from participants in such a way that I could recreate their activities without the use of archival and observational data. The result may not have been the most apropos to the grounded theory process. However, by conducting this analysis, I have seen the benefit of conducting a similar study, so that I might use theoretical sampling to flesh out the mini-frameworks (Strauss & Corbin, 1998) that have arisen out of initial analysis. Furthermore, for the purposes and constraints of elaborating richly on my analysis, this manuscript focuses on the interview from a single participant. The sample code snippets I include are also usually the initial and not the refined codes and memos I created later in my analysis, perhaps appearing to be less well-thought out than a final memo or coding set might appear. Due to these constraints, any theory generated is going to be rather specific and questionable regarding its transferability (Lincoln & Guba, 1985).

Context

While the focus of this paper is on the procedures used to analyze the data, the purpose of this paper is to demonstrate how to conduct a specific qualitative analysis in the context of a single study. I now present that context to help the reader understand my purpose for choosing certain descriptions or codes over others.

As the intent of grounded theory is to generate a theory, purpose statements in grounded theoretical studies tend to be expressed in terms of providing descriptions of possible relationships that possibly govern interactions in the studied context. A purpose statement for my example study is: The purpose of this grounded theory study was to identify a theory that describes how the original goals of a technology-integration in mathematics professional development program were sustained among individual participants following the program's completion.

Two different schools (K-2, 3-5) participated in a year-long professional development experience to learn how to use technology and a hands-on approach to mathematics. Specifically, I investigated the perceived factors that influenced participants' perceptions and use of technology and investigative approaches to mathematics once the professional development had ended. The question addressed by this study was, "how were original goals of a professional development program that was focused on integrating technology in mathematics sustained among individual participants after the program's completion?"

Specific questions I asked participants focused on (a) their perceptions of their own technology use in the classroom, (b) their increased or decreased level of technology use since completing the professional development, and (c) inhibiting or enabling circumstances that may have influenced these increases or decreases in technology use.

Participants

Teaching does not necessarily guarantee learning. Therefore, I theoretically sampled for participants who showed programmatic adoption *during* professional development, as they would be the most likely to continue implementing ideas promoted during professional development beyond the experience. To determine suitable candidates, I gathered archival records of the initial participants, including interviews, surveys, lesson plans, and lesson reflections developed for and during professional development. I then compiled a list of five potential teachers to contact. I contacted all five teachers via email with a description of the study and the Institutional Review Board approval case number, and asked whether they would be interested in participating in a face-to-face interview at their school. Of these original five, four agreed to interviews. Participants signed a consent form prior to beginning the interview, and I informed them that I could stop the tape recording at any time should they so desire, or strike anything questionable from the record. I took notes during the interview on a pad of paper and transcribed the audio recordings within three weeks of each interview. This manuscript focuses on the interview of a single, 5th-grade mathematics teacher, Mrs. Black (a pseudonym). While the study involved the analysis of the experience of three other teachers, the intent of this paper is to demonstrate the detailed process of conducting a grounded theory analysis on a set of data. Due to size constraints, it would not be possible to show this level of detail with all participants. Thus, the focus of the paper necessarily limits the scope of the analysis.

Mrs. Black was a Caucasian female in her early 40s and had taught for 14 total years. Hers was a diverse teaching portfolio. She first taught sixth grade for six years in a different county, then moved to a private school. After five years, three at that school and two at another private school, she moved to Rory County Elementary School (RCES, grades 3-5), a pseudonym, where she had been a fifth grade teacher for three years at the time of the interview.

Data Collection

I used a semi-structured interview protocol to address three areas: investigations in mathematics, technology integration, and professional support. The interview lasted roughly one hour. It was audio recorded and I subsequently transcribed the interview within three weeks of the initial interview. Mrs. Black was interviewed in her own classroom after school. Because I had been one of the support staff for her professional development experience, we were familiar with each other prior to the interview.

I analyzed the interview using an open coding scheme, based on Glaser and Strauss' (1967) framework for codes, properties, and dimensions, as recommended above. The remainder of this paper focuses on my specific analysis of Mrs. Black's interview using this framework.

Analysis

I first coded the data from Mrs. Black's transcript using a *line-by-line* action word concept, as modeled by Charmaz (2002). I utilized Charmaz's grounded theory approach, because her action-oriented coding examples were clearly stated. In addition, an action-verb approach appealed to me as an instructional designer (who learned to use such descriptions when writing learning objectives), and I felt it was an approach I would be able to follow easily. Due to my training as an instructional designer, I avoided general action verbs such as use, understand, know, etc. According to Gagné, Briggs, and Wager (1992) such words are not specific enough and can usually be replaced by the action they are describing. Pidgeon and Henwood (1995) note that line-by-line coding is a great practice for beginners because of its generative nature. Lines, however, are a completely arbitrary distinction, as the number of the lines depends on the width of the space they are placed in and relates in no way to the stated content. Instead, I attempted to code every statement (i.e., distinct ideas in the flow of conversation), which is a unit of meaning to the participant. In some statements, I was able to code every line, as evidenced by the last few lines in statement 30 of Figure 1, where I felt several distinct ideas were present. In others instances, I felt the entire statement reflected a single action (see statement 34 in Figure 1). In cases where I felt no new actions occurred, I simply did not code that portion (see statements 31-33 in Figure 1). I used Microsoft Word to line up the codes in the margins and highlighted the part of the statement being described by the action code (See Figure 1).

Figure 1. Coded Segment of the Participant's Interview, Showing Initial Action Codes

Original Transcript	Action Codes
30. T: I did it in my classroom total group, with the LCD projector. I hooked it up to the Internet and we went as a group to the Illuminations website. And, at the time, I think we were doing decimals. I think it was decimals. And, there is a place that you can go on the Illuminations site, under the Tools, teacher's tools. And it's on fractions and decimals and how they are equal. It shows like a pie and then it gives you the decimal amount, the fraction amount, and we just played with that some. And I showed them how decimals are equivalent to fractions. And it was done total group so they could all see. Well after we finished that then I just took them through the Illuminations website and showed them some different things, like the fraction tool, um, the Factor game, and they, a lot of them have used the Factor game, played against each other.	30."Internetting" with Illuminations as a whole class lesson /modeling technology 30. modeling math concepts w/ technology 30. involving the whole class 30.modeling the software 30. students collaborating
31. P: Now, you say a lot of them have used that…	
32. T: (interrupting) in the computer lab	
33. P: That, that, the way that you said that. Is that their choice to use it, or is that something that you asked them to do?	
34. T: Actually, I had not told them exactly which games they can use. When we go the computer lab now, unless we are using a certain software, they can go the Illuminations website and choose one of several things that we've gone over in class. A lot of them choose to do the Fraction game, where	34. Students choosing their own games ("free choice")

When I completed this initial coding scheme following Charmaz's (2002) action-wording recommendations on the entire interview, I wrote a memo on emerging themes that I had not expected to see, such as the importance of certain personality traits in the teacher (See Figure 2). I began to wonder whether these traits were not fostered by her professional development experiences. My memoing and musing on this question played an important role in later analyzing the data, the results and implications of which will be discussed in my findings section. What is important to note is the simultaneously generative and refining nature of memos (Richardson, 2003). By writing the memo, I began to link different passages together (indicated by the number of the statement in the original passage in parentheses). Returning to the memo later revealed that I had categorized these related ideas under the same concepts. Because I used memoing as a generative analytical process as part of open coding, I also later coded portions of my memos to help me identify emerging themes (See Figure 2). Furthermore, this first memo ended up being an outpouring of many different types of memos, from theoretical to analytical to conceptual connection memos (Punch, 1998) (I learned later that it is more useful to separate the different types of memos, instead of mixing everything together). This set the stage for developing further thinking, and I realized how important it was to conduct memoing in tandem with my analysis (Pidgeon & Henwood,1995).

Figure 2. First Memo, Written After Initially Coding the Entire Interview

Memo #1	Code
What *did* stick out to me in this first pass through the data was teacher's role in going out finding and testing her own resources. She mentions at the end of the interview that this is the kind of person she is ("I am the type of person that if the need comes along I will find the resource"). I am curious, then, as to the importance of an individual teacher's personality. Can this willingness to search for additional resources be fostered through professional development or is it a fixed personality trait? I tend to think that it can be fostered because she mentions a number of times that she would not have used the technology as she does now in her previous jobs (90).	Teacher's role influenced by personality ("type of person" [in vivo])
Does this suggest that a way to get teachers to begin using technology is to expose them to technology training over a long period of time? Also, her experiences came from three different PD series. If PD can foster an "I'll find the resource I need" attitude, are they more (or most) effective if they are different experiences?	Expose teachers to technology over time
Something else that might suggest this attitude can be fostered is the fact that the participant complained about having to evaluate software, claiming that if it were a worthwhile item, she would do so on her own time (250).	Complaining about evaluating software
She had to learn how to evaluate software in at least two of the three technology programs she participated in. Does this suggest that PD seminars can foster the ability and disposition to identify and evaluate potential resources? This was an important part of the TIM program.	Would evaluate on own time.

After writing a few memos, I returned to my dataset and ensured that the codes matched the data by asking questions and comparing codes. Was what I termed "Interneting" at the beginning of the dataset the same as "Finding Resources" at the end of the dataset (See Figure 1)? Or, was "Interneting" more like "Allowing the Students to Explore" that I defined in the middle? I also asked myself whether two codes termed the same were really addressing the same issue by analyzing the text they each represented. I found myself writing memos throughout the process (Richardson, 2003) as I noted distinctions and anomalies among classifications.

I began the process of categorization by first ensuring that every code had its corresponding statement number. I then compiled all the statements in a different file and categorized them without looking at the data. I did this because I reasoned that if I could successfully compare and compile the classifications into distinct categories without their textual representations, I had met the condition of fit (Glaser & Strauss, 1967). In grounded theory, "fit" is the extent to which concepts fit with the incidents they are describing. I attempted to make this an emic (Headland, Pike, & Harris, 1990) process by using participants' own words whenever possible. I denoted such coding by using the phrase "[in vivo]" whenever such a code occurred (see Figure 2). I began to ask questions such as "what is this saying?" How is this concept like another concept? How is it different? And so the categorization proceeded. Once I had compiled all the codes into categories, I again referenced their corresponding original text and assured myself that the category labels either were or were not related to the codes I had placed them with. There were some codes that were seemingly the same as others in the category by name, but which proved to be an excellent fit for inclusion in another category. This process was peppered with memo-writing as to the interesting differences and similarities between and among certain concepts, mostly staying at the conceptual connection level (Punch, 1998). I hoped that by separating the codes from the text and then reconnecting and re-comparing them, I would neither focus too heavily on either a subset of the data or my personal analysis. Strauss & Corbin (1998) explain how they best categorize different codes:

> We are not saying that we place our interpretation [solely] on the data or that we do not let the interpretations emerge. Rather, we are saying that we recognize the human element in analysis and the potential for possible distortion of meaning. That is why we feel it is important that the analyst validate his or her interpretations through constantly comparing one piece of data to another. (p. 137)

I hoped that by comparing my interpretations on differing levels (data to data, code to data, code to code, data to code) that I would enable both the creative (Patton, 2002) and the grounded (Glaser & Strauss, 1967) elements to emerge from the process.

I next went through each of the core categories (Strauss & Corbin, 1990) (after writing several more memos, of course) and created a table to define the properties of each category, including an example embodying the properties statement (see Table 1). I first labeled each category and then provided a clear definition for what I would include in that category. To provide further evidence, I then included one to two key statements that I felt best embodied that category. These acted as the key prototype to which I compared other codes.

Table 1. Properties of Major Categories
(Properties are used as defined by Strauss & Corbin, 1990, pp. 103-104)

Classification	Properties	Example
Personal Information	Demographic or self-defined attributes about the participant.	(258) "I am the type of person that if the need comes along I will find the resource"
Reasons NOT to use technology in the classroom	Intangible causes identified by the participant as justification for not using technology in the classroom.	(132) I tried to use it a few times, but I never did go back to it. I mean, it's on all of my computers. Some of the kids have toyed with it, but we never did really use it in a lesson
Outside PD influences on technology use in the classroom	Professional experiences with technology training that caused the participant to do things encouraged by TIM.	(92) Well I was right out of In-Tech at then end of the year and I think we started TIM
Difficulty of use (as opposed to ease of use)	Specific problems mentioned with technology/activity that made it too difficult to use in the classroom.	(216) But I made it hard on myself. If I had done it in a, a low, a lower key, easier, easier to manage thing. I don't know if I'll ever do that again;

Interaction with colleagues	Exchanges with co-workers that lead to or take away from incorporating PD principles into practice.	(187) if they know that I use certain software, they'll come and ask me, 'how did you get into it? How did you use it?'
"Finding things I need" (finding resources and generating ideas)	Processes the participant engages in to encounter useful teaching resources and generate ideas for lessons.	(98) I learned how to go to Illuminations and find things that I need, um, I've learned to go to Google and type in, you know, 'two digit division' (laughs) and find stuff that I need.
Qualities of technology I use	Desirable characteristics of technology that make it most likely to be used by the participant.	(116) Well, like whenever you go to get your gas. You know, that pattern always changes, of how to link those things together. And I've found, and I was playing on Math for Real World Monday. I found, that even though you do that stuff over and over, it's al, it's still hard. I mean, I have a hard time, like, whenever you do to the little restaurant and you have to get your food. It took me forever to match those prices to those little trays. So it's still a challenge no matter how many times you do it.
Ways of teaching with technology (pedagogy)	The specific manner in which technology is used or integrated into the classroom.	(30) And I showed them how decimals are equivalent to fractions. And it was done total group so they could all see. Well after we finished that then I just took them through the Illuminations website and showed them some different things
Shortages	Justification for not using technology tools in teaching due to a lack of something.	(90) Well, for one thing we only had two computers. We did have a computer lab, but I really didn't know what to do with it. We, we did not have a whole lot of software.
Effect of technology on students	Descriptions of student activity, knowledge, or perception being altered due to interaction with technology.	(152) When I see the light come on in their head and they sit there with that math essentials and they can fill in every box and every square, and click the Enter button and they've got all of it right. and then they come back to the classroom and they get their paper out and their textbook and they're writing down and they, 'oh, yeah, I remember this because of the computer lab. I saw this in the computer lab. You have to carry the one here' or I mean, they're linking what they're doing down there back to what they're doing in class.

I then began the process of grouping like phenomena within each category. Interestingly, even at this stage, I found that some of my categorizations still misrepresented the category and were a better fit somewhere else. For example, the category "difficulty of use" seemed too similar to statements included in the category, "Reasons not to or to stop using technology." The dimensions of difficulty indicated that it was more likely a sub-category of "Reasons not to or to stop using technology than its own category. It was at this point, while I looked for properties within each of the categories, that I eliminated some categories entirely. However, the distinction that caused me to eliminate this category only occurred after I identified properties *and* dimensions in two other categories ("shortages" and "reasons NOT to use technology").

Then, the fun began. As I grouped the different subcategories of each major category, I tried to think in terms of dimensions. If a sub-category could not be measured on the same scale as a sister sub-category, then I interpreted it as a distinction of property and not dimensionality. This is akin to the approach in linguistics of determining whether something is an allophone or a phoneme. An allophone is the more specific of the two, yet changing the allophone does not change the meaning of the word. For example, adults understand a child who pronounces “that” as “tat” because one is an allophone of the other, which is a phoneme (from this information, one cannot tell which is which, though. Curiously, one must constantly compare such cases against other cases to figure out which is the dominant structure). Now, if a child were to make a similar replacement, say “sh” for “s,” he could get in very real trouble when he tells his parents he is going to go sit on the rug (an example taken from observations in my mother’s pre-school). I found myself thinking along these linguistic lines as I tried to separate property from dimension (see Table 2).

Table 2. Reasons NOT to use Technology in the Classroom

Label	Sub-Category	Property	Dimension
56. Students “[maxing out]” on software 58. Students finishing the software 78. Experimenting w. software 132. Not using software because of difficulty in understanding how to use it 134. Not using software to its fullest (potential)	Cognitive Development (tried and succeeded) Tried and failed Lack of understanding (memo: does this overlap w/ shortages?)	Things that affect the mind. Deals with understanding.	Understanding/comprehensio n
228. Teaching differing ability levels simultaneously 216. Giving up on activity because of management difficulty 222. Making the task harder for the teacher 199. Class behavior making a difference 216. Giving up on activity because of management difficulty	Management/ Cognitive Development Management/Student behavior	Administration of learning.	Manageability of tasks. Also varies due to cognitive or behavioral issues and may also vary as to the source of the variation (e.g. the student or the teacher)

Label	Sub-Category	Property	Dimension
236. NOT using the mobile lab	Just not using it ????	A reason without justification	This is a dichotomous measure. Either there is a reason or there is not. Memo: Most likely, things in this category are representations of things that need to be looked into more thoroughly to find the answer. Nonetheless, instances where someone states “I just didn’t use it” are important and frequent. See “Not using software to its fullest potential” above

At this point, I had categorized, compared, and sub-categorized all the statements into separate categories. Looking over all the “completed” categories, I engaged in selective coding (Strauss & Corbin, 1990) with categories that seemed to be more impactful in the participant’s use of technology in the classroom. I began to wonder whether or not the citations I grouped in “Reasons NOT to use technology” really belonged together or whether or not this was too ambiguous as a category label. Yet, as I examined the original citations the codes were pulled from, and attempted to provide an emic view of the teacher’s reasons for integrating (or not) technology into her mathematics curriculum, they seemed to fit the definition I provided. Not wanting to be the researcher who never takes the findings beyond defining dimensions (Pidgeon & Henwood, 1995), I turned to an analytic memo. I examined what it was that made these things fit into this category. Although I hesitate to include the entire memo on this category as a whole, I think the progression of ideas from one frame to the next communicates the confusion I was experiencing, finally resulting in the use of a model to synthesize and advance the concept of how the various ideas came together, tying together findings in this category and throughout the others as they related.

I first drew different graphic representations on paper to try and understand the issue best. While I initially believed that these subcategories were unrelated, through visual modeling I literally began to see how one might affect the other.

In the graphic model I created (See Figure 3), each end of an arrow is a negative occurrence in which a teacher either does not use or abandons technology in mathematics altogether. While it is expected that no one will use technology at the beginning of the spectrum, on the other end there exists the possibility of abandoning particular programs after only a short time if everyone using that program *maxes out*, or reaches the full potential of that program too quickly. Likewise, the program must reach a balance cognitively. If no student can understand the program, it results in no one using it, but if all the students want to play the “Teddy Bear game,” for example (a kindergarten-level game on making combinations) the teacher will abandon using the program as well. As Mrs. Black reported, “That’s just a little bit below them, and I told them they’re not allowed to do that.” Finally, the issue of manageability makes a task more or less likely to have a negative impact on technology use in the classroom. For example, because

Mrs. Black reported that year's class was "so well behaved" the teacher could literally take them to the computer lab twice a week, as opposed to her neighboring teacher's rowdier class that "she would not dare take to the computer lab." Thus, even a well-intentioned project that balanced cognitive skills and technology use may be abandoned in the case of an unmanageable class.

Table 3. Memo on the Dimensions of Reasons NOT to use Technology

Memo—Reasons NOT to use technology—dimensions	
As I try and group the different reasons not to use technology in the classroom as defined by the teacher, I find some interesting things happening. The first few reasons were actually that the teacher *had* used the technology, but that the students had "maxed out". Can this really qualify as a reason NOT to use the software since the teacher had to use the software to get to this point? It has important implications for software developers in that they need dynamic software that will always challenge the learner so that they can't "max out". For, PD, which is important to this study, it implies the necessity of providing the teachers with enough resources to actually be able to continue PD principles throughout the course of the year instead of becoming a unit or even a lesson. In fact, the teacher refers to this later as she asks for a continuous source of resources (254, 276) and is actually pleased that what she got out of the experience is learning how to use Illuminations for finding resources (28, 34) and has even shared that resource with other teachers (187) and parents (187, 268). So does this mean that by using the software it falls into disuse?	"maxing out" [in vivo code]
Lack of instructions seems to stick out a lot. If the teacher can't understand the software, that is cause to either not use or abandon it (132, 134). Sometimes she attributes this to the software while other times to her own ignorance with the program. Either way, functional ignorance is a reason *not* to use software or technology.	"functional ignorance"
Management issues also seem to have varying dimensions in this category. They can range from class behavior to teacher workload to student's cognitive development (which is where you begin to get some overlap with the other dimension of *not* using a piece of software).	
Cognitive Development meets Management is an interesting intersection where the various categories meet dimensionally. If I were to make a line along which technology is NOT used or abandoned, it would begin with lack of instructions, moving to experimentation with the software and then either abandonment due to the manageability of the class's behavioral makeup or teacher workload, to actually using the software and succeeding, but having too many cognitive ability levels to manage the task, to abandoning the technology due to the ceiling effect of all students learning how to use the technology. A graphic might look something like the following (See Figure 3).	

I realized that there was a paradox in this graphic representation of how my categories related. While Figure 3 attempts to explain why teachers never adopt or eventually abandon technology in the classroom, it also contains the sweet spot or ideal conditions under which a teacher is *least* likely to abandon technology use in the classroom. That spot is the convergence of management, understanding the software, and a balance of those using the technology in the classroom. This may be somewhat confusing due to the fact that this is a graphic of "NOTs." Alternatively, it became easier to understand this relationship when I changed management from negative to positive. I thought in terms of manageability instead of unmanageability. From this perspective, I changed the title to "Effective Conditions for Classroom Technology Use" to relay the fact that the ideal plane is the condition in which a teacher is the *most* likely to adopt technology in the classroom. A graphic representation might look like the following: (see Figure 4).

Figure 3. Reasons Teachers Choose to NOT use or to Abandon Using Technology in their Mathematics Lessons

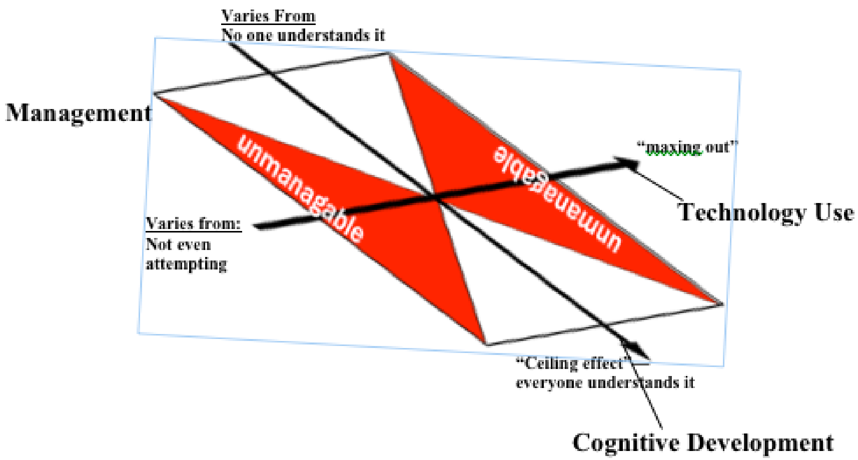
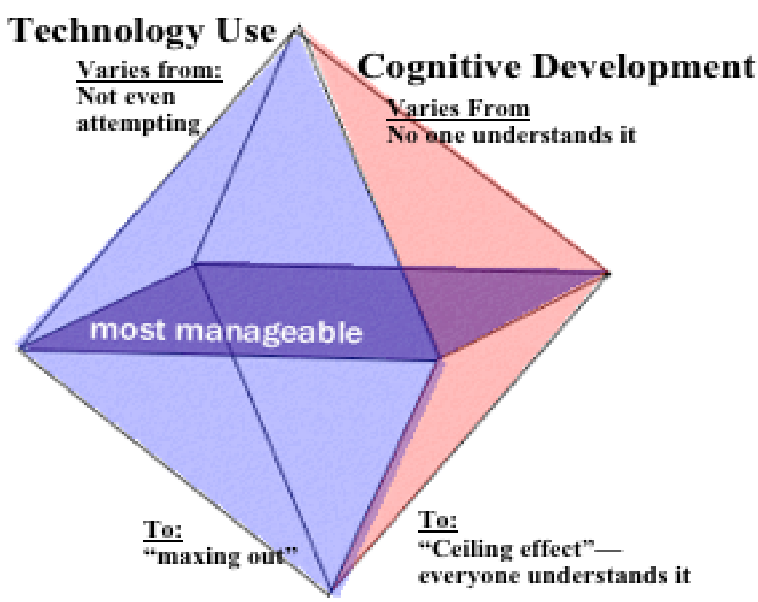


Figure 4. Effective Conditions for Classroom Technology Use



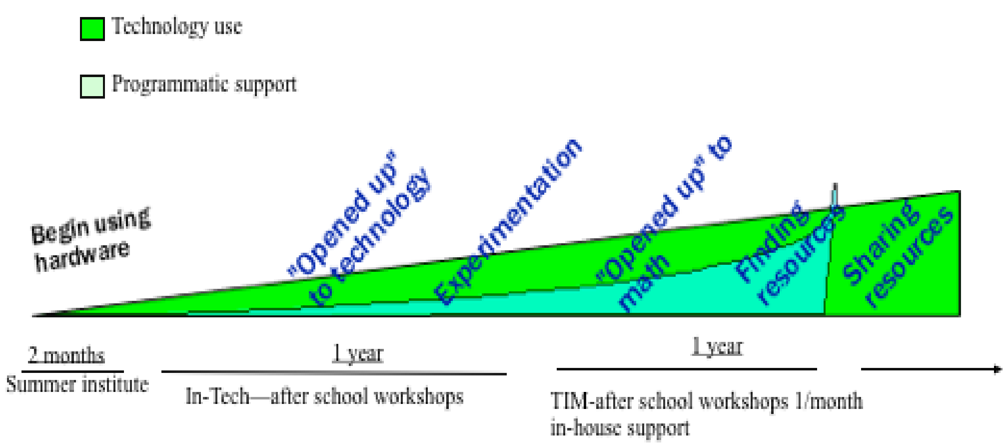
The implications for such a model are important to understand in the context of technology integration post-professional development experiences. In effect, the teacher needs to create conditions in the classroom such that her students are neither too challenged nor challenged too much (i.e., Vygotsky's Zone of Proximal Development). Likewise, *the teacher's* challenge comes in terms of manageability (which, of course, has many different dimensions). Perhaps the most surprising aspect of this model is the concept of *maxing out*—or utilizing the technology until it is no longer useful. This suggests that there either has to be a constantly replenishing supply of technological resources or that the software chosen needs to be dynamic enough for the students' cognitive group that it offers new problems to the students every time it is used. When I examined the qualities of software most desirable to Mrs. Black, she advocated such dynamic software most heavily. This was perhaps best explained as she spoke of her own experience using a program called *Math for the Real World*™. "I found, that even though you do that stuff over and over, it's all, it's still hard. I mean, I have a hard time, like, whenever you do to the little restaurant and you have to get your food...so it's still a challenge no matter how many times you do it."

These findings are surprising when considering that all teachers interviewed told me that the challenge to teaching with technology is shortages of three things: time, hardware, and software. These align readily with Brickner's (1995) first-order barriers to change. "First-order barriers to technology integration are described as being extrinsic to teachers and include lack of access to computers and software, insufficient time to plan instruction, and inadequate technical and administrative support" (Ertmer, 1999, p. 48). While these are all legitimate reasons teachers may not use technology, they do not form the core argument for or against technology use, as I soon discovered with Mrs. Black. Usually, they fall under the category of management in some form or another. A curious experience with Mrs. Black illustrated that shortages are often only a superficial answer to why she did/did not use technology. When Mrs. Black spoke of not using technology, she actually possessed the technology, but *chose* not to use it. She spoke of a time when the school had a "mobile lab," an entire class's worth of laptops and a projector that teachers could use in their classroom any time they wished. And yet, she reportedly did not use the mobile lab. In the current study, she complained of having only one working and up-to-date computer in her classroom and wishes that she had more so that she did not always have to go down to the lab (which she did at least twice a week). Ironically, the computers in the lab were the very same laptops that made up the mobile lab only two years earlier. They were neither newer nor more powerful or accessible. If simply having functioning, up-to-date software and technology was the key to successful technology implementation, she would likely have used the computers more frequently two years earlier. This experience revealed that there was more involved in creating the conditions for successful technology adoption in Mrs. Black's classroom than issues solved through supply. This analysis revealed that there must be a balance between cognitive development, technological experimentation, and task manageability.

Additional Findings and Implications

While the above argument forms the crux of this emerging theory of technology adoption, I feel it is important to note a surprising finding that may be particular to this participant, yet important, and perhaps even crucial, to reaching the level of technology experimentation necessary to sustain any sort of classroom technology use. Because this was a study on *post-programmatic* influences, I expected to see issues that occurred or were occurring *after* professional development. Yet, this teacher's history with technology integration professional development programs is out of the ordinary. Roughly two years before participating in this project (the year after she had the mobile lab in her classroom, which she didn't use at the time); she participated in a summer seminar on using technology. She moved from there to year-long series-a-month workshops on integrating technology. With only two month's reprieve, she began a four-day summer workshop for this project, accompanied by year-long after school workshops and weekly in-house support from the project staff. Staff members were available at her beck and call throughout the school year to model lessons, help with pedagogical and technological issues, and co-plan lessons. She commented that prior to beginning any of these programs, she would not use technology, even though she had it available to her (as witnessed by the mobile-computer lab experience mentioned above). To visualize her development, I plotted her progression above a timeline of these three programs (see Figure 5). Doing so allowed me to see how her

Figure 5. Progression of Mrs. Black's Technology Integration Experiences



From this perspective, the most influential factors to Mrs. Black's seemingly widespread use of technology in the classroom may have actually occurred *before* this final professional-development experience. That is, *pre-programmatic experiences may have been just as critical, if not more so, than post-programmatic experiences.* This implies that teachers need "three good doses of technology," as Mrs. Black put it, or at least multiple consecutive professional development experiences on the same topic to feel comfortable enough to where they are actually sending home websites for parents to use with their children at home (i.e., "sharing resources"). This indicates to me that theoretic sampling (Glaser & Strauss, 1967) needs to be conducted to find more teachers who have participated in back-to-back technology integration professional development experiences. As it is, I can only muse on how the "melding together" of these three programs affected Mrs. Black's newfound propensity for integrating technology in her fifth-grade mathematics lessons.

Reflections

There are several things that did or did not work for me in attempting to use grounded theory analytical methods with this study. I will briefly discuss the more pertinent of these below.

Bottom-up Coding

Overall, I found the emergent, grounded theoretical method to result in slightly different findings than the top-down emergent thematic coding I originally employed with these data. In the top-down method, I first chunked the information into semi-thematic units, then I found themes within those units, then I looked for individual instances within those themes. Because I first analyzed these data from a different perspective (i.e., not from a grounded theoretical perspective), and because Mrs. Black's interview was the third interview I analyzed in the initial analysis, I believe I was initially influenced by the codes I had found in earlier interviews to the extent that I may have seen something in this interview that seemed more prevalent than it appeared when using the bottom-up grounded theory approach (e.g., the issue of time was more prevalent originally). This current grounded theory analysis seems to have resulted in a more emergent and faithful representation of the data, perhaps due to the careful constant comparison I employed (checking codes against codes, then against the original text, then against categories and sub-codes, then back to the original text, to the final sub-codes and their dimensions, then finally comparing categories against each other, and finally identifying the underlying relationships). In other words, I felt this analysis was actually grounded in the data I analyzed instead of in impressions I had after conducting the interviews.

Action Coding

One thing that I found difficult about using action words to code my data was that I felt restricted by what I could say was happening. There were instances in which I felt it would be better to use some sort of adjective to describe what was emerging, but that I confounded and abstracted the idea by using action words. This was especially the case when what I was wanted to describe was not the participant's own actions. For example, several instances in which Mrs. Black spoke of how the software affected students, I was more prone to describe its effects than to attribute it as an action of the software. On the one hand, I felt that I may have lost some important nuances. In other cases, forcing myself to use this strict coding paradigm may have caused me to attribute a lot more of the action and responsibility to the participant. I noticed how her own role and personality spoke out to me during this coding, which was something I did not fully capture (at least not to this extent) when simply using a top-down, emergent coding scheme. One positive aspect I noticed as I used action words was that it forced me to think on more of a conceptual level while still attempting to stay close to the wording of the data.

Memoing

One thing I often have trouble doing is getting myself to begin writing. Once I begin writing, the words start to come out (kind of like going to the gym—getting there is the hardest part). By using memos, I was able to close this gap by effectively ending every analysis session by writing. This provided the diving board from which to jump when I began writing, using the very text of my memos as a first draft. So, instead of putting my toe into the cold water and slowly, but agonizingly beginning the process (or worse yet, deciding it would be better to stay out of the water and get a tan), I was able to dive right in and get wet all at once. Memoing was key to a successful analysis. Through conducting analytical memos, I was able to move beyond the minutia of finding, naming, and defining categories to identifying the underlying themes that tied them together. Further, memoing allowed me to have a different forum for first drafts, so that my first attempt to write up the data in article form was actually a series of reworked second or third drafts.

Models and Diagrams

Qualitative researchers often experiment with alternative representation of data, which encourages interpreting the data from different perspectives (Frost et al., 2010). Yet, many editors ask that authors limit the number of tables and figures due to publication constraints. In contrast to this practice, Dey (1999) comments that the use of models is not only a way of representing ideas, but also of developing them. I have to agree. My understanding of what was happening with "reasons not to use technology" was becoming confounded and muddled by simply writing the memo. I was finding areas where I saw contrasts, but could not see convergences. Drawing a graphic helped me to see these points of convergence. Furthermore, experimenting with different shapes helped me to understand how one concept interacts with another. Further advancing the model to a three-dimensional representation helped to develop the connections among ideas.

Conclusions

Though I originally collected these data and analyzed them using a top-down, emergent coding scheme, the use of a grounded theoretical approach helped me to feel more grounded in the data. As presented here, the study is incomplete. It does not include the same analysis on the remaining data. Additionally, as a true grounded theory program of research, theoretical sampling ought to be conducted to seek out other teachers with similar back-to-back professional development experiences to see the influence of repeated exposure on a teacher's likelihood of adopting a particular approach to teaching. None of the other teachers in this study had such an experience, and therefore more data would need to be collected to validate this emerging theory of technology adoption in elementary mathematics classrooms following multiple professional development experiences.

Perhaps most important to the present exercise is that I have opened up the black-box of my own analysis for more scrutiny than normally allowed in a research report. This manuscript does not fit into either of the two categories typically published. It is neither a proposal on how to modify existing methodological practices, nor is it a simple report of the data, presenting rich, detailed findings and a discussion of those findings as they relate to the current state of knowledge around that particular topic. Rather, this manuscript offers a third type of article, one that opens the researcher's thinking in a hermeneutical way, while attempting to faithfully adhere to an existing analytical methodology and remain close to the data. Whether the original authors and current methodological proponents of grounded theory would agree with my application of their proposed principles is up for debate. And that's just the point—this manner of presenting the analysis allows researchers to critique not only the interpretation of data, but also the application of the analysis that spawned that interpretation. I believe such openness will play two important roles. First, it enables novices to better understand how to carry out a particular analysis. Second, it allows researchers to see the pros, cons and other nuances associated with a particular approach.

Lincoln and Guba (1985) long ago made a plea and recommendations for increasing the dependability and trustworthiness of qualitative research. They said:
"The operational word is *credible*. The implementation of the credibility criterion—the naturalist's substitute for the conventionalist's internal validity—becomes a twofold task: first, to carry out the inquiry in such a way that the probability that the findings will be found to be credible is enhanced and, second, to demonstrate the credibility of the findings by having them approved by the constructors of the multiple realities being studied" (pp. 295-296).

This manuscript attempts to provide a way to answer, in part, Lincoln and Guba's first concern. Manuscripts written in such a genre potentially provide a point of debate for novice and expert qualitative researchers alike to more fully scrutinize their analytic processes, thereby providing a window into the oft-called for credibility in qualitative research.

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