



Interactions among knowledge, beliefs, and goals in framing a qualitative study in statistics education

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Abstract

In the recent past, qualitative research methods have become more prevalent in the field of statistics education. This paper offers thoughts on the process of framing a qualitative study by means of an illustrative example. The decisions that influenced the framing of a study of pre-service teachers' understanding of the concept of statistical sample are explained by describing the goals, knowledge, and beliefs brought to the research project. Each framing decision is portrayed as a function of these three overarching cognitions. It is suggested that mapping one's goals, knowledge, and beliefs while framing and carrying out a qualitative study can be useful for maintaining the quality of the study.

1. Introduction

It has been argued that the researcher is the most important instrument in a qualitative study ([Corbin and Strauss 2008](#); [Denzin and Lincoln 2005](#); [Eisner 1998](#)). One of the reasons for this is that the researcher must make decisions about the framing of a study that will ultimately impact its quality. Such decisions include formulating and refining research questions, theoretical orientations, and methodological procedures. Unfortunately, there is no algorithm that prescribes precise steps to be taken in making these decisions. However, I believe that it can be helpful to

study the decision-making processes of others, not for the sake of replicating them exactly, but for adapting and extending elements of them for use in different situations. In that spirit, I offer below a reflection on the cognitive processes that influenced some critical decisions made in the framing of a qualitative study on pre-service elementary school teachers' understanding of the statistical concept of "sample" ([Groth and Bergner 2005](#)).

The abstract for the study to be considered suggests some of the critical decisions that were made in the process of framing it:

The study describes the nature of pre-service teachers' idiosyncratic metaphors for the concept of statistical sample. These metaphors were investigated because of their potential to provide insight about individuals' content knowledge and how that content knowledge is enacted during teaching. Personal metaphors were elicited from 54 pre-service teachers through writing prompts. The writing prompt responses revealed seven different categories of thinking. In some instances, pre-service teachers struggled to construct a metaphor for the concept of sample. In the majority of cases, they constructed a metaphor for sample and discussed its relationship to their knowledge of the concept. The categories of thinking highlight some of the aspects of the concept of sample that teacher educators need to attend to over the course of instruction, and they also point out directions for further research related to metaphorical thinking about statistical content and its interaction with teaching practice ([Groth and Bergner 2005, p. 27](#)).

Some of the critical choices made in framing the study, implicit in the abstract, were: pre-service elementary teachers as research participants, a qualitative design for the study, metaphor as a lens on participants' cognition, and the idea of sample as the content of interest.

In this reflection, I will describe how the researchers' goals, knowledge, and beliefs influenced the decisions made in framing the metaphor study. These three overarching cognitions, taken together, have been used to explain the motivation underlying the pedagogical moves that teachers make ([Artzt, Armour-Thomas, and Curcio 2007](#); [Schoenfeld 1998](#)). I thought it appropriate to use the three overarching cognitions to frame the reflection, because the research report on pre-service teachers' understanding of "sample," was intended to teach as well as contribute to research. Part of the motivation for the study was to serve the teaching function of alerting readers to patterns of thinking prevalent among the research participants.

It should be noted at the outset that beliefs, goals, and knowledge can interact with each other in complex and sometimes unpredictable ways. The reflection below illustrates that there is not a simple chain of influence linking the three constructs. For instance, it will be shown that sometimes knowledge may lead researchers to adopt certain beliefs and goals. It will also be shown that beliefs and knowledge may combine to motivate adoption of a certain goal. There are certainly many more possible interactions among beliefs, knowledge and goals than those described below. Hence, the purpose of the following reflection is primarily to draw attention to the idea of mapping one's beliefs, knowledge, and goals during qualitative research rather than to exhaustively catalog all possible interactions.

Although this article describes the framing of a qualitative study, there is ample reason to believe that some of the issues raised also apply to framing quantitative research. When designing a

quantitative intervention study, for example, researchers must make decisions on a number of measurement issues, such as the nature of the treatments, the context for the study, and the particular assessment measures to be used ([Scheaffer & Smith, 2007](#)). These subjective decisions, made at the outset of a study, largely determine the types of conclusions and interpretations that can ultimately be drawn. Each decision can be influenced by researchers' beliefs, knowledge, and goals. I invite quantitative researchers to engage in the type of reflection described below to examine their own research practices and judge for themselves the extent to which it helps characterize and reveal the decision-making structure involved in their work.

2. Critical framing decision 1: Choosing to study pre-service elementary teachers

2.1 Influence of knowledge

Knowledge of pre-service elementary teachers' content knowledge strongly influenced the decision to focus upon them in the metaphor study. Experiences teaching content and pedagogy courses for pre-service teachers and the research literature made the authors aware of the challenge inherent in helping them develop in-depth understanding of content. For instance, it often takes a great deal of time and effort to help them understand how to write word problems that model a fraction division problem like "one-half divided by one-third." [Ma \(1999\)](#), for example, asked teachers to carry out the aforementioned fraction word problem writing task and found that the vast majority of U.S. teachers she studied could not produce a correct word problem. Such observations from the research literature, coupled with the researchers' teaching experiences, provided motivation to make it a goal to map, in detail, the nature of pre-service elementary teachers' content knowledge for teaching statistics. The need for such a map is perhaps even more pronounced in statistics than in mathematics, since statistics is a relative newcomer to the K-12 curriculum ([Conference Board of the Mathematical Sciences 2001](#)).

2.2 Influence of goals

The research goal of mapping the structure of participants' content knowledge differs from the goal of testing a teaching strategy aimed at improving their content knowledge. [Schoenfeld \(2000\)](#) discussed two purposes for educational research: pure and applied. The purpose of pure research is to try to understand the nature of thinking, teaching, and learning. The purpose of applied research is to use insights gained from pure research to help improve teaching and learning. The metaphor study was mainly an exercise in pure research, as one of the goals for the study was to begin to build the collective knowledge base of pre-service teachers' knowledge of elementary statistics. Such a knowledge base is growing in mathematics education but is just beginning to form in statistics education.

2.3 Influence of beliefs

Although pure research goals drove the framing of the metaphor study, belief in the importance of drawing upon pure research to help inform instructional practices was also influential. Pure research that maps teachers' knowledge has the potential to provide a basis for later applied

research. The teaching experiment, for example, has become an increasingly common design for applied research in statistics and mathematics education (Ben-Zvi, Garfield, and Zieffler 2006). A teaching experiment involves designing a unit of instruction, teaching it in a classroom setting, continuously assessing the impact of the instructional upon students' learning, and modifying teaching actions as necessary to help students meet pre-defined learning goals (Steffe and Thompson 2000). Early on in a teaching experiment, researchers must construct a hypothetical learning trajectory (Cobb 2000; Simon 1995) that predicts how students will progress toward the pre-defined learning goals under a given set of instructional activities. Even though the trajectory is usually refined in light of empirical data as the experiment progresses, it is vital to have a plausible initial basis for the construction of the trajectory. It is in the initial construction of the trajectory that pure research can be the most useful. Having some knowledge of pre-service teachers' understanding of the idea of "sample," for instance, can provide a viable initial basis for selecting instructional activities that may help expand their knowledge. Therefore, although pure research goals were in the forefront in the study of pre-service teachers' knowledge, the goal of helping inform future applied research also helped drive the study because of belief in the importance of connecting pure research to practice. The need for pure research to inform the practice of building pre-service elementary teachers' content knowledge is especially pronounced in light of the earlier-mentioned difficulties they tend to have in understanding content.

2.4 Summary of interactions among knowledge, goals, and beliefs

Figure 1 summarizes the interplay among knowledge, beliefs, and goals that influenced the decision to study pre-service teachers. In Figure 1 (as well as Figures 2, 3 & 4), knowledge elements are contained in ovals, beliefs in rounded-off rectangles, and goals in rectangles. Knowledge of difficulties that pre-service teachers have in developing content knowledge motivated the goal of mapping their statistical content knowledge. Producing such a map is a pure research goal. However, the authors also believed in the importance of using pure research to inform applied research, which led to the goal of framing and reporting the research in a manner that would be helpful to advise the initial design stages of teaching experiments and possibly other types of applied research.

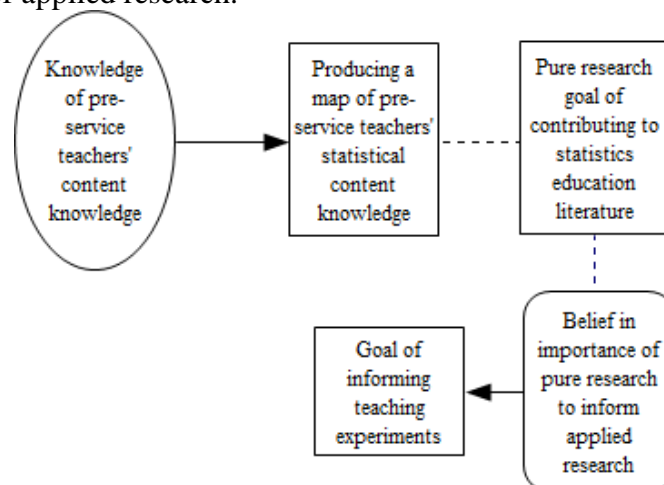


Figure 1. Knowledge, beliefs, and goals related to the decision to study pre-service teachers

3. Critical framing decision 2: Choosing a qualitative design for the study

At first glance, it may seem strange to choose qualitative methods for examining individuals' understanding of a quantitative field of study. As [Gal \(2007\)](#) noted,

There is a somewhat tenuous relationship between quantitative and qualitative research in an area whose subject matter, statistics, is based on quantitative information, and where some of the researchers and teachers (as well as manuscript referees...) are mainly trained in quantitative methods (p. 2).

Given the seeming tension between qualitative research and statistics, it is fair to ask why a qualitative design was chosen for the study of pre-service teachers' understanding of the concept of "sample."

3.1 Influence of beliefs

Beliefs about research were influential in choosing a qualitative design. [Maykut and Morehouse \(1994\)](#) described two conflicting categories of beliefs about research: positivism and phenomenology. Positivism asserts that explanations and findings from one research setting can be generalized to other settings. Examples of the influence of a positivist paradigm can be seen in the recommendations of the recently-released [National Mathematics Advisory Panel \(2008\)](#) final report. One of the report recommendations is for more randomized controlled trials (RCTs) of curricula. The positivist assumption underlying such a recommendation is that the RCTs will allow for hard and fast generalizations about "what works" in classrooms. Phenomenology, on the other hand, asserts that only tentative generalizations of explanations and findings can be made from one research setting to other settings. Going back to the RCT example, although RCTs may provide helpful information about the effectiveness of a curriculum in one setting, they provide only working hypotheses ([Cronbach 1975](#)) about how the curriculum may influence learning in another setting.

3.2 Influence of goals

Working from a perspective more aligned with phenomenology than with positivism, attempting to produce hard and fast generalizations that apply to all pre-service teachers was not a primary goal of the metaphor study. Instead, the main goal was to produce as rich a description as possible of participants' thinking and their relevant experiences with statistics that may have influenced their cognitive patterns. In light of this goal, a qualitative approach made sense, because it provided a venue for the description of the broad patterns of thinking observed, supported by specific examples of participants' responses. We wanted readers to think about the qualitative descriptions provided in the report in connection with the pre-service teachers with whom they work. The work of making generalizations is then left, as it should be (from a phenomenological perspective), to the reader. He or she can judge the extent to which the descriptions given in the report provide insight about his or her specific setting for teaching and research by considering similarities and dissimilarities between the setting described in the

research and his or her own setting. Making such inferences from qualitative studies has been referred to as “naturalistic generalization” ([Stake and Trumbull, 1982](#)).

3.3 Influence of knowledge

As instructors of pre-service teachers, we knew that rich qualitative reports can be quite helpful in the process of making naturalistic generalizations. In the past, we had recognized common threads between our settings and those described in qualitative studies of teachers, and those common threads helped us anticipate and address issues that arise in carrying out the tasks of teacher education and research. [Ma’s \(1999\)](#) study, for example, suggested that teachers’ understanding of rational numbers and the meanings of computational algorithms can be quite fragile. This feature of Ma’s research led us to regularly probe our own prospective teachers’ knowledge in these areas. In doing so, we found they exhibited many patterns of thinking similar to those described in the research. Becoming aware of problematic mathematical thinking opened the door for addressing and correcting it. We hoped that the metaphor study would serve a similar function by encouraging readers to investigate patterns of thinking about the idea of “sample” held by prospective and practicing teachers with whom they work.

3.4 Summary of interactions among beliefs, goals, and knowledge

[Figure 2](#) summarizes the beliefs, goals, and knowledge related to the decision to use a qualitative design for the study. Beliefs about research more aligned with phenomenology than with positivism and knowledge of other similar qualitative studies fed into the goal of producing rich descriptions of participants’ thinking. It should be noted that the goal of producing rich descriptions of participants’ thinking also connects to one of the goals in [Figure 1](#): that of informing applied research like teaching experiments. Such rich descriptions can help others anticipate, in detail, the types of thinking they might encounter in similar situations with similar individuals.

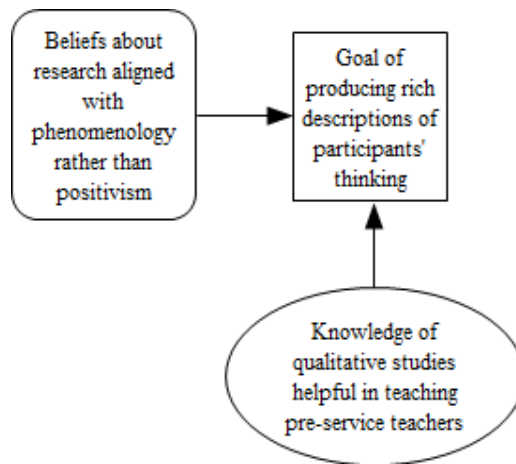


Figure 2. Beliefs, knowledge, and goals related to choosing a qualitative study design

4. Critical framing decision 3: Choosing metaphor as a lens on participants' cognition

4.1 Beliefs and knowledge motivating a goal

[Shulman's \(1987\)](#) landmark distinction between content knowledge and pedagogical content knowledge undergirded some crucial framing decisions. Content knowledge allows teachers to understand the landscape of any given subject area, and pedagogical content knowledge allows them to make the subject area understandable to students. We believed that both types of knowledge are necessary, but not sufficient, to be an effective teacher. Our belief that both types of knowledge are necessary in order to teach effectively led to the goal of examining both of them as part of the study. Setting the goal of studying both content knowledge and pedagogical knowledge was thus done to increase the range of potential applicability to research and practice in statistics teacher education.

4.2 Knowledge leading to refinement of initial goal

Knowledge of metaphor as a potential window on both types of knowledge needed for teaching led to the goal of examining pre-service teachers' subjective metaphors for the idea of sample. Individuals' metaphors provide a window on their content knowledge because analogy is a basic mechanism in learning. [Gentner and Holyoak \(1997\)](#) summed this up by stating,

One basic mechanism [for learning] is analogy – the process of understanding a novel situation in terms of one that is already familiar. The familiar situation – often termed the base or source analog – provides a kind of model for making inferences about a particular situation – the target analog (p. 32).

[Martin \(2003\)](#) provided a collection of examples illustrating how a variety of statistical concepts can be understood analogically. Among the examples he mentioned were: thinking of hypothesis testing in terms of a judicial trial, thinking of an average as a balance point, and thinking of the process for choosing the bin width of a histogram in terms of setting the focus on a camera. An individual with well-developed knowledge of content will see the similarities and dissimilarities between the source and target analogs in each case. Hence, in addition to asking participants to construct metaphors for “sample,” we also asked them to discuss the similarities and differences between the metaphors they constructed and the concept. We believed this would allow us to examine participants' content knowledge in greater depth.

In addition to revealing details about content knowledge, teachers' metaphors provide insight about their ability to help students understand content (pedagogical content knowledge). Although students must ultimately construct their own understanding of content, their construction of knowledge may at times be influenced by metaphors offered by teachers during classroom instruction ([Presmeg 1992](#)). In light of this, it is helpful if teachers are careful and systematic about sharing analogies and metaphors with students. [Glynn \(1991\)](#), for example, suggested that teachers identify the source and target analogs for students, identify relevant features of each one, map similarities and differences between them, and then draw conclusions. Such a process provides a means for teachers to effectively draw upon their personal metaphors about content for the task of making the content understandable to students. Therefore, by asking

pre-service teachers to write their own personal metaphors, and then asking them to explain the strengths and limitations of the metaphor, we believed that we gained insight about an aspect of their ability to make the content understandable to students as well as gaining a better understanding of the nature of their content knowledge.

4.3. Summary of interaction among beliefs, knowledge, and goals

The beliefs, knowledge, and goals connected to the decision to use metaphor as a lens on participants' cognition are summarized in [Figure 3](#). The belief in the importance of pedagogical knowledge as well as content knowledge interacted with the knowledge of metaphor as a lens on both types of knowledge to lead to the goal of examining participants' metaphors. We also went beyond just examining metaphors to asking participants to explain the similarities and differences between the source and target analogs in the metaphors. This additional probing was motivated by the bit of knowledge that the ability to explain such similarities and differences reveals aspects of content knowledge as well as pedagogical content knowledge. Examining participants' knowledge of the strengths and weaknesses of their self-constructed metaphors thus became an additional goal for the study.

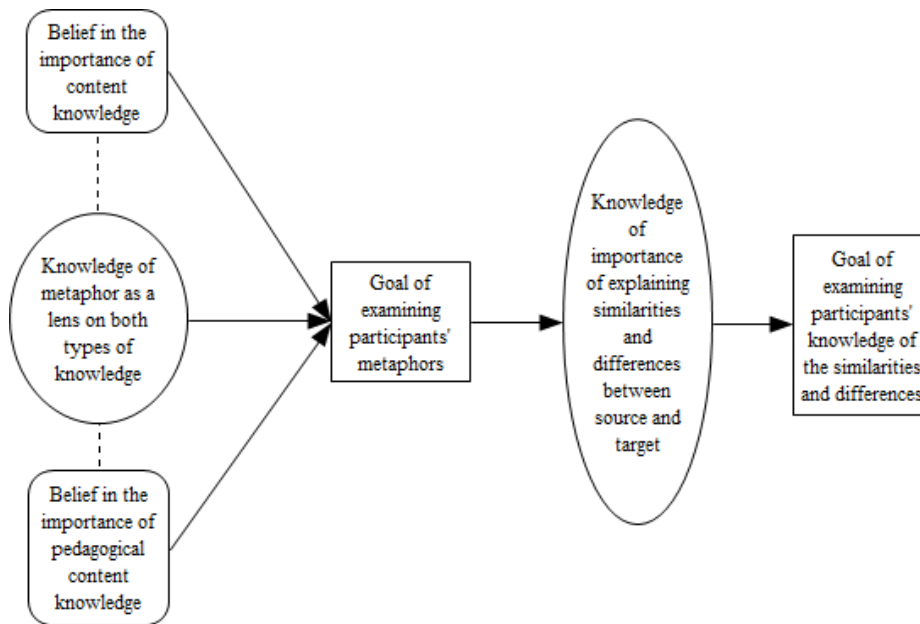


Figure 3. Beliefs, knowledge, and goals related to using metaphor as a lens on cognition

5. Critical framing decision 4: Choosing the concept of sample as the content of interest

5.1 Knowledge influencing beliefs and beliefs influencing goals

Knowledge of the current state of teaching statistics in grades K-8 helped motivate the decision to focus on the concept of statistical sample. Local K-8 teachers seemed to portray data analysis

mostly in terms of producing data displays and summary statistics. These tasks were often given as ends in themselves, rather than as a means for drawing conclusions from data. Part of the cause of these practices was that the state curriculum document teachers were responsible for following framed the study of data analysis in a similar fashion, focusing on issues like how many pieces of data should be in a data set from which the arithmetic mean is calculated ([Maryland State Department of Education 2004](#)). The reflections of other researchers on the current state of affairs in K-8 statistics ([Scheaffer 2002](#); [Friel, O'Connor, and Mamer 2006](#)) provided evidence that the problem was not just a local one. We believed that foundational ideas in statistics, like the sample-population relationship, are underemphasized, yet possible to teach in grades K-8 ([Franklin, et al. 2007](#)). In focusing on teachers' understanding of the concept of sample, we had the goal of drawing attention toward an idea that we believed can and should be a greater part of K-8 statistics education in the U.S. in general.

5.2 Knowledge reinforcing goals

Knowledge of the research literature also motivated the focus on the concept of sample. The literature contained studies of K-8 students' knowledge of the concept of sample, but not much information on teachers' knowledge. [Jacobs \(1999\)](#) and [Watson and Moritz \(2000\)](#) each asked students to explain the concept in their own words. In each study, some students drew upon things they were familiar with, like samples of food and samples of carpeting, essentially forming analogies and metaphors in stating their explanations. As researchers, we were curious to see how pre-service teachers' metaphors would compare to those of students documented in the previous literature. The [Watson and Moritz \(2000\)](#) study was especially helpful in facilitating the comparison, because they arranged responses into a hierarchy reflecting the extent to which students thought of samples as being representative of a population. After carrying out the study, we were able to draw the conclusion that the levels of thinking exhibited by pre-service teachers in the study actually closely resembled the levels of thinking of K-8 students that have been studied.

5.3 Summary of interactions among beliefs, knowledge, and goals

Beliefs, knowledge, and goals related to focusing on the concept of sample are summarized in [Figure 4](#). Knowledge of current teaching practices in K-8 statistics education fed into the belief that sample/population relationships are currently underemphasized in the curriculum enacted in classrooms at those grade levels. This motivated the goal of drawing more attention to the possibilities for teaching the concept in grades K-8. This goal was also motivated by knowledge of the landscape of the current literature. Current literature was available to help understand and categorize participants' responses. At the same time, however, the study was intended to fill a gap in the literature in regard to teachers' knowledge of the concept of sample.

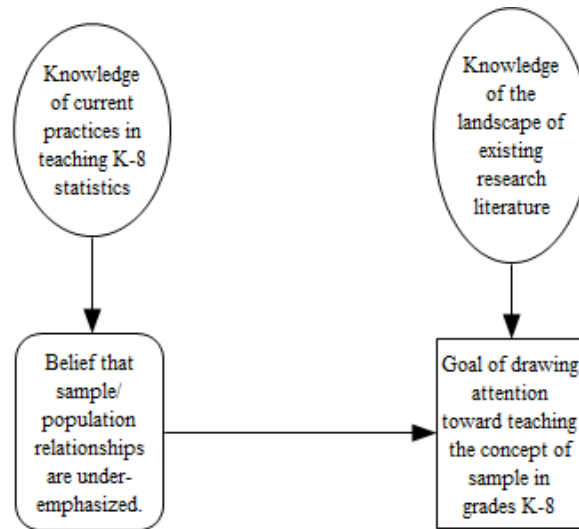


Figure 4. Beliefs, knowledge, and goals related to focusing on the concept of sample

6. Conclusion

As stated earlier, one of the primary reasons for the extended reflection above is to provide a glimpse of the decision-making processes involved in a qualitative study. Making these decision-making processes explicit allows others to consider how a different set of beliefs, knowledge, and goals might change the study for the better or for the worse. The reflection above might also provide a model for others to consider as they frame their own studies. Explicitly mapping one's beliefs, goals, and knowledge can facilitate reflection upon how the three types of cognitions influence the quality of the study. For example, one might identify questionable beliefs or gaps in knowledge by carrying out such a process. The worthiness of different goals might also be considered, especially as they are made explicit and shared with other researchers. If one accepts the premise that the researcher is, indeed, the most important instrument in any qualitative study, then making beliefs, knowledge, and goals explicit so that the researcher and others may examine and comment upon them can be viewed as a means for helping to 'calibrate' the qualitative researcher in statistics education.

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