ABSTRACT

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Physics Education researchers have been working to understanding how students learn physics, which has led to the creation of a body of research-based curricula. It is equally important to study novice instructors, graduate teaching assistants (TAs), who often teach these students. The study of TAs has similarities to how students have been studied: it is important to identify what preconceptions they often enter the classroom with, what resources they may have that they could apply to their physics teaching, and how both the classroom environment and past experiences affect what they are doing in the classroom. Although TAs are responsible for a significant portion of students' instruction at many universities, science TAs and their teaching have not been the focus of any significant amount of study.

This dissertation begins to fill this gap by examining physics graduate students who teach discussion sections for introductory courses using tutorials, which are guided worksheets completed by groups of students. While assisting students with their conceptual understanding of physics, TAs are also expected to convey classroom norms of constructing arguments and listening and responding to the reasoning of others. Physics graduate students enter into the role of tutorial TA having relative content expertise but minimal or no pedagogical expertise.

This analysis contends that considering the broader influences on TAs can account for TA behavior. Observations from two institutions (University of Colorado, Boulder and University of Maryland, College Park) show that TAs have different valuations (or buy-in) of the tutorials they teach, which have specific, identifiable consequences in the classroom. These differences can be explained by differences in the

TAs' different teaching environments. Next, I examine cases of a behavior shared by three TAs, in which they focus on relatively superficial indicators of knowledge. Because the beliefs that underlie their teaching decisions vary, I argue that understanding and addressing the TAs individual beliefs will lead to more effective professional development. Lastly, this analysis advocates a new perspective on TA professional development: one in which TAs' ideas about teaching are taken to be interesting, plausible, and potentially productive.

INVESTIGATING AND ACCOUNTING FOR
PHYSICS GRADUATE STUDENTS' TUTORIAL CLASSROOM PRACTICE

By

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Chapter 1 Introduction

The physics education community has a significant knowledge base regarding how people (that is, students) learn physics. In the process of doing that research, we have identified a variety of things that are important to pay attention to: what ideas and knowledge students bring into the classroom, what resources they might already have from past experiences, and how the minute-by-minute interactions they have in the classroom (with their teachers and with each other) affect what they think is appropriate behavior in the classroom. Physics TAs also deserve study, because they are often instructors for a significant portion of the students' class time. Little research has been done on physics TAs. We can begin by exploring the same topics that we already know matter for physics learning, but now with the aim of understanding physics teaching. For example, physics graduate students enter the classrooms they'll be teaching with beliefs about what it means to teach and learn physics, usually based on their own past experiences. They have experiences they can apply to teaching physics, either from formal teaching (or tutoring) or because of the physics learning they have done in groups as undergraduate students.

This work provides a foundation for TA research by providing evidence for several big ideas:

- TAs' attitudes about teaching are affected by the environment in which they work, from the type of classroom they teach in all they way up to the meta-messages they receive from other professors and TAs about the importance of and correct methods for teaching physics.
- TAs who value the materials they teach are more likely to convey these values to their students.
- TAs can share classroom behaviors that look similar, but these behaviors can be supported by beliefs and motivations that vary by TA as well as by context.

We can benefit from understanding TAs' ideas and beliefs as they begin teaching, in order to take them into consideration when we are trying to convince them to teach in a new way.

- When TAs participate in professional development, they should be treated as partners in the endeavor of educating students.

1.1 Motivation

My work focuses on TAs teaching tutorials. These are physics graduate students, often in their first or second year of graduate school, who are instructors for the discussion sections of introductory physics classes that use guided worksheets (tutorials) to structure group learning instead of the more typical problem-solving discussion sections. I explore TA behavior at many different levels. For example, I analyze the beliefs, knowledge, and expectations that TAs draw on at a minute-by-minute level when interacting with students in their classrooms – an analysis that involves just one group and TA at a time, interacting for periods of just a few minutes. Another analysis takes place at a broader level, concerning how the classroom and departmental environment in which TAs work affects how much they support the reform curriculum they use in their teaching.

The ultimate goal of research such as this is to create and implement more effective TA professional development (PD) for physics graduate students teaching reform curricula. As I discuss in more detail in chapter two, physics departments and TA instructors have an opportunity to significantly affect physics instruction through the professional development they offer to physics graduate students. For example, a University of Maryland TA may teach one or two hundred students during a semester, and these students often spend between one quarter and one half of their physics contact hours with their TAs. During this time, the TA has the opportunity to affect not just what content these students learn, but also their understanding of what it means to learn physics. Moreover, some of these TAs will become professors once they graduate, and their jobs as TAs may be their only significant teaching experience. Thus, TA professional development can be a chance to immediately improve undergraduates' learning and epistemological beliefs about physics as well as a chance to affect physics instruction in future decades. The research presented in this dissertation will hopefully serve as a starting point for the development of more effective TA PD.

1.2 An introduction to TAs

Graduate student teaching assistants are students, teachers, and apprentice researchers, and their roles vary depending on the context in which they are acting. As beginning researchers, they are supported by their advisors and other faculty. As physics students, they are often considered to be experts. (Although in some cases their physics knowledge may be less than perfect (McDermott, 2001; McDermott, Heron, Shaffer, & Stetzer, 2006), in most cases their students view them as experts in the subject and the TAs themselves frequently expect that they should have mastered introductory material.) As instructors, however, most are novices. It is common for a first-year physics graduate student to be placed in charge of a discussion section or laboratory with only a few hours or days of training. Because they have limited teaching experience and limited training, they are likely to draw on their past experiences as a student of physics to inform their teaching. For that reason, we review a typical pre-graduate-physics-student experience here.

The undergraduate physics culture that shapes many physics graduate students is distinctive, with its own norms and expectations. In his ethnographic study of physics undergraduates at a large research university, Nespor (1994) characterizes the physics undergraduate program as one that monopolizes students' time from their first year, tightly constraining their activities and personal associations so that success depends on immersing one's self into study groups with other physics students and avoiding too much time spent on family or other social events. Physics undergraduates across various institutions usually study from the same small set of accepted textbooks and use a relatively standard undergraduate curriculum that prepares them for the relatively standard curriculum across graduate schools in the United States. In other words, a student graduating with a physics undergraduate degree does not simply possess knowledge about physics; she has been shaped to become a physicist, which usually includes acceptance of the physics' community's values.

While the past experiences of various graduate students vary, they have all chosen to become professional physicists, and as a result, have begun to absorb the norms of the discipline of physics. The graduate students who are accepted by the University of Maryland (UM), a Tier 1 university with a large and prestigious graduate program, are likely to have worked particularly hard as undergraduates in order to achieve the high grades and test scores required for acceptance to UM.

The cultural practices that graduate TAs absorbed when they were undergraduates influence what they consider appropriate when learning and teaching physics. For example, most graduate students learned in a traditional manner and they have learned how to successfully learn when material is presented in lecture form. They might think that students who have trouble learning in such a manner are either unmotivated or just not "cut out" for learning physics. Likewise, physics graduate students have taken mathematically intensive classes, and they have learned to value the role that mathematics plays in physics, which might make them feel like physics courses relying on conceptual reasoning are not exposing students to the full beauty and usefulness of physics. These cultural practices shape what graduate TAs value, and can also exert an influence on what they do in the classroom.

1.3 Dissertation structure

The data analysis chapters in this dissertation are a compilation of three papers that were written for publication. Chapters Four and Five have already been accepted for publication, and Chapter Six has been submitted for publication. These chapters were written with co-authors and have not been substantially altered from their published form. Thus, each contains a literature review, theoretical framework, and conclusions that are specific to that chapter. In addition, the dissertation connects these chapters and places them in a larger context with a literature review (Chapter Two) that places TA research overall in a larger field of research and a theoretical framework (Chapter Three) that describes my general explanatory framework for interactions and cognition.

1.3.1 Chapter Two: Past research relevant to the study of tutorial TAs

This chapter begins by reviewing research on graduate student TAs in the STEM (science, technology, engineering, and mathematics) disciplines. It describes various types of professional development that have been offered to STEM TAs, as well as how the effects of those programs have been assessed. I then discuss the classroom practice that professional development aims to affect. I argue that detailed observations of TA teaching leads to better understanding of the motivations and beliefs that support their practice.

The second half of the chapter reviews a portion of the research on K-12 teachers that can inform TA professional development. I discuss research on various factors that can influence teachers' practice: pedagogical and epistemological beliefs, contextual factors, and pedagogical content knowledge.

1.3.2 Chapter Three: A theoretical framework for explaining interactions and cognition

This chapter introduces the theoretical framework that supports my work as a whole. Although each data analysis chapter depends on certain aspects of my theoretical framework more than others, all the research presented in this dissertation is concerned with generating explanations for TA classroom practice. Thus, I introduce a framework called *framing* for explaining certain parts of what happens when individuals interact. I then summarize two different perspectives on where thought lies, in the mind (cognitivist) or within the interactions of people and their environments (socio-cultural); both of these perspectives influence the analysis in this dissertation. The chapter closes with a discussion of the *resource framework,* which considers whether ideas are appropriate to a given situation rather than being categorically right or wrong. The resource framework shapes the upcoming analysis in two ways. First, I treat beliefs like resources, as varied, context-dependent elements of thought. Secondly, I look for resources that TAs have that could be productive seeds on which to build responsive professional development.

1.3.3 Chapter Four: Accounting for tutorial TAs' buy-in to reform instruction

This chapter examines how TAs value (buy into) the tutorials that they teach. I begin by presenting a case study of a TA who does not buy into particular characteristics of the tutorials. His lack of buy-in influences what he does in the classroom. After I have demonstrated that buy-in has the potential to affect teaching practices, I present a comparison of two groups of tutorial TAs, one at the University of Maryland, College Park and one at the University of Colorado, Boulder. An analysis of the TAs' beliefs (as articulated in their interviews) shows broad differences in their buy-in, both in the types of tutorial attributes they support as well as the amount of buy-in they espouse. I then discuss the differences in the "social and environmental context" experienced by the two groups of TAs, which includes the classroom, departmental, and institutional levels of implementation. I argue that these differences have the potential to strongly influence TAs' buy-in to tutorials.

1.3.4 Chapter Five: Similar teaching behaviors are supported by varied beliefs about teaching and learning

In this chapter, I identify a teaching practice I call "focusing on indicators," by which I mean a TA's acceptance of relatively weak evidence of student indicators. These indicators include key words, diagrams, or the correct numerical answer. I present cases of this behavior in three tutorial TAs and discuss how the beliefs that underlie the behavior vary for each TA. For example, the "focus on indicators" in one case is supported by a belief that a TA should ensure students have the right answer. A similar behavior in a different episode is supported by a TA's belief that TAs should help students work productively in the right direction. Examples like these support the argument that effective TA PD cannot simply target unsuitable teaching practices but also should address the beliefs that guide TAs' teaching.

1.3.5 Chapter Six: A new perspective: Respecting TAs' beliefs and experiences

In this chapter, I advocate for a new perspective on TA professional development, using the same theories that have proved successful with undergraduate physics students' learning. Physics education has learned the importance of respecting the knowledge that students bring to the classroom; I argue that such respect, paid to the naïve knowledge that beginning physics instructors bring to the classroom, can benefit TA instruction as well. I present multiple teaching episodes of a TA named Alan. My initial analysis of these episodes focused on the ways Alan's teaching was not aligned with the goals of tutorials. Further analysis showed that Alan's beliefs were well aligned with what he did in the classroom. When using a perspective that endeavors to respect his beliefs and experiences, I am able to locate "productive seeds" within his beliefs and experiences, upon which more responsive professional development could be based.

1.3.6 Chapter Seven: Summary and future directions

In Chapter Seven, I summarize the findings discussed in Chapters Four through Six. I examine the limitations of these findings, discuss directions for possible future research, and consider implications for TA professional development. I conclude by reflecting on the obstacles that may impede improvement in TA PD and signs of support for the endeavor.

Chapter 2 Past and future TA research: previous research on TAs and the teacher research that should guide future studies

2.1 Introduction

At large research universities, teaching assistants (TAs) play an important role in undergraduate physics instruction: they often lead discussion sections, teach labs, grade homework and exams, and conduct office hours. It is not unusual for introductory physics students to have as many contact hours with their TA as with their professor. And while TAs are not often responsible for determining course content or deciding the types of activities (lecture, problem solving, etc.) in which students engage, they are the people who implement those decisions. The decisions that TAs make have the potential to influence their students' ideas about what it means to learn physics and what the students actually learn. In light of the possible influence TAs could have on large numbers of students, the research on them has been sparse.

The larger purpose of the research discussed in this thesis is to provide information that could lead to improved professional development (PD) for TAs. There are two types of information that could contribute to this improvement: knowledge about TAs' classroom behavior and knowledge about the influences on TA practice. The existing research on TAs has largely focused on descriptions of PD programs and limited assessments of their effects on TAs, usually with respect to how TAs' attitudes or beliefs may have changed. What are still rarer are detailed analyses of TA classroom practice and how both PD and TAs' beliefs and knowledge can affect that practice.

This chapter begins by reviewing the literature on TAs, including descriptions of PD programs, how their effect on TAs has been evaluated, and how TA practice has been analyzed. The second part of the chapter reviews research on teacher practice, focusing on how beliefs, context, and pedagogical content knowledge influence teachers' classroom practice. The literature discussed in this chapter sets the stage for analysis in Chapters Four through Six by providing an overview of literature useful for understanding TA practice. First I review what is known about TA professional development and I argue that detailed observations of TA practice will lead to better explanations of *why* TAs make the teaching decisions they do. I end by outlining some of the ways that researchers have attempted to explain science and mathematics teacher practice, because such literature could inform future TA PD. In addition, some of the analysis chapters include reviews of research useful for that topic: Chapter Four considers how reformed teaching correlates with student thinking and the effects of context on professors' instruction, and Chapter Six reviews research on responsive TA PD.

2.2 Previous research on STEM graduate teaching assistants

Research on TAs falls primarily into two categories: research that considers their job as TAs as one aspect of their role as graduate students and research that concentrates on their participation in professional development (PD) programs. Studies in both categories rarely include the in-depth characterizations of TA teaching practices that I argue are necessary. Studies that have included fine-grained descriptions of TA teaching are considered separately, in Section 2.3.2. Because research on graduate TAs is a small field, this discussion includes research on TAs in all of the STEM (science, technology, engineering, and mathematics) disciplines, in order to consider as much of the relevant literature as possible.

2.2.1 TAs identify past experiences and environmental constraints as effects on their teaching practice

Some researchers have looked at TA teaching as one part of students' overall graduate experience. In contrast to most TA literature, these studies do not attempt to describe or assess professional development that is offered to TAs. Instead, they examine the multiple roles of graduate students, in which they must be researchers and students in addition to instructors (Belnap, 2005; Bucher, 2002; Hume, 2004; Lin, 2008). Because the data mainly comes from the TAs themselves (through interviews or surveys), these studies can help us understand what TAs perceive as influences on their teaching. For example, Lin (2008) found that most of the Ohio State University physics graduate students she interviewed planned to teach as they had been taught and that some reported that their classroom decisions (such as whether to use group work) were constrained by the lecturer who supervised them. Another analysis, motivated by pilot study results that the PD offered to a group of University of Arizona math TAs had a limited effect, identified influences on TAs such as time demands, actions of supervisors, and past instructors (Belnap, 2005). Findings of this sort provide a starting point for research on TA PD, because they identify influences that should be further investigated.

2.2.2 A variety of TA PD programs have been offered

There are a significant number of studies that describe professional development programs offered to TAs (Etkina, 2000; Gilreath & Slater, 1994; Hollar, Carlson, & Spencer, 2000; Lawrenz, Heller, Keith, & Heller, 1992; Price & Finkelstein, 2006; Robinson, 2000; Rushin, et al., 1997). These studies can suggest specific techniques, such as peer observation (Robinson, 2000) or the use of experienced graduate students to lead training workshops (Hollar, et al., 2000). Other studies describe the activities that make up semester- (or quarter-) long courses (Etkina, 2000; Lawrenz, et al., 1992; Price & Finkelstein, 2006).

Lawrenz et al. (1992) is a typical example of descriptive PD research. It describes a mandatory course at the University of Minnesota that prepares physics TAs to lead group problem solving sessions and laboratories. The curriculum included discussions of constructivist theories of learning and the development of lesson plans. The TAs also learned about problem solving by solving problems in a group and then grading sample student solutions. An external evaluator assessed the course by observing TAs teaching, interviewing them, and administering questionnaires. The results of this evaluation, which also compared two cohorts of TAs, were broad and little data was cited to support them. For example, they found that the TAs in the second year "appeared more confident in their role as teacher, and there appeared to be more direction and purpose in the lessons." (Lawrenz, et al., 1992, p. 109).

2.2.3 Limited assessments of TA PD suggest positive effects

Some researchers have attempted to measure the effects of their training programs for TAs using surveys, written assignments, or interviews that assess reported changes in the TA's attitudes about teaching or learning (French & Russell, 2002; Hammrich, 1994, 2001; Ishikawa, et al., 2000; Ishikawa, Potter, & Davis, 2001). The studies using surveys have provided glimpses of TA changes after PD, including more appreciation of the importance of attention to student ideas (Ishikawa, et al., 2000), and an increased belief that skills learned while teaching can improve their research (French & Russell, 2002).

A study of this sort, conducted by Ishikawa et al. (2000) at the University of California, Davis, relied on written assignments and a free-response survey to assess the beliefs of two cohorts of TAs before and after a PD course. The researchers characterized common beliefs of the group of TAs as a whole before and after the PD course. Before the course, the TAs described the abilities of a good teacher as those of communicating knowledge, helping students, and motivating students with their enthusiasm. (These results were not separated by cohort.) After the course, the TAs in the first cohort added the skill of being "aware of student learning" as a characteristic of a good teacher; this was the only noticeable difference between the pre- and post-course assessments of the first cohort. The second cohort showed more changes in their conception of a good teacher. They were less likely to relate good teaching to the ability to communicate knowledge and they measured good teaching by the amount of student learning that occurred. An example of a response demonstrating this awareness was one that said, "When whatever you were trying to get into the student's head sticks there, there you are." (Ishikawa, et al., 2000, p. 6). Thus, after their participation in the PD course, TA's responses reflected a change from emphasis on the teacher to an emphasis on the students.

2.2.4 Limited observations of TA practice suggest straightforward categorizations of TA behavior

When TAs' teaching is observed, it is often done to assess the effectiveness of the training they were given (Ezrailson, 2004; McGivney-Burelle, DeFranco, Vinsonhaler, & Santucci, 2001; Pellathy, 2009) or because the observations are part of an assessment for a PD class (Allen, 1976; Etkina, 2000; Roehrig, Luft, Kurdziel, & Turner, 2003).

In the studies that use observations as part of a PD class, the main purpose for the observations is to generate feedback for the TAs, which is shared with them (Allen, 1976; Etkina, 2000; Roehrig, et al., 2003). These studies use observations to provide numerical assessments of the classrooms or general descriptions of what they have learned through their observations. For example, as part of the semester-long course Etkina offered to Rutgers University physics students, she visited each TA's classroom four times. Etkina rated the TA in categories such as "adequacy of wait time" and "assessment of student understanding" on a numerical scale. She summarized her observations with the reflection that, "After three years of observations of more than 20 TAs I have a clear picture of typical difficulties that TAs experience… A universal problem is that the TAs do not understand that every class has a goal." (Etkina, p. 130) The results of the classroom observations are provided as feedback for the TAs, but they are not included in the study; the purpose of the observations appears to be pedagogical rather than for research.

Research that explicitly aims to understand science graduate students' teaching (Calder, 2006; Ezrailson, 2004; McGivney-Burelle, et al., 2001; Pellathy, 2009) has used multiple measures to characterize TAs and their teaching. In these studies, observations are often used to categorize TAs' instruction. For example, Pellathy (2009)investigated the effect of PD workshops designed to improve the pedagogical content knowledge (PCK) of physics TAs at the University of Pittsburgh. He audio taped four TAs teaching discussion sections and coded the transcripts of the classes to determine how often they used different representations (such as analogy, graphs, or mathematics) when teaching problem solving.

As a result of these observations, Pellathy concluded that TAs infrequently used the multiple representations they were taught in their trainings and that they often omit steps needed to understand the procedures. For example, TAs rarely defined the system they were considering when solving work-energy problems. This is necessary because the definition of the system determines whether energy transferred from one object to another is considered internal energy (for a transfer within the system) or work (for a transfer from outside the system). This study's categorization of TA practice through coding allows us to see the relative prevalence of certain types of behaviors, which helped support Pellathy's conclusion that the PCK offered in the TAs' workshops did not significantly affect their teaching.

2.3 Understanding TA classroom practice

The research discussed up to this point provides an introduction to how TAs think about their teaching, descriptions of the PD programs TAs are offered, and an overview of how the effects of these programs have been assessed. These findings are a useful beginning: it is important, for example, to understand what TAs perceive as the influences and constraints on their teaching. One component that could contribute to improved TA instruction is a better understanding of what TAs do in the classroom. In this section, I argue that the research I discussed earlier has not paid sufficient attention to TA classroom practice. I then discuss a study that attends to TA teaching in the way I advocate; the detailed analyses of the TAs' teaching, along with interviews, allows us to better understand how TAs' beliefs affect their teaching.

2.3.1 TA classroom practice has been insufficiently studied

As the TA instructors develop PD programs for TAs, we need a way to assess their effect on TAs. Studies that primarily focus on describing a particular PD program may serve a purpose for other TA instructors who need suggestions for tomorrow's class. Their value is limited, however. If the effects of the program on the TA's teaching and his students are not included, the average TA PD instructor cannot determine whether a suggested training would benefit his TAs. When PD is not sufficiently assessed, we also miss an opportunity to understand the relationship between particular interventions and changes in TAs.

One way to evaluate PD is through surveys and written assignments. Surveys provide a way to assess larger groups of TAs and to identify shared knowledge or beliefs. However, a limitation of analyses built primarily on written materials is that they cannot address the question of how knowledge or beliefs affect practice. This is because the use of self-reported classroom analysis means that researchers may not be able to identify influences that the TAs had not recognized themselves and the TAs' self-reports may not accurately reflect their teaching practices. Multiple studies in math and science education have demonstrated that teachers' self-reports of their behavior and beliefs do not consistently correlate with their classroom actions (Bryan, 2003; Cohen, 1990; Jones & Carter, 2007; King, Shumow, & Lietz, 2001; Levitt, 2002; Simmons, et al., 1999; Tobin & McRobbie, 1997).

As discussed in Section 2.1, researchers have observed TAs in the classroom for the purposes of understanding the constraints on their teaching and to assess the effect of TA PD on the TAs. As an example of the limited descriptions of TA practice found in many works, consider the study of University of Arizona mathematics TAs discussed in Section 2.1.1 (Belnap, 2005). As part of a study to understand why the PD offered to the TAs was not significantly affecting the TAs practice, Belnap observed several TAs in the classroom. The following excerpt is a summary of Belnap's observations of three classes taught by a TA named Lisa.

From the very beginning, Lisa's teaching style consisted of lecture, which she would begin shortly after giving a few announcements or reminders. Initially, this lecture incorporated a cycle of instruction, illustration, and assessment. First, she would provide definitions and explain ideas, then she would show various examples, and finally, she would lead the class through sample problems, quizzing them occasionally for an answer or for single steps in a problem (Belnap, 2005, p. 50).

This characterization gives a general idea of the types of activities one might observe in Lisa's class. However, there are many details that could be included to give a better understanding of Lisa's teaching, such as whether examples and questions are chosen in response to student ideas or how much reasoning was required for an answer to be considered correct. Detailed knowledge about TAs' teaching practices, in addition to detailed knowledge of factors affecting that teaching, is needed to explain how teaching decisions are made. Understanding how teaching decisions are made, in turn, help us understand what TA instructors can do to better support and enable effective teaching practices.

2.3.2 Detailed observations of TA classroom behavior lead to better understanding of the motivations underlying those behaviors

As we have seen, descriptions of TAs in classrooms often characterize their teaching broadly. Fine-grained analyses of TAs' beliefs and practices are one way to better understand what drives their teaching decisions (Seung, 2007; E. Seymour, 2005; Speer, 2001). One such example is a dissertation by Speer (2001), which suggests that typical assessments of instructor beliefs, especially surveys, are insufficient for understanding the individual instances of classroom practice.

Speer studied two graduate mathematics TAs at the University of California, Berkeley who shared two beliefs: that learning mathematics requires problem solving in addition to procedural skills and that mathematics includes learning about ideas and relationships. However, the detailed case studies of the two students, Zachary and Karl, show important differences in their beliefs. These differences only became apparent during interviews in which the TAs discussed video clips from their classes. The use of video-clip interviews placed the TAs' explanations of their actions and motivations within the context of specific examples.

One example of a dissimilarity uncovered through the video interviews is the TAs' beliefs about questioning. Although both TAs thought that it was important to question students, Zachary felt that questions were necessary to check the strength of student understanding and to provide a mechanism for students to learn. Furthermore, when students were unable to answer his questions, he considered this evidence that they did not understand the concept. As a result, his questions were often motivated by his desire to understand the students' difficulties and to help them identify and overcome their problems themselves. On the other hand, Karl asked questions to model the behavior he wanted students to emulate when problem solving and to monitor their learning so he knew when to intervene. Karl looked for situations where he needed to intervene because it was important to him that students not stray too far from the material that he had prepared and that all students complete the same problems. As a result of his corrections, students in Karl's class spent less time exploring why their original answers were incorrect than in Zachary's class. In addition, Karl often assumed that a student's lack of a correct answer was due to low confidence or a momentary "forgetting" of what they already knew. This meant that he had fewer chances to find the inadequacies in his students' conceptions.

These detailed case studies point out subtleties that a survey assessment alone would not have detected and the observations of classroom work provide a way to see how these belief differences about questioning compared to classroom teaching styles. This suggests that surveys that ask about teachers' beliefs, even if they are specific, would be less likely to reveal the finer-grained differences that lead to different teacher behaviors. Surveys might also not reveal the different beliefs that might be activated, depending on the context of the particular situation. The students in Zack's and Karl's classrooms had different classroom experiences, but these variations could only be understood though the careful examination of behavior in the classroom.

Past research on TAs has begun to answer important questions about TAs. We have some tentative ideas about what TAs think their job in the classroom is, what they think constitutes good teaching, and some of the general difficulties they face when teaching. We can build upon this, as Speer has done, by examining episodes of TA classroom practice to better understand the actual behavior of TAs in classrooms, what motivates it, and how it affects students.

2.4 Research on K-12 teacher practice as a guide for TA professional development

Considering the limited research on TA instruction and the effectiveness of PD offered to them, where could we look for research to inform the study of science TAs? The natural place to look is at science education's attempts to explain teacher practice, especially novice teacher practice. The application of this literature should be done carefully, however, because while TAs have many similarities to novice teachers, they also differ in important ways.

It seems apparent that there are some differences between TAs and teachers. Teachers have typically had more instruction in educational methods. Because TAs are graduate students, most have more instruction within the discipline they teach, compared to teachers. (While only 33% of physics K-12 teachers have a physics degree (Neuschatz & McFarling, 1999, p. 9), 90% of physics graduate students have a degree in physics or astronomy (Mulvey & Tesyafe, 2006, p. 6)). Each population is a member of a different community, and likely identifies differently: TAs primarily identify themselves as physicists, or physics students, and only secondarily as instructors, whereas teachers consider “instructor” to be a primary part of their identity. The job of teaching also serves a different purpose for each: teachers have chosen to make education their profession, while graduate students act as teaching assistants because it supports their choice to attend graduate school, and they may or may not plan to teach once their schooling is completed.

The similarities between novice teachers and TAs, however, suggest that research aimed at explaining teacher practice can help inform research on improving TA practice. For example, both novice teachers and TAs have little experience in running their own classrooms and must balance the tasks of teaching and classroom management. Both groups are considered experts by their students, yet they both may not identify themselves as pedagogical experts. They both may work with curriculum that they have not chosen themselves. They are both learning how to balance classroom management while creating opportunities for student learning. In addition, while they have spent many years as a student, they may not have much experience in attending to and responding to student thinking.

2.4.1 Teachers’ pedagogical and epistemological beliefs may influence their practice

Although we must be careful when using teacher research to understand TAs, it can provide a starting point for understanding their behavior. The vast field of teacher belief literature on teacher beliefs is a good starting point. Because I am interested in understanding what influences the decisions TAs make in the classroom as they teach, I focus this discussion on research that has examined teachers’ instruction, through observations or recordings, as well as their beliefs.

One focus of teacher belief literature is on identifying and categorizing teachers’ beliefs (Brickhouse, 1990; Southerland, Johnston, & Sowell, 2006), which are often assumed to be a coherent set of beliefs that describe an individual and her behavior. A difficulty with these studies was that this alignment between beliefs and behavior is assumed rather than verified. Other studies go beyond categorization to compare teachers’ beliefs to their practice (King, et al., 2001; Lederman, 1999; Levitt, 2002; Simmons, et al., 1999), and find that some teachers demonstrate a strong correspondence between their beliefs and practice but others do not. This apparent conflict between teachers’ beliefs and their classroom practice has led to more nuanced examination of belief variability, including explanations that distinguish between professed and enacted beliefs and a consideration of teachers in a transitional period between traditional and reform methods of instruction. In this section, I look at a few examples of how researchers have used teachers' beliefs to explain their practice.

2.4.1.1 Teacher beliefs can support or interfere with implementation of reform curricula

Teacher beliefs can be roughly categorized into three types: *pedagogical*, *epistemological*, and *nature of science*. (Nature of science beliefs are often assessed separately and less frequently, and so will not be discussed here.) Pedagogical and epistemological beliefs include ideas about how students learn, such as by receiving information from the teacher or by making meaning of their own experiences; what the role of the teacher should be, such as a guide, a transmitter of knowledge, or the maintainer of order; and what counts as evidence that students have learned, such as reproducing information or applying it novel situations. Researchers have studied how beliefs influence the implementation of reform curriculum or reformed standards (Cronin-Jones, 1991; Haney, Lumpe, Czerniak, & Egan, 2002; Peterson, 1990; Wiemers, 1990); they have also considered how beliefs shape particular classroom practices, such as teachers' use of questions (Rop, 2002) or how they assess students' prior knowledge (2006).

Cronin-Jones (Cronin-Jones, 1991) presented two case studies of middle school science teachers showing how teacher beliefs that conflicted with the philosophy of a reform constructivist curriculum affected the implementation of that curriculum. Using interviews and classroom observations, Cronin-Jones showed that the two teachers she studied shared beliefs that their students should learn factual knowledge, that they needed repeated drills, and that they required careful direction. As a result of these beliefs, the teachers taught the curriculum in a different way than it was intended. For example, because the teachers believed that students needed a great deal of direction, they often modified the group work activities to be done individually or presented the material through a lecture.

Schoenfeld's case studies (1998) show how a deep understanding of teachers' beliefs (along with their knowledge and goals) can be used to provide a causal story of their individual decisions. In each of the four cases, the teacher's beliefs, knowledge and goals for a sample teaching episode were carefully detailed. A model of the episode was developed which demonstrated how particular goals and beliefs contributed to each action that the teacher took. One example is a case study of a physics lesson taught by Jim Minstrell, a physics education researcher and high school physics teacher. When a student suggests an alternative to the conventional method for computing the mean of a set of numbers, the teacher's belief that physics is a sensemaking activity and that student contributions should be encouraged are reasons why the teacher then gives the class time to discuss the new method. The episode analysis addresses how student moves present choices where the teacher must decide the direction of the lesson. For example, when the student suggested an alternative, addressing it meant a digression from the lesson plan. The teacher could have dismissed it quickly or explained why it was essentially similar to previous suggestions. Instead, his knowledge about how students think about averages allowed him to immediately recognize what the student means, and his belief that it is important to encourage student inquiry caused him to temporarily suspend his plan for the class and pursue the student's idea.

In Chapters Four and Five I give specific examples of how TAs' beliefs influence their teaching, resulting in an implementation of reform curriculum that differs from what the curriculum developers intended. The research reviewed in this section suggests that instructors' beliefs can align with their classroom practice (an alignment also seen in TAs) and thus that successful implementation of reform curriculum depends in part on attending and accounting for TAs' beliefs.

2.4.1.1.1 Teacher beliefs and teacher practice mutually influence one another

The past sections may appear to posit a clear, directional effect from teachers' beliefs to their practice. At times it is hard to tell whether this directionality is a convenience, because it may be hard to examine how both beliefs and experiences interact, or whether there is a tacit theoretical assumption that the primary effect goes in one direction. Some of these studies clearly emphasize that beliefs and teaching experiences interact in an ongoing feedback loop (Aguirre & Speer, 1999; Fennema, et al., 1996; Franke, Carpenter, Levi, & Fennema, 2001; Levitt, 2002; V Otero, Finkelstein, McCray, & Pollock, 2006; Schoenfeld, 1998). In Chapter Three, I discuss the implications of assuming unidirectional effects (such as how beliefs influence teaching) and make a case that beliefs and experience must be considered as two factors that mutually affect each other.

In order to understand how examining the complex interaction between teachers' beliefs and practice has resulted in more effective professional development, consider a group of studies on the implementation of Cognitively Guided Instruction (CGI) (Fennema, et al., 1996; Franke et al., 1998; Franke, et al., 2001). CGI is a professional development program for teachers that helps them learn the purpose of recognizing and utilizing student thinking about mathematics. The training teaches them a theoretical model of children's problem solving abilities and problem difficulties, and helps focus their attention on understanding students' problem solving strategies. In one study of two dozen elementary teachers from schools in and around Madison, Wisconsin, the authors compared the students' conceptual and problem solving abilities to classes of these teachers prior to their three years of CGI instruction (Fennema, et al., 1996). The students' abilities increased for every teacher in every grade level and the majority of the teachers were found to have increased beliefs in the ability of students to do math without modeling algorithms.

The authors describe the process of teacher change in the following way. In the early PD sessions, the teachers learned various ways to categorize math problems, which helped them use a wider range of problems, and they learned ways that students typically solve various types of math problems.

> When they tried out problems with their own students, teachers could see that the children actually invented strategies to solve the problems similar to those discussed in workshops. At this point, there began to

> be iterative changes in teachers' knowledge, instruction, and beliefs. As the teachers saw that their students were capable of inventing strategies and doing more than they had anticipated, they increasingly made problem solving a greater part of their instruction, the children increasingly solved harder problems and reported their thinking… and so it continued. (Fennema, et al., 1996, p. 431)

This analysis demonstrates that one element underlying the success of the CGI program is the acknowledgement that beliefs and practice must change together in order for the changes to be sustained.

The data and analysis presented in this dissertation do not explicitly address how TAs' beliefs and practice mutually influence each other as TAs develop their beliefs and classroom behaviors. More longitudinal data would be necessary to address this question. However, the analysis of individual episodes describes how TAs' beliefs and practice mutually reinforce each other as the TAs interact with their students. In addition, Chapter Six argues that effective TA PD should include opportunities for TAs to regularly practice what they are learning in their PD courses as they are learning it, and to participate in PD activities that respond to the TAs' beliefs. This argument is based on the success of programs such as CGI, which focus on simultaneously developing reformed teaching and beliefs supporting reform teaching, as well as the analysis in Chapters Four and Five that show how TAs' instruction suffers if TA instructors do not attend to TAs' beliefs.

2.4.2 Contextual factors influence teacher practice

Another way that teachers' behavior has been explained is by examining how the environment in which they work affects what they do in the classroom. These contextual factors, (also referred to as environmental, institutional, or social factors), can both support or impede reform teaching, although past research has focused mainly on issues that interfere with improving instruction. In their review of research on teacher learning, Borko and Putnam (1996) identify obstacles to teacher learning that include discipline- based university courses emphasizing algorithmic learning, school policies providing little free time for teachers to reflect or collaborate, and expectations of parents and administrators. Contextual factors can affect teaching by influencing which beliefs the teachers rely on in a given situation, or by shaping what they think is allowed or possible in their classroom. In particular, researchers have looked at how contextual factors influence how reformed curriculum is implemented (Davis, 2003), whether teachers pay attention to student ideas (Levin, 2008), and whether they focus on procedural or conceptual understanding (Cohen, 1990; Eisenhart, et al., 1993).

Rop (2002) examines how a chemistry teacher's response to student questions varies depending on which beliefs are prioritized, which in turn depend on the context of the questions. The case study, conducted at a Midwestern suburban high school, analyzes the teacher's beliefs (which Rop calls "teacher assumptions") and his responses to "Student Inquiry Questions" (SIQs), student questions that are content related and arise from curiosity. The teacher, Mr. Kelso, considered SIQs evidence of student understanding and effort, but was also wary that they could divert time and attention from each period's objectives. For example, when a SIQ was asked during the few minutes at the end of class, he engaged in an extended dialogue with three students about the question. This action was in line with his beliefs that SIQs can help him diagnose student understanding and that students who frequently ask them are intelligent and understand the lesson. However, when a student asked an SIQ during the time he had allotted for the lesson, Mr. Kelso deflected the question. This behavior was aligned with another set of beliefs, in which SIQs were seen as annoying and a disruption to the lesson. The difference in Mr. Kelso's responses in the two situations is connected to the pressure that Mr. Kelso felt to cover the material the students will need for the next year's class. If his students are not prepared, Mr. Kelso will have let down his students and the instructors in the science department who will be teaching the students in the future. This example shows that while a teacher's decisions are influenced by his beliefs, these beliefs can be shaped by the environment in which they work, which in this case is the limited class time and the departmental value that good teachers "cover the book."

These results from teacher literature align with the analysis of Chapter Four, which shows how context can affect instructor practice. This chapter describes the differences in context at two universities and argues that these differences help account for observed differences in buy-in to reform curriculum from TAs at the two universities. These contextual factors include some of the issues that Borko and Putnam mention, such as university policies and expectations of students and supervisors.

2.4.3 Teachers can improve their practice by improving their pedagogical content knowledge

While some education researchers have focused on the effects of insufficient content knowledge of preservice science teachers, this has not been a significant concern for those involved in TA training. There is anecdotal evidence that graduate students have conceptual difficulties with the introductory material that they teach (Roehrig, et al., 2003; Stetzer, 2010), but it is difficult to find research investigating how TAs' content knowledge (or lack of it) affects their teaching.[1]

An aspect of graduate student knowledge that likely to be lacking is pedagogical content knowledge. Schulman (1986) argued that the focus on pedagogical knowledge at that time was ignoring the importance of a different kind of knowledge, what he called pedagogical content knowledge (PCK). This category includes knowledge needed to teach a particular subject: the ideas and knowledge the students might bring to the classroom, common misconceptions or difficulties, and multiple presentations of a topic, including metaphors, rephrasings, and examples. This is the knowledge that TAs, who have previously participated in classes only as students, may well be lacking, because understanding the various ways that students

[1] The University of Washington (UW) physics education group routinely asks physics graduate TAs to complete conceptual tests. The TA results are compared to undergraduate student and in-service teacher post-test results after instruction using the curricula developed at UW. It is not unusual for undergraduates or in-service teachers to meet or exceed the level of conceptual knowledge of TAs (McDermott, 2001; McDermott, et al., 2006). These results suggest there is potential for improvement in TA conceptual understanding.

can make sense (or fail to make sense) of a particular subject goes beyond understanding how you made sense of the subject as a student. Research on teachers has demonstrated that helping teachers gain PCK is a difficult task (Lederman, Gess-Newsome, & Latz, 1994), even when the explicit focus of the PD is on that task (Fennema, et al., 1996; Franke, et al., 1998; Franke, et al., 2001; van Driel, Verloop, & de Vos, 1998).

Research on pedagogical content knowledge has not been used in isolation to explain teacher behavior, but rather is considered in conjunction with teachers' beliefs, goals, or content knowledge to account for their practice. It has also been used to explain improvements in teacher instruction. There are at least two ways that teachers' increased PCK can lead to improved science instruction: PCK helps teachers recognize student ideas more easily and it allows them to prepare instruction that anticipates common student difficulties.

A demonstration of how improved PCK can lead to better instruction is found in a study of an experienced math teacher teaching at a Midwestern urban middle school (J. Seymour & Lehrer, 2006). The teacher, Ms. Gold, is teaching a unit connecting algebraic reasoning to geometric ideas. The case study is built on video clips of lessons where Ms. Gold wants to her students to learn about slope using various representations, such as Cartesian graphs, equations of the line, and similar rectangles. She begins by asking students to use their similar rectangles (a group of rectangles whole sides have the same ratio) to write an equation for the steepness of the line, but the students do not understand the task. Following the suggestion of the participating researcher, she asks them how a graph and the corresponding equation "do" the same kind of multiplication. This prompts many students to explain their ideas. Eventually Ms. Gold assigns each student the task of writing a rule that will tell another student how to reproduce a line. In the initial task, Ms. Gold cannot make the students understand her question, but after a different question provides a place for student ideas, she tries to makes sense of the various ideas being presented. This allows her to become more familiar with the different ways students describe slope and she begins to align her word choice and use of representations with those of her students. When she teaches this lesson again the next year, she is better able to assess student difficulties and to tailor her assistance to respond to student thinking and context. This is due to her improved PCK relating to the particular topic of slope. She can now make sense of more student ideas and can employ an array of tasks and questions that have proved successful from the previous year. In addition she continues to adapt to the new ideas that she hears from her students. This case study shows how the teacher's ability to translate between her students' ideas and the target concepts improves as her PCK improves.

The analysis presented in this dissertation does not specifically address TAs' PCK. The results discussed in this section demonstrate that increased PCK can improve instructors' abilities to teach in a reformed manner, and this suggests that TA instructors should consider PD that improves TAs' PCK. At the University of Colorado, Boulder, undergraduate Learning Assistants (LAs) participate in a semester-long course to improve their PCK; the use of LAs in tutorial instruction has significantly increased student scores on the standardized Force and Motion Concept Evaluation, even in comparison to reformed classes that did not use LAs (Otero, et al., 2006). However, increased PCK does not automatically lead to changes in instruction: Pellathy's work to improve physics TAs' use of representations in problem solving (discussed in Section 2.2.4) showed that after explicit instruction on relevant PCK, TAs showed increased knowledge about various problem-solving representations but this knowledge was rarely used during their teaching (Pellathy, 2009). It may be that increased TA PCK needs to be accompanied by changes in beliefs and attitudes about teaching and learning before sustained changes in classroom practice are observed.

2.4.4 Conclusion

The limited amount of research on STEM TAs has demonstrated that PD can lead to changes in their beliefs about teaching and learning and their understanding of what constitutes good teaching. PD programs can also increase TAs' pedagogical content knowledge and their confidence in their abilities. Research on how these changes in TAs beliefs, knowledge, and attitudes translate to changes in classroom practice is insufficient. When TAs' teaching is observed, their teaching is often categorized in simple ways; detailed observations by researchers like Speer (Speer, 2001) show how we can improve our understanding of how TAs' motivations underlie their behavior.

The more extensive research on teacher practice provides insight into how TA PD can be improved. While the similarity between teacher and TA influences cannot be unproblematically assumed, work showing the influence of teachers' beliefs, context, and PCK on their teaching practice lead us to expect similar influences on TAs.

This chapter has established the need for additional research on physics TA PD and TA practice. The next chapter describes the theoretical framework that underlies the research on TAs to be presented in Chapter Four through Six.

Chapter 3 A theoretical framework for explaining interactions and cognition

3.1 Introduction

The work in this dissertation is primarily concerned with generating explanations for TA practice in the classroom. The analysis is based on data from two sources: episodes of TA/student interactions and interviews of TAs discussing their teaching and their students. I want to be able to explain TAs' teaching decisions using both environmental factors and elements of their thinking. I use video of TAs and students in the classroom to both identify teaching practices and, in part, to explain those teaching practices. Thus, Section 3.1 discusses how I interpret what goes on when people interact with each other. I also explain TA practice with the interviews in which TAs discuss their teaching. Because I analyze TA thought, I use the next two sections to enunciate my assumptions about what grain size we should consider when analyzing thinking and how cognition is organized. Section 3.3 discusses whether I analyze thinking as it is occurring in an individual's mind or as individuals interact with their larger environment. Section 3.4 describes how I understand the nature of the "stuff" in people's minds (including ideas and beliefs). Lastly, because I use what the TAs talk about in their interviews to characterize their beliefs, Section 3.5 introduces my definition of the term 'beliefs' and discusses two characteristics beliefs sometimes have: context-dependence and stability.

To see the type of questions I address in this chapter, consider an excerpt of a teaching episode that is discussed in Chapter Five. In this episode, a group of four students has called a TA, Alan, over to the table to ask him a question about the problem they were working on.

S4: How does this look to you?
[Alan looks at S4's paper]
S1: It's like the opposite of the…
Alan: Well, yeah, that's what it ends up looking like. I mean, I'm not sure that you can always say that it will be the exact opposite of… Maybe this one, in this case it happens to be.
S3: Okay.
Alan: But, I mean, I'm guessing you guys sort of thought this one through and sort of figured out-
S3: Yeah.
S4: Yeah.
Alan: -why it would look like that.
S4: Yeah, definitely.

This episode proceeds so unproblematically that it is easy to gloss over how Alan and the students have established, with minimal effort, an agreement about what should be happening, namely that Alan should verify that the students' are doing the right thing. What assumptions underlie this shared understanding that the TA's job is to check answers? How do Alan and his students decide what they should be saying or doing in each moment? What verbal and nonverbal signals do they provide to each other to verify that they are understanding what is going on in the same way? In addition, if we say that Alan "thinks" he should be doing something, is this idea something we expect to be consistently influencing his teaching, or will it depend on the particular context?

To begin with, let us consider the first issue, which is how I explain what is happening when people interact.

3.2 Explaining interactions: Framing

3.2.1 The answer to "What is it that's going on here?" is how individuals figure out what to do next

As mentioned in the introduction, the central goal of my work is to understand TAs' teaching. In part this is done by examining episodes of instruction to determine what TAs think they are doing in the classroom and why they might think that behavior is suitable. Every time individuals (in these cases, a TA and students) have an interaction, each person must decide what activity he or she is engaged in, based on the environment and the conversation and body language of the other participants. This decision is usually unconscious and is constantly being revised as the interaction continues. In other words, a TA and his or her students are unconsciously working to answer the question, "What is it that's going on here?" (Goffman, 1974, p. 8).

Framing is the process of determining the answer to this question. The construct of framing, developed in anthropology and linguistics (Bateson, 1972; Goffman, 1974; MacLachlan & Reid, 1994; Tannen, 1993a) includes people's use of expectations of what actions are appropriate and what events might be expected in a particular situation. Framing also helps direct an individual's attention (Hammer, Elby, Scherr, & Redish, 2005b). An example of framing is the interpretation of a loud debate as either a friendly discussion or an argument. Similarly, a teacher may frame a physics problem as an opportunity for sense making or as an occasion for rote use of formulas.

To see how a person's framing affects his behavior, consider a father at his child's soccer game. He might frame his activity as rooting for a sports team or as time to nurture children. How he frames the soccer game will lead him to notice different things: if he is rooting for a sports team, he may pay attention to who is scoring points, whereas if he is nurturing his child, he may note who is having fun. This would also affect his behavior, leading to more partisan cheering in comparison to general encouragement. This example also demonstrates the role of context in framing, because a league championship might be framed as a competition, while an unscored scrimmage is more likely framed as an opportunity for fun. Contextual cues can also cause a change in frames, such as when a father rooting for the team suddenly focuses on his child's wellbeing if she is injured.

Because all the episodes I analyze involve students working collaboratively in the classroom while interacting with their TAs, there are two types of framing that are particular interest: epistemological framing and social framing. Epistemological framing refers to how teachers and students figure out which of their expectations about learning and teaching are relevant in the particular situation (Redish, 2003). In the introductory example, Alan's students seem to have expectations that they should agree on the answer they choose, and that one of the TA's jobs is to make sure they have the right answer. Social framing involves individuals forming an idea of what they should expect from each other during interactions. In the above example, students expect that they can call the TA over when they need help, and Alan probably expects that his students will listen to him when he is speaking. For individuals working together collaboratively, the social and epistemological aspects of framing interact. A TA who thinks it is important to build on student's ideas may frame a discussion as "understanding a student's idea of momentum"; the same discussion could also be framed as "checking a student's answer" if the TA was helping students prepare for an upcoming exam.

3.2.2 How individuals frame depends on the context and how other participants are framing the situation

Framing allows TA's behavior to be explained by both the immediate situational characteristics as well as the indirect influences from past experiences. How a person frames is influenced by the past, when previous interactions helped create her expectations about the current situation. The immediate situation influences her framing as all the participants interact using speech and nonverbal signals to form their shared understanding of the activity.

The episodes I consider in the analysis chapters demonstrate how TAs' framings are influenced by both internal expectations and external cues from the environment and other participants. In Chapter Four, I discuss how the TA Oscar's beliefs, focus of attention, and behaviors all interact, feeding back into each other to help him establish a stable epistemological frame. I assume that context will affect TAs' thinking and actions in the tutorial classroom. This assumption is supported by the analysis in this dissertation. The case study of Alan, discussed in Chapter Five, provides an example of how context helps shape his teaching decisions: in one episode he frames the interaction as checking an answer, whereas in another he sees his job as giving a hint. In Chapter Four, I also provide examples of how the social and environmental context affects how TAs frame their tutorial teaching.

A group's framing of an interaction becomes stable when the individual ways of framing reinforce each other. Because framing takes place continually, the behavior of others then becomes further information that individuals can use to check whether they are framing in the same way as the group. We see, when examining episodes of Alan's teaching in Chapter Six, that when Alan frames an interaction as "answering a question," his students provide cues that support his understanding that this is an appropriate activity. They expect help, and consider TA-led explanations appropriate in discussion sections. They listen attentively, ask questions to clarify what he is saying, and direct their attention to him; these actions all reinforce Alan's idea that answering their question is the right thing to be doing.

3.2.3 Framing in other disciplines

Frames, scripts, and schemata are related and overlapping terms in the fields of linguistics, artificial intelligence, cognitive psychology, social psychology, sociology, anthropology, and other disciplines.[2] My use of framing is most closely related to work done by Goffman (1974) and Tannen (1993a). Goffman, a sociologist, used frames to understand how experiences are organized. His frames are often generalizable to the human experience and he draws on examples from newspapers and literature to explain his frames. For example, he suggests categories of frames that include interpreting events as "stunts," which push the boundary of what a person expects but still is explainable. This contrasts with an "astounding complex," in which a natural event is not explainable with natural laws. Goffman's goal when using frames is different than mine, because he seeks to understand how people in general make sense of the events that happen to them, while I examine particular individuals. His work does not suggest particular frames that we would expect to see in classrooms, but he does provide explanations for how frames function that are directly applicable to understanding instructors and students in the classroom. For example, Goffman identifies "out of frame" activities as those that people know they should not directly attend to. An example would be one student asking another to borrow a pencil while the TA is talking to the group. The other students know in this case that they are supposed to continue paying attention to the TA rather then the side conversation. Similarly, Goffman's "flooding out" occurs when a frame is broken through intense laughter or the realization that participants have been framing the interaction in different ways. In the classroom, this might occur if one student cracks a joke in the middle of an intense argument; the resulting laughter might flood out the frame and change what the students are doing.

Some linguists use frames to analyze the particular actions of individuals (Hoyle, 1993; Tannen, 1993a; Tannen & Wallat, 1993). Tannen's work describes how expectations are formed, how researchers can see evidence of these expectations, and how these expectations influence participants' behavior. As Tannen explains it, people interpret their situations not in a sterile, rational way; instead their interpretations are influenced by their past experiences. As experiences accumulate, people organize them into typical event sequences (which Schank and Abelson call scripts (Schank, 1980)) that they can then draw on in new, but similar, situations[3] (Tannen, 1993a). As people engage in the situation, "structures of expectation make interpretation possible, but in the process they also reflect back on perceptions of the world to justify that interpretation" (Tannen, 1993a, p. 21). Thus, expectations guide behavioral choices, but the results of these actions are then compared to the set of expectations originally used and the actions and expectations continually feed into each other.

The work presented in this dissertation is heavily influenced by Tannen's style of analysis, including types of evidence and how interactions influence framing. Among other evidence of frames (which I discuss in Chapters Four, Five, and Six), I use Tannen-identified linguistic markers such as omissions, hedges, and evaluative

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[2] An overview and history of the uses of these related terms appears in Chapter One of Tannen's Framing in Discourse (1993a).

[3] One frequently used example is the fast-food schema, in which a menu on the wall, plastic tables, and food served in disposable containers cuse a relatively stable set of expectations: that customers order and pay for their food before they sit down and that the food will be inexpensive (Redish, 2003; Schank, 1980).

language. In Tannen and Wallat's analysis of a conversation between a girl, the doctor examining her, and the girl's mother, the doctor shifts frames quickly as she teases the child, answers the mother's questions, and narrates her results of the examination for a video camera recording being made for other doctors (Tannen & Wallat, 1993). In this case, the doctor frames her activities differently for each of the three audiences. As she interacts with the child to build rapport and examine her, and with the mother to discuss the child's health, interactions can shift or reinforce her framing. For example, the mother withholds her question while the doctor is reporting her findings to the camera, reinforcing the "reporting frame."

3.2.4 Explanatory trade-offs between direct local and indirect contextual factors

One of the tensions in describing behavior is how to account for the influence of both moment-by-moment interactions and the larger context in which individuals live and work. The tension is particularly salient to the analysis in Chapter Four, which discusses TA buy-in to reform instruction at two different universities. In that chapter, my use of framing is influenced by the work of Erikson (2004), who stresses that there is a tradeoff between scope and precision. When we consider how an individual's actions at a particular instant are affected by his moment-by-moment context, such as the particular students a TA is addressing or the particular problem they are solving, we can make quite specific arguments about these influences. At the same time, we are rarely able to trace how the larger context might be influencing particular decisions. In addition, this immediate explanatory power does not extend to other TAs or even the same TA in other circumstances.

When we step back to consider how that same TA's behavior is influenced by the larger environment, such as the attitudes of his coworkers or the type of class he is teaching, our explanations must necessarily become broader. That is, considering the larger context allows us to account for TA behavior by considering his past experiences and the large-scale situation in which he is working. These influences cannot be captured by videotape, and force us to make more general claims about their impact on the individual TA. The ability to make arguments about groups of TAs who share similar contexts helps compensate for the lack of detailed explanations.

3.2.5 Framing does not imply a particular cognitive perspective

In the previous section, I presented framing as a way of accounting for how people navigate their interactions with people and objects in the world. This framework allows for at least two players – the person (or group) who is framing, and the person (or people or objects) with whom the person (or group) is interacting. What has not been made explicit so far in the discussion is whether it is most effective (for the analyses presented here) to consider the cognition that motivates people's behavior as residing in one individual, a group of people, or people and their environment as a system, and whether using the construct of framing requires me to choose one of these perspectives.

As I discuss in Section 3.3, there are different ways to think about where cognition takes place. The cognitivist perspective focuses on thinking as it happens in the mind of a single individual, while the socio-cultural perspective focuses on cognition as it occurs within individuals' interactions with each other and their environment. Framing is compatible with either of these perspectives; thus, the use of framing does not force the choice of either perspective. For example, a researcher using a cognitivist perspective and framing might focus on the expectations an individual brings to a particular situation and how this individual interprets signals from other participants to either verify or contradict her understanding of the situation. On the other hand, a researcher with a socio-cultural perspective might use framing to attend to how the participants mutually construct a shared understanding of the nature of their activity. In the following section, I argue that both of these perspectives are different ways of explaining the same phenomena. They do not provide fundamentally different explanations for what is taking place; instead, each perspective highlights different aspects of the situation, which allows different questions to be answered.

3.3 Thinking can take place both in the mind and in interactions

The cognitivist and socio-cultural perspectives both address the issue of what grain size we can consider when studying cognition. Both acknowledge the role of the individual and what happens in her head, and the role of the people and the environment with which she interacts. They differ in whether they emphasize the role of the individual or the role of the interactions.

When the physics education community discusses how theories can be understood along the socio-cultural to cognitive spectrum, these discussions are usually focused on learning. My work rarely addresses the question of how learning is occurring, for TAs or for students. However, explaining TA practice very much relies on understanding the cognitive processes that guide behavior in the classroom. Thus, the question I must answer here is which grain size will be more appropriate to my analyses.

3.3.1 Cognitivist perspective

The cognitivist perspective takes the individual and his thoughts as the appropriate unit of knowledge. Knowledge is a "structure of mental representations" (Greeno, 1997, p. 92); in other words, when a researcher using the cognitivist perspective says a person knows something, it means that that person has cognitive structures, such as concepts or beliefs, or demonstrates abilities like reasoning and problem solving that are seen to stem from these concepts (Cobb, 1994; Greeno, Collins, & Resnick, 1996).

This view holds that a person learns by actively constructing knowledge. A researcher using this perspective would focus on the cognitive components such as beliefs, goals, and knowledge that a person possess, and use these components to explain a person's actions (Greeno, et al., 1996). While the role of the world in which the person acts is acknowledged and valued, the primary focus is on an individual's mind.

To better see the assumptions and the ways attention is focused within this perspective, consider Speer's study (2001) of mathematics TAs that was discussed in the previous chapter. Speer gathered data on two TAs, Zachary and Karl, by videotaping their teaching and then discussing the TAs' beliefs and teaching practices as prompted by viewing the videotaped teaching with them. Speer sought to draw out fine-grained differences in the two TAs' behaviors and beliefs. This included constructing "belief profiles" of each individual's beliefs about students, teaching, mathematics, and how learning occurs. These belief profiles were a way to characterize differences in the two TAs.

This work largely springs from a cognitivist perspective. The attention is on the beliefs that are in each TA's head, and these beliefs are used to explain each TA's teaching behaviors. Because the behaviors that are discussed are taken from particular video episodes, the behaviors are embedded in particular contexts. While the context, including what the students say and what they have written on their worksheets, is considered and used to help explain the behavior, the primary focus is on how the TA's beliefs drive their behavior.

3.3.2 Socio-cultural perspective

The socio-cultural perspective takes as its unit of analysis the "individual-in-social-action" (Cobb, 1994, p. 13). That is, the mind of a person cannot be separated from the context in which the person is acting and knowledge is seen as something that is distributed across the people and the things with which they interact, in contrast to a cognitivist understanding that knowledge resides in someone's head. This perspective focuses on understanding the situation as a whole, rather than the individual actors. For example, Hutchins (1996) examines the navigation of a ship in a port, a complex task requiring many people to coordinate different pieces of information, which included taking bearings and locating the ship's position on a map. Individual's activities are considered, because the role of the bearing taker is different than that of the log keeper. But the unit of analysis is the navigation team and their tools as a whole. This larger unit allows us to better understand how the action of maneuvering the ship takes place, because the action itself depends on many people and their interactions with the objects around them.

From the socio-cultural point of view, learning occurs as people involve themselves in a community of practice (Cobb, 1994). Because knowledge is demonstrated through participation in a community, learning happens as people gain the ability to participate (Greeno, et al., 1996). In the case of a graduate TA, learning how to teach includes learning how to explain concepts to students and participating in discussions with colleagues (other TAs and professors) about how to help students learn.

Consider an example of a classroom study that was conducted from a socio-cultural perspective. Roth et al. (1999) examined how the arrangement of a classroom affected how sixth and seventh grade students participated in a science unit on simple machines. The data collected included video recordings of the activities, photographs of the position of objects in the room, observations, and interviews. The researchers investigated how particular artifacts, such as projectors and experimental equipment, affected student participation. For example, when class ideas were recorded on a transparency, it provided a way for all participants to see the ideas, but which ideas were recorded and how they were written down was mediated by the teacher. When students worked on projects in small groups, they were able to help each other more and they were all able to participate and manipulate materials. However, the activity also loosened the constraints on the content so that discussion was not always on scientifically productive content.

The socio-cultural perspective used in this study supports the researchers' focus on how the context allows for and encourages particular kinds of participation from the individuals. The students are not analyzed separately from their environment in which they are learning, which includes the instructor, the objects they are using to do their experiments, the layout of the classroom, and the types of activities in which they are engaged. The focus is on how the environmental aspects affected the activities of the group of students as a whole. In contrast, a cognitivist view might have focused on how individual students interacted with the environment, such as whether a student's actions were aligned with the context or how a student used or ignored objects during that class's activities.

3.3.3 Choosing a perspective of where thought occurs

On a spectrum spanning cognitive and socio-culturally oriented perspectives, the work presented here lies somewhere in the middle. Consider, for example, the analysis of TAs' buy-in to tutorials that is presented in Chapter Four. The data I use to measure TAs' buy-in comes from interview excerpts. These interviews were intended to elicit TAs' thoughts and beliefs about tutorials, and thus I consider the beliefs that they discuss there to be limited to the context of their teaching of tutorials in an introductory physics course. Although the context is seen as restricting the application of these beliefs (i.e. I do not necessarily assume that the TAs would profess the same beliefs about their own learning), the use of beliefs in that case means that I am focusing on individual TA's ideas. The analysis in Chapter Four also depends on data and analysis that align more with a socio-cultural perspective. A case study in that chapter shows how one TA's behavior is influenced by his beliefs and how his students' responses to that behavior interact in the moment to affect his practice. This pulls the focus of analysis away from what is exclusively in the TA's head to include how the immediate context, including students' responses, the topic being discussed, and terminology in the tutorial, interacts with the TAs' beliefs and knowledge to shape his teaching decisions. At the end of that chapter, I also use a grain size that is larger that what might be expected from either a cognitivist or socio-cultural perspective. This occurs when I describe the different elements of the "social and environmental context" at two institutions and how these elements might plausibly affect TA buy-in. That section acknowledges that beliefs and knowledge are not acquired in a vacuum. Instead, past experiences influence what beliefs a person holds, and the larger environment in which the TA works, including departmental norms, opinions of peers, the type of class they are teaching, influence which beliefs are actively influencing their practice.

This is only one example of the analysis that is presented, but it is representative of the perspective I use. The cognitive perspective gives us tools for understanding what is going on in a TA's mind (so far as that is possible) and how these cognitive elements influence decisions. The socio-cultural perspective provides a way to see how the rest of the world reacts to and interacts with a TA's decision, which then affects the next decision. The choice of whether to focus on the mind of an individual or the individual's interactions with the world depends on what question is being investigated.

The effect of a choosing (whether this choice is conscious or not) a more socio-cultural- or more cognitively-oriented perspective affects not only the conclusions I might draw but also what questions I might ask. Otero cites a particularly illustrative case, in which biologists studying sea sponges only recently found that these stationary animals orient themselves so that sea currents transport food to them. This had not previously been noted because biologists had been studying the sponge as a unit, rather than the sponge-water system ((Clark, 1998) as cited from (Otero, 2003)). When they considered the interaction of the sponge and its environment, they were better able to understand how the sponge functions.

In this section I have discussed the need to consider what is happening in a TA's mind as well as the environment in which the TAs teach. When we consider what goes on inside the mind, however, we must consider how ideas are structured in the mind, because this has implications for how we expect to help people learn or change their ideas. The next section addresses this question.

3.4 Elements of cognition: Resources

3.4.1 A resource framework considers whether ideas are appropriate to the given context, rather than right or wrong

In this work I explain cognition using a resource-based framework, in which learners (whether they are students or beginning teachers) have ideas that are activated in different situations. People use these activated resources to construct knowledge and guide their behavior. These ideas are not categorically wrong or right, but rather are appropriate or inappropriate for the particular situation (Hammer, et al., 2005b). Such a framework provides an explanation for how novices can become experts: they begin to use resources from other contexts, adding new ones, and build up a more coherent structure of ideas (Smith III, diSessa, & Roschelle, 1993) Smith et al. characterized such a framework as one that "emphasizes knowledge refinement and reorganization, rather than replacement, as primary metaphors for learning (1993, p. 116)."

3.4.1.1 People have knowledge which is varied, context-dependent, and sometimes contradictory

The idea that people construct knowledge in the moment using smaller knowledge elements contrasts with an idea that views people's thinking as arising from more permanent, stable, and coherent knowledge structures. The latter framework is often called a misconceptions framework, because it characterizes students as having stable, incorrect ideas called misconceptions. Misconceptions are ideas that originate from previous learning, and they are usually identified because they are widespread (i.e. seen in many students), stable, and resistant to change.

Research that deals with misconceptions frequently has two goals: to identify misconceptions and to replace them with correct knowledge. In order to learn correct ideas, students' misconceptions must be elicited, then effective instruction leads them to confront the misconception and discover why it is wrong. After that, students can learn a more expert idea (Smith III, et al., 1993).

In contrast, a resource framework maintains that misconceptions are not always stable knowledge structures but rather concepts that are applied in the wrong context (Smith III, et al., 1993). The concepts are robust because they have the ability to explain aspects of the world when they are activated in some contexts, but are categorized as wrong when activated in others. Smith et al. argue that the misconceptions framework conflicts with how constructivism theorizes that learning takes place. If we categorize the majority of a students' knowledge as either correct or part of a misconception, it is difficult to account for what pieces students have that they could productively use to construct the correct knowledge, because the misconception model does not provide these pieces. Smith et al. also argue that a premise inherent in much misconception research, that instruction should confront misconceptions, is flawed. They argue that confrontation in instruction can convey to students that attempts to build understanding are ineffective.

These arguments have primarily been made in the context of student ideas, but they apply equally well to the thinking of instructors. My analysis does not rely on the details of what the resource framework has to say about how concepts are organized or the size or permanence of resources. The primary idea that I draw from this framework is that people's minds contain smaller cognitive elements upon which they can draw. Thus, analyzing TAs' thinking from a resources perspective rather than a misconceptions perspective allows us to consider professional development for TAs that can identify and build upon some of the cognitive elements that they have available.

3.4.2 The resource framework is consistent with respect for instructors' naïve ideas

3.4.2.1 We should respect novice teachers' ideas as we respect novice students' ideas

People do what they do partly because it has worked for them in the past. Teachers may teach in a traditional manner because it is the way that they have experienced instruction, and, in the case of physics graduate students, it is a system in which most of them have excelled. Because these behaviors and decisions have served TAs well in the past, it is unreasonable to expect them to simply discard them when TA instructors present alternative teaching methods.

I take a theoretical position of respecting naïve ideas. The physics education community has done so regarding people's physics ideas, with the benefit that we can help students identify ideas that can be the basis for effective constructivist instruction (Hammer & Elby, 2003) and where they will need to reconcile these ideas with formal physics concepts. The same theoretical framework applies when the "students" are novice teachers; now the naïve ideas can be a basis for effective professional development.

The idea of respecting novice TAs has two components. The first is treating TAs with courtesy, which includes considering TAs to be partners in the enterprise of educating undergraduate students. The research that is presented here supports the finding that failing to treat TAs in this way is one of the environmental components that leads to TAs' dissatisfaction with the curriculum they are teaching (Chapter Four). In addition, I argue that treating TAs as partners in education rather than as novice instructors to be continually corrected is simply the decent thing to do. The second part of treating TAs with respect involves looking for productive seeds within their existing beliefs. This second component is discussed in greater detail in the following subsection (3.5.2).

3.4.2.2 Part of respecting TAs' beliefs involves identifying productive seeds

The physics education research community uses students' ideas as a foundation for assisting students construct their own knowledge. We have learned that it is ineffective to ignore the ideas that novice students bring into the classroom. Similarly, we cannot assume that TAs will easily abandon the beliefs and practices they already use in their teaching. TA instructors can help TAs learn to teach more effectively by identifying beliefs and practices the TAs already have that they could draw upon. These resources include those that TAs already use in other contexts. For example, they have discussions with colleagues in which the answer is not known by one of the participants, and they can use this experience to encourage similar conversations among their students. Another productive resource would be conversations in which they try to understand an idea without evaluating it. Thus, a significant motivation for studying TAs' classroom practice is to better understand how TA instructors can foster situations where TAs can discuss their ideas about teaching and learning. The TA instructors can then create professional development programs that could build on the productive seeds they find in TAs' beliefs and values.

In this chapter, I have already repeatedly referred to TAs' beliefs. I would now like to more carefully define the term 'beliefs' and discuss two characteristics of beliefs may have, their stability and their dependence on context.

3.5 I use 'beliefs' to refer to TAs' declarative knowledge about teaching and learning

This work depends on using TAs' beliefs to explain their classroom behavior. The idea of beliefs has been defined in many ways, and I am using the term in quite a general sense, to describe the declarative knowledge that TAs have about teaching and learning. Other researchers have carefully defined how beliefs are different than knowledge, goals, and values (Pajares, 1992), but these distinctions are not critical to the argument that I am making. My use of the term *beliefs* does differ from how the term is often used in the established beliefs literature. Much of the research that uses beliefs to explain teachers' practice does not explicitly consider beliefs to be context-dependent; instead, they are seen as broad constructs that are relatively stable across varying contexts (Pajares, 1992). In this analysis, I begin with the assumption that the context TAs are in can influence the beliefs they draw upon.

3.5.1 Beliefs can be stable

One characteristic of the beliefs that I discuss in this work is that they are often stable. When I describe a TA's beliefs as *stable*, I mean that the ideas that TAs express in their reflections about their teaching are generally consistent with the teaching practices that we observe. I am not implying that these beliefs are consistent across all contexts and I am not taking a position on whether beliefs always exist in the mind.

Much of the data presented here shows TAs whose practice is consistent with the reflections they offer about that practice, which would seem to support a view of their beliefs that is more globally consistent across contexts than the perspective I have chosen. However, I argue that the narrow context in which beliefs are invoked is the reason TAs' practice and beliefs appear so consistent. The episodes of TAs' teaching that I analyze are all from tutorial classrooms, where these TAs are teaching introductory physics to junior and senior life science majors using tutorials. The reflective interviews attempted to elicit TAs' ideas about teaching and learning within this particular context. For example, the TAs were asked, "What do you see as the advantages and disadvantages of tutorial-style teaching for you and for your students?" The TAs' responses often included examples from their classroom or reactions from their students. Thus, it seems likely that the beliefs I attribute to the TAs are connected to this particular situation. The analysis I present here does not address the question of whether the stability of these beliefs would extend to other teaching or learning contexts.

3.5.2 Beliefs can be context-dependent

Part of my theoretical assumptions about beliefs are that they are context-dependent. The context can affect an individual's belief by influencing what beliefs are activated, as well as which of those beliefs the individual consciously decides are relevant to the situation. Consider the two episodes of Alan's teaching that I discuss in Chapter Five. Multiple behaviors could be supported by his beliefs, which include (1) the belief that students generally find conceptual physics questions easy but quantitative problems difficult and (2) the belief that teachers should usually be generous in attributing understanding. Alan's behavior is different in each episode, although in each case he is attending to relatively superficial evidence that students understand. His behavior differs because different contexts make certain beliefs more salient. In one case, the students have produced a correct qualitative answer, and Alan quickly validates their answer, supported by his belief that conceptual questions are straightforward. In the second case, the students are struggling with a formal physics question, and rather than leading them to the answer, he prompts them to think about one particular concept and indicates that they will have to do more thinking. The context of the second situation brings to the forefront his belief that formal, quantitative problems are difficult. His belief about the importance of giving students the "benefit of the doubt" means that he accepts their affirmation that they understand his hint but the particular context means that he is less likely to attribute as much understanding as in the previous case.

In this case, the effect of the each context is to "foreground" certain beliefs that Alan has. In all of the TAs that I discuss in this work, I do not observe that different situations in the tutorial classroom prompt conflicting beliefs in an individual TA. Instead, the context causes certain beliefs to become more salient at a particular moment.

The findings of this research support the idea that TAs beliefs and practice in tutorials are consistent. Thus, the idea that the TAs' beliefs are stable is an empirical result rather than a theoretical assumption. My initial expectations that individuals' beliefs are often influenced by context is what allowed me to see this result, rather than just assuming it.

3.5.3 Beliefs support (but do not determine) framing

I have discussed how beliefs and framing can both be used to explain people's behavior, but this then leads to the question of how the beliefs and framing are related. The relationship between beliefs and framing is one in which each component influences, but does not determine, the other. Thus, stable beliefs play a supporting role in framing. In example of a soccer dad discussed in the framing section, a man who believed in the need to develop toughness in a competitive world would more likely frame a soccer game as a partisan event than a man who believed that strong children are products of unconditional love. Beliefs can only influence framing, though: they cannot determine it, because that would exclude the effect of context, such as the other participants' responses. We would expect that how people regularly frame their activities could, over time, also influence their beliefs. In this analysis, however, I present minimal longitudinal data that could address this question. Therefore, my primary focus is on the effect of beliefs on framing.

How a TA frames her teaching is influenced both by her negotiations with students about what kind of activity they are all engaged in and by the stable beliefs that the TA has about teaching and learning. The TA may be guided by her beliefs about what would be appropriate in this situation, but the students' responses then either support or undermine the TAs actions, so that together they construct a shared framing of the activity. (This is not to say that participants always have the same framing: mismatched framing is common, and can lead to humor or conflict depending on whether the participants recognize that they are framing in different ways (Goffman, 1974).)

It is not unusual to find TAs that express apparently contradictory beliefs about teaching. This contradiction, however, can be explained by the role of context. People can hold contradictory beliefs that are nonetheless quite stable in particular contexts. For example, most people think lying is wrong, but complimenting someone's new hairstyle, regardless of its aesthetic appeal to you, is generally considered acceptable. Similarly, a TA could express his belief that tutorials are too easy for students, and yet also think that students cannot do them. Thus, when I claim that a TA's framing is supported by stable beliefs, I assume that he has other stable beliefs, which in a different context could have led to a different framing. For example, Chapter Four discusses the plausible relationship between TAs' buy-in and their social and environmental context; this analysis leads to the conclusions that changing the context in which TAs work would change their buy-in.

3.6 Conclusion

In this chapter, I have not attempted to lay out an argument for which theoretical framework is optimal for answering my research questions. This is because each of the upcoming analysis chapters asks a different kind of question, and there is not a single theoretical framework that spans them all. Each analysis chapter therefore includes a specific framework, which emphasizes different components of the perspectives I have discussed in this chapter.

I have attempted to present a description of the various perspectives and how they have been used. Framing provides a way to analyze an individual's actions and account for them by understanding his expectations and the expectations of those interacting with him. A cognitivist framework places the focus of understanding thinking in a person's mind, while a socio-cultural framework answers the same question by looking at the interaction of a person and their environment. A resources-based framework assesses resources based on their appropriateness rather than correctness, which influences my analysis of how we can help TAs learn to be better instructors. Together, these perspectives provide us with tools to better account for TAs' classroom practice.