TEACHING TO LEARN: ANALYZING THE EXPERIENCES OF FIRST-TIME PHYSICS LEARNING ASSISTANTS

by

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Teaching to Learn: Analyzing the Experiences of First-time Physics Learning Assistants

Thesis directed by Associate Professor Valerie K. Otero

The Colorado Learning Assistant (LA) Model has demonstrated that it is successful in helping to meet multiple goals including enhancing student learning in LA-supported courses, increasing conceptual understanding of physics among LAs, and improving the teaching practices of former LAs in K-12 schools. The research reported here investigated the experiences of first-time physics LAs taking into account the goals of the program, the learning philosophies implicit in the design of the LA experience, and the learning philosophies embedded in materials used in the physics department's implementation of the LA model. Through interviews and analysis of LAs' written reflections, two generalized models were established. These models represent the views of teaching and learning that undergraduate students generated throughout their first semester serving as LAs in Physics 1110. LAs' views and experiences, and the philosophy that drives the LA model are described as they pertain to a spectrum of views of formative assessment found in the literature. Inferences are made about the importance of the participatory learning model that drives the LA program. Finally, the value of the program for science education more broadly and the dependence of formative assessment sophistication on the teachers' understanding of science will be discussed.

To Josh, my husband, my rock.

It’s your faith in me that made this possible.

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Table of Contents

List of Tables

List of Figures

"At the very, very beginning, when I first became a learning assistant, they would always talk to us about questioning - how to question students and how to have open-ended things and encouraging us to see if the students understand where things are coming from and why they work. . . . It really gave me a good picture of, 'This is how I would like my class to be. I want the students to work together in this way. This is how I'm going to facilitate; I'm going to guide them along to get to the answer and not just tell them the answer.' That was a huge part of the learning system. That's still what I think now, and that's still what I try to do and what I want to do, and it all started with being a learning assistant."

from DebbieH[1] (a first year Math teacher and former LA)

Rationale

Science education is important for all students but it plays an essential social justice role for students in urban schools. As Barton argues,

> Science holds a uniquely powerful place in our urban society. It opens doors to high-paying professions, provides a knowledge base for more informed conversations with health care workers, educators, and business and community leaders, and it demystifies key urban environmental issues like air and water quality standards, population density, and toxic dump and building regulations. Our global society has a history of environmental racism and hierarchical relationships between those who know science (and how to manipulate scientific findings) and those who do not (2002, p. 1).

[1] All teachers and LAs have been given pseudonyms.

Teaching students to engage in scientific inquiry can provide students the opportunity to make sense of their world thereby empowering them to exert greater autonomy over their lives, their community, and their nation (Proweller & Mitchener, 2004). Learning science provides an opportunity for students who would most likely be marginalized in their city to develop a new identity which allows them to move beyond a history of discrimination. To teach science well is to help stop the replication of marginalization of poor and minority urban youth. Science education is not just about forming a more scientifically literate workforce or better cities but it is also a civil rights issue. As Tate asserts "civil rights should no longer simply be concerned with physical space in schools but with access to high-quality academic preparation" (Tate, 2001, p. 1015). High-quality science education is an issue of social justice – acknowledging the wrongs of history and preventing their effects from being replicated in future generations – and an issue of equality. Therefore providing all students with excellent science education, especially those who are typically denied such education, is not just good economic or political policy, it is a constitutional imperative.

Despite the importance of science education, most students in urban poverty do not have the access to the "kinds of science classes, teachers, resources and opportunities necessary for academic success in science" (Barton, 2002, p. 2). For instance, in the New York City school district – the largest in the country – 50% of the public high schools do not even offer a physics course. This translates to 23% of New York City public school students not even having an opportunity or the option to take physics, a course often needed for success in math, science, or engineering college degrees (Kelly & Sheppard, 2008). In this school district there is a strong correlation between a students' race and SES and their access to physics courses. Schools that offered physics had a racial composition of 72% Black and Hispanic and 28% White and Asian.

Schools that didn't offer physics typically had a racial composition of 91% Black and Hispanic and nine percent White and Asian (Kelly, 2008). In urban schools across the country, the low-level tracks for high school students sometimes lack science courses all together (Oakes, Ormseth, Bell, & Camp, 1990). Providing students the opportunity to study physics in high school is not just about improving their high school physics class. At many universities high school physics is a requirement for entrance into many STEM degree programs. Even if students without high school physics are allowed into these programs they are often required to take remedial courses which will prevent them from graduating in four years. This will force them to bear the burden of even high college costs or larger student loan debts. Without the opportunity to pursue a STEM degree these students are barred from many careers which could allow them to help make changes in their communities (e.g. doctors, engineers, science teachers, science researchers, etc.). In order to accomplish change, the country needs to hear from experts in health care, city planning, environmental issues, and business who understand the needs of our urban communities.

Students in high-poverty and minority urban schools who do have access to science courses are most often taught by under qualified teachers (Darling-Hammond & Sclan, 1996). This is especially disheartening since research has shown that, of the factors which can be influenced by education policy, being taught by a qualified teacher will have the largest effect on a student's achievement in math and science (Darling-Hammond, 2000; Sanders & Rivers, 1996; Sanders, Wright, & Horn, 1997; Strauss & Sawyer, 1986). These studies suggest that the teacher has a greater effect on students' academic performance than the size of their class or the composition of their class. A qualified teacher is typically defined as one who holds both a full teaching certification and a degree in the content being taught, with the teaching certification

having a slightly larger effect than the content degree and both factors having a larger effect than measures of the teacher's experience (Darling-Hammond & Youngs, 2002). Despite the importance of a degree in the content being taught, two in three physics teachers do not hold a degree in physics (Hodapp, Hehn, & Hein, 2009). This statistic refers to the country as a whole; the ratio would be much more alarming for urban schools.

If the country wants to improve our students' access to quality science instruction, specifically physics instruction, it must increase the number of certified science teachers, especially those with degrees in physics. It should not be enough to simply improve the quantity of certified teachers, though. Teacher educators should also work to improve the quality of the teaching of future teachers. Teacher preparation programs need to be rethought in order to better prepare teachers for the subject-specific, pedagogical expertise needed in America's classrooms (Feiman-Nemser, 2001; National Science Teachers Association, 2003). This level of rethinking is required not only of those who teach science in K12 classrooms or those who prepare K12 science teachers, but also of those teaching science at the university level. Improving the quality of future science teachers will require that universities rethink how they teach science to future science teachers.

The Colorado Learning Assistant (LA) program began at the University of Colorado, Boulder (CU-Boulder) a decade ago. The program is focused on recruiting and preparing talented math and science teachers and improving the quality of math and science education for all undergraduates. The program has been implemented in eleven science, math, and engineering departments at CU-Boulder and is currently being emulated by over 35 four-year institutions. Each year the program hires 240 LAs. These LAs are talented undergraduates hired to assist instructors in transforming their undergraduate courses to be more student-centered and

interactive. LAs lead "learning teams" in which students articulate and defend their ideas and analyze authentic scientific data. While most LAs are not considering careers in teaching when they first apply to the LA program, many express an interest in teaching following their experience. This recruitment has led to a dramatic increase in the number of secondary math and science teachers certified at CU-Boulder and across the state (Otero, Pollock, & Finkelstein, 2010). The LA program not only recruits undergraduates to help in science and math courses but also prepares them to facilitate student learning in these transformed courses. First, LAs further their content understanding in weekly meetings with the lead instructor of the course in which they work. Second, LAs develop their pedagogical knowledge through a weekly science and mathematics education seminar. This class is attended by LAs from all departments and addresses practical techniques as well as readings from cognitive science, learning theory, and physics education research. Finally, LAs engage in actual practice as they lead learning teams of 6-20 students. Research has shown that learning gains in LA supported courses are twice as high as learning gains in traditional courses using similar assessments (Otero et al., 2010; Pollock & Finkelstein, 2012). Research has also shown that upper division students who had the LA experience outperform their peers who did not have the LA experience as freshmen (Pollock, 2009). Research on LAs who pursue careers in K12 teaching show that they are more likely to successfully use reformed teaching methods than their colleagues who completed the same teacher certification program (Gray, Webb, & Otero, 2012).

The Colorado LA program is now being emulated across the country. Almost ten years after the start of the Colorado LA program, it is now funded by institutional funding sources, not by outside grants, suggesting that this program is not only successful, but also sustainable. For all of these reasons I believe that the Colorado LA program provides an experience that greatly

enhances even the best traditional teacher preparation programs. The study presented here was designed to investigate this supposition and elucidate the factors that are critical to the success of the LA program. I hope that by better understanding the LA program universities will be able to prepare more high quality math and science teachers who will be able to reach out to student who will greatly benefit from quality math and science instruction.

An important aspect of quality teaching is the use of student-centered instructional strategies such as formative assessment (National Research Council, 2000; Sadler, 1989). Formative assessment is the practice of using evidence about students' understanding to make informed decisions about the next step or steps in instruction (Black & Wiliam, 2009). Research shows that formative assessment can significantly improve student achievement, however it continues to be rare in classrooms (Black & Wiliam, 1998; Shute, 2008). One reason for the rarity of formative assessment is the difficulty in helping future teachers obtain a deep conceptual understanding of formative assessment so they are able to integrate it meaningfully into their teaching practices (Buck, Trauth-Nare, & Kaftan, 2010; Otero & Nathan, 2008).

The purpose of the study presented here is to investigate how participants in the LA program developed and employed their understanding of formative assessment in their university teaching context. I hypothesized that the learning environment of the LA program successfully helped LAs develop a deep, conceptual, practice-based understanding of formative assessment, that would serve them well if they chose to pursue careers in K12 teaching. The research presented here investigates this problem by focusing on how LAs learn about formative assessment as undergraduate STEM majors in their first semester of the LA program. In order to investigate LAs' understanding of the concept of formative assessment and not their familiarity with teaching jargon, this study focused on the broader issue of LAs' understanding of teaching

and learning. I assumed that since formative assessment is a philosophy of teaching and learning, it would be helpful in interpreting the LAs' views and placing these views in the context of research on teaching and learning. Therefore the research addresses this issue by answering the following research questions.

Research Questions

1. How do LAs talk about teaching and learning?
2. How do LAs talk about how they help students learn?
3. How do LAs' ideas about teaching and learning change over their first semester in the LA program?

Literature Review

The purpose of this chapter is to develop a conceptual framework to frame the study presented here. The intent of this research is to understand what LAs learn about teaching and learning through their experience in the LA program. In order to investigate this question I must first address the assumptions that undergird the LA program and this research. Both the LA program and this research make two assumptions that will be expanded upon in the following sections.

The first assumption is in response to the question, *"What is good teaching?"* At the crux of the LA program is the belief that good teaching relies on *formative assessment* – the process of gathering and using evidence about student learning to inform instructional practice. While this term may not be used throughout the LA program, the concept of formative assessment is visible in all the aspects of the program including the transformations of the undergraduate STEM courses. The concept of formative assessment is especially important to the LA pedagogy seminar. This is because the underlying goal of the LA pedagogy seminar is for LAs to develop a view of teaching and learning based on formative assessment. While teaching is a very complex process that involves many different practices, the research described here focuses only on the formative assessment aspects of good teaching. This focus is a result of the scaffolded nature of the LA program. In their teaching experiences, LAs are not asked to take on all of the tasks of a teacher. Instead, their role allows them to focus on the moment-by-moment interactions with students and the science concepts. This means LAs are able to practice their formative assessment skills without being overwhelmed by the other tasks of teaching. Since formative assessment is the aspect of good teaching most relevant to the experiences of LAs, this is the focus of this section. The section defines formative assessment as used in this study and

place this definition within the context of other uses of formative assessment in the research literature.

The second assumption is in response to the question, *"How do the LAs learn?"* This research assumes that LAs are learning because of the *situated* or *experiential* nature of the LA program. This means that the LAs are not learning in one particular element of the LA program while they are implementing what they have learned in a second element. Instead, the LAs learning is tied up in the entire LA experience. This also means that the evidence of this learning cannot be separated from the LA experience. Instead the evidence for the LAs' learning lies in how they participate in the program. This assumption undergirds the methodological decisions that will be described in the next chapter. The concept of *situated* or *experiential* learning will be described, along with the theoretical perspective of learning as participation, in more detail in a later section of this chapter.

What is good teaching?

Formative assessment has increasingly become a central part of education research and of recommendations for good teaching practices. For the purposes of this study formative assessment will be defined as in Black and Wiliam. Specifically,

> Practice in a classroom is formative to the extent that evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers, to make decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have taken in the absence of the evidence that was elicited. (2009, p. 9)

While this definition of formative assessment includes decisions made by teachers, the student and peers, the research reported here concentrates only on decisions made by the teacher. The

reason for this is that the LA program provides few opportunities for peer assessment or for student decisions to drive the curriculum.

There are two key aspects of the definition of formative assessment above that separate it from other definitions of formative assessment. First, this definition specifies that formative assessment is ultimately about using evidence to make decisions about instruction; separating it from other definitions that view formative assessment only as a teaching strategy (Wiliam, 2009). Second, this definition clarifies that formative assessment does not require that a teacher always does something unplanned based on the collected evidence but can continue with the lesson as planned though now supported by new knowledge about students obtained from the assessment (Wiliam, 2009). This definition is consistent with the more illustrative definition from Atkin, Black, and Coffey (2001) which views formative assessment as the process of asking and answering the following questions: "Where are you going to?" "Where are you at?" and "How are you going to get there?" In other words, *how can I help you bridge where I now think you are at to where I want you to be*? This definition is illustrated in Figure 1a. Taken together, asking, answering, and acting upon these three questions creates the formative assessment process. In most cases this is an iterative cycle where a student moves along a continuum where their final state of the process becomes their initial state of the next formative assessment process (Furtak, 2009). This means the formative assessment process becomes a feedback loop as teachers continuously gather evidence about their students' understanding, respond to that evidence, and then gather evidence about the students' response to the instruction. This process is demonstrated in Figure 1b.

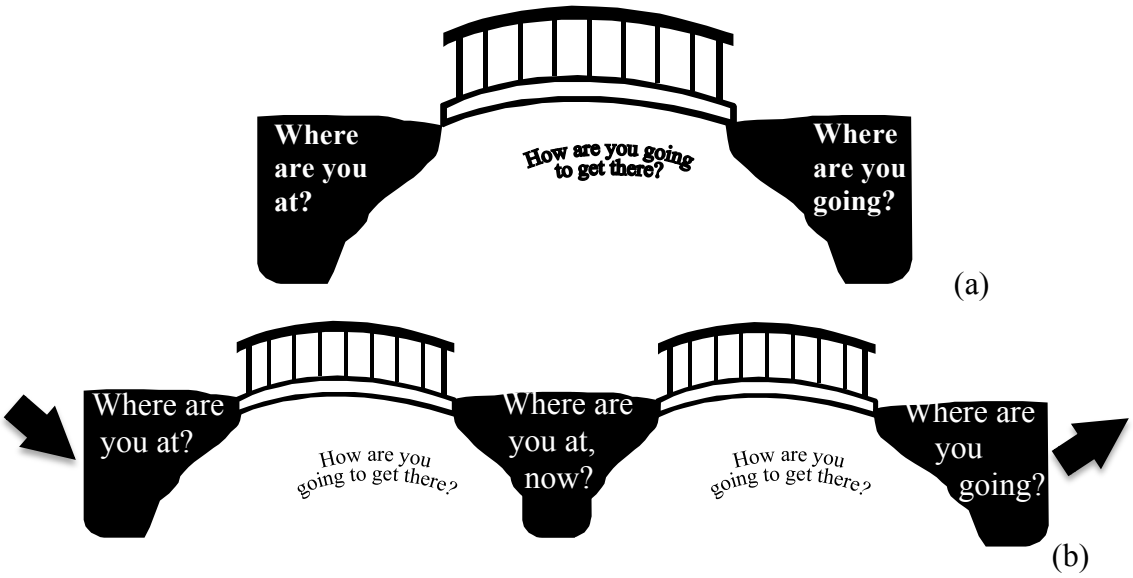

Figure 1.The Formative Assessment Process.

Categorizations of formative assessment.

In the following categorization scheme, I attempt to organize some of the vast literature on formative assessment that is most relevant to the LA experience. My scheme includes the following categories from the literature - feedback (Kluger & DeNisi, 1996; Ramaprasad, 1983), interactive and planned formative assessments (Cowie & Bell, 1999), and two categorizations I created, source-focused formative assessment and bridge-focused formative assessment. This scheme is shown in Figure 2.

Many definitions of formative assessment (e.g. Black & Wiliam, 1998; Sadler, 1989) use the term feedback (Shepard, 2009). Therefore, my categorization of formative assessment will begin by defining feedback and categorizing the many types of feedback mentioned in the literature. Feedback is defined by Kluger and DeNisi, in their meta-analysis of feedback research, as "actions taken by (an) external agent(s) to provide information regarding some aspect(s) of one's task performance" (1996, p. 255). Feedback has been studied extensively in its own right and has been found to improve student achievement (Kluger & DeNisi, 1996;

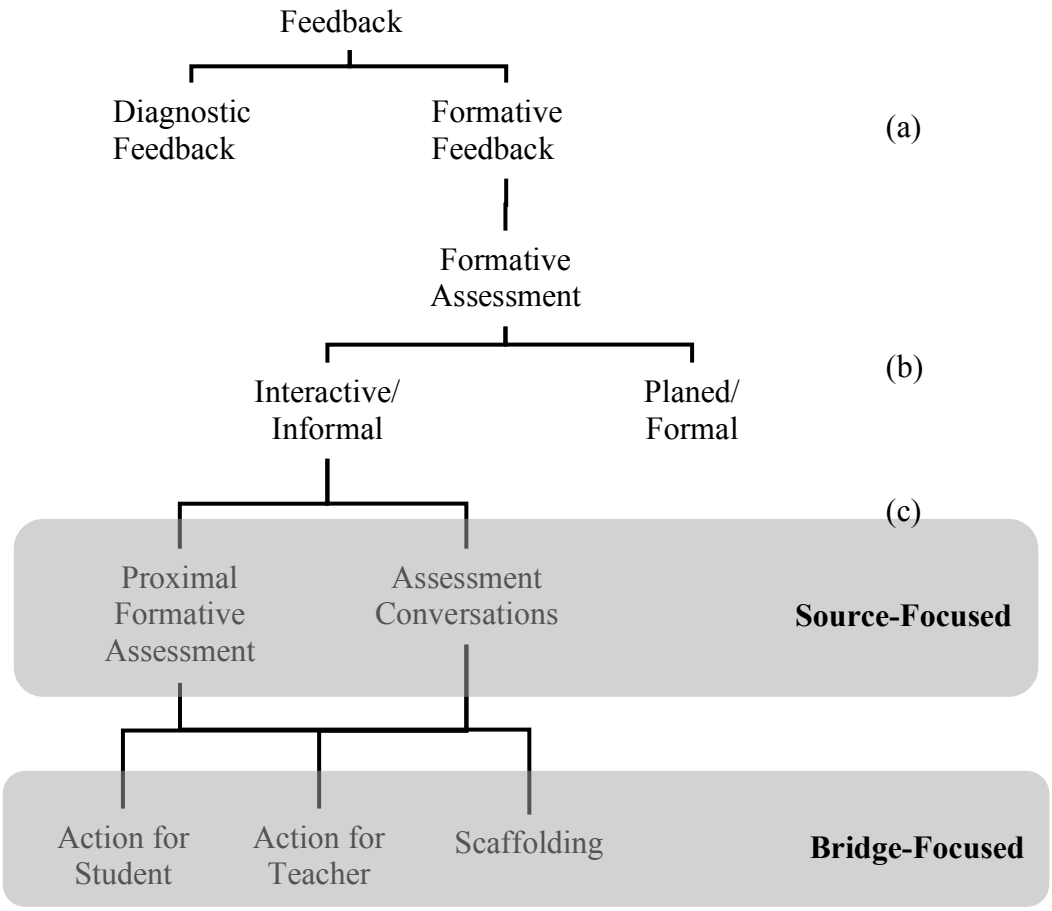

Figure 2. Categorization of Formative Assessment Literature.

Ramaprasad, 1983). To clarify the relationship between feedback and formative assessment it is helpful to consider the framework of feedback discussed by Wiliam (2007). Wiliam distinguishes between diagnostic feedback and formative feedback. *Diagnostic feedback* provides information to students about their current understanding of a topic or what they got wrong on an assessment. *Formative feedback* includes this same information but also includes an "implicit or explicit recipe for future action" (p. 1062).[2] Therefore, using these definitions a

[2] It should be noted that Wiliam's (2007) use of the term diagnostic feedback, which is used here, is different than that used in Black and Wiliam's (1998) meta-analysis. There diagnostic

teacher engaged in formative assessment is giving *formative feedback* to her students. In other words, *formative assessment* and *formative feedback* use essentially the same instructional strategies and both terms are used in the literature (Black & Wiliam, 1998; Shute, 2008). The next level of organization in Figure 2a considers the various types of formative assessment described in the literature.

One of the broadest categorizations of formative assessment is Cowie and Bell's (1999) distinction between *planned* and *interactive formative assessment*, also known as *formal* and *informal formative assessment* (Ruiz-Primo & Furtak, 2006). *Planned formative assessment* refers to activities that were built into a lesson. Examples of this include pre-assessments (Furtak, 2009), clicker questions (Beatty & Gerace, 2009; Mazur, 1992), and end of class written wrap-up activities, often called exit tickets. Pre-assessments (or pre-tests) are questions that teachers include in their lesson plans at the beginning of a unit or lesson to get an idea of what students know or how they are thinking before the unit or lesson begins. Based on student responses, the teacher may adjust the lesson or unit to review a topic, to accelerate the pace, or to include new material. Not all pre-assessments are formative assessments. Sometimes teachers use pre-assessments only to compute learning gains by subtracting pre-scores from post-scores (e.g. pre/post testing; Hake, 1998). For this study, clicker questions will be considered the questions teachers pre-planned to ask during the lesson to assess students' current understanding and therefore are an example of *planned formative assessment*. Students respond to these questions using electronic voting machines, coded cards that are held up, or small whiteboards. Not every example of teachers using clickers is an example of formative assessment. Sometimes clickers

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feedback is defined in the same way Wiliam defines formative feedback and is contrasted with feedback that only measures distance from a standard.

are used simply to evaluate students or to engage students in the learning by making them interact with the content. If in these situations, the teacher does not gather students' responses and *use* this information to inform her later instruction, then these are not examples of using clicker questions as formative assessment. Another example of *planned formative assessments* is the end of class written wrap-up activities teachers plan as part of their lessons. These activities are often called exit tickets, because students are required to hand something in before they leave class. The teacher then uses these responses to assess students understanding of the material. Based on this information the teacher can then plan her future lesson to address students' understanding. Formative assessment can also be used by researchers to develop a curriculum as they get feedback from implementations of the curriculum and use this information to improve the activities (e.g. McDermott, 2001).

The other broad type of formative assessment in the literature, *interactive formative assessment*, refers to the evidence teachers collect through interactions with students or groups of students during the course of a regular lesson (Cowie & Bell, 1999). This differs from *planned formative assessment*, because the teacher is taking advantage of opportunities that arise during the lesson that could not have been anticipated prior to the lesson. *Interactive formative assessments* may not be as systematic as *planned formative assessments*, in the sense that the same interaction may not happen with every student and the information gathered from the formative assessment may not be documented by the teacher. LAs do not design their own lesson, so they only have an opportunity to engage in *interactive formative assessment*, therefore the following discussion will focus only on *interactive formative assessments*. I divide *interactive formative assessment* into two subcategories as shown in Figure 2c.

Interactive formative assessment can be further divided based on the focus of the literature, as shown in Figure 2c. Formative assessment research that focuses on how the teacher decides where students "are at" in their understanding can be labeled *source-focused formative assessment*. This can include the extensive literature from the 80's and 90's on students' difficulties (Driver, Guesne, & Tiberghien, 1985; Getner & Stevens, 1983), "misconceptions" (Ambrose, Heron, Vokos, & McDermott, 1999; D. E. Trowbridge & McDermott, 1980) and resources (diSessa, 1993; Hammer, 2000; Minstrell, 1992; Rumelhardt, 1980). The preconceptions literature focuses on categorizing the typical "starting places" of students in various curricula. Often this literature also proposes lesson activities that can serve to bridge students from these "starting" places to the scientific idea (e.g. D. E. Brown & Clement, 1989; D. E. Trowbridge & McDermott, 1980). Other examples include assessment conversations (Furtak & Ruiz-Primo, 2008) and proximal formative assessment (Erickson, 2007). Assessment conversations are characterized by a specific cycle of communication interaction. "The teacher asks a question to elicit student thinking, the student provides a response, the teacher recognizes the students' response, and then uses the information collected to support student learning" (Ruiz-Primo & Furtak, 2006, p. 207). This communication interaction is referred to as the ESRU cycle (elicit, student, recognize, and use). Assessment conversations use these ESRU cycles to engage in formative assessment. Like other types of *source focused interactive formative assessments*, assessment conversations engage in the entire formative assessment process, but the literature about assessment conversations focuses on how teachers collect information about where a student is currently at in their understanding. In assessment conversations, this information comes from the discussions teachers engage in with their students. Typically these discussions are with the entire class. Another type of source focused formative assessment is

proximal formative assessment (Erickson, 2007). Like assessment conversations, proximal formative assessment focuses on how teachers gather information about their students. Proximal formative assessments leverage a wider range of sources for the information that teachers use to understand where students are in their understanding at a given moment in time. Unlike assessment conversations that focus only on students' responses to teachers' questions, proximal formative assessment focuses on the information teachers collect from conversations with students as well as the observations they make of students' interactions with each other, of students' work on classroom activities, and any other source of information about student understanding present in the classroom such as whiteboards. While teachers using *source-focused, interactive formative assessments*, such as assessment conversations and proximal formative assessment, engage in the entire formative assessment process, the literature on these types of formative assessment typically focuses on how teachers collect the information needed in the elicitation component of the formative assessment process.

The literature that I've characterized as *source-focused formative assessment* focuses on how teachers collect information about their students. Another group of literature focuses on how teachers respond to students once they've collected this information. I'll refer to this literature as *bridge-focused formative assessment*. Teacher responses, which are the focus of *bridge-focused formative assessment*, can include both verbal responses and actions. Examples of *bridge-focused formative assessment* literature include the scaffolding literature (Shepard, 2005; Wertsch, 2007a), literature focused on the feedback teachers give students (Kluger & DeNisi, 1996; Ramaprasad, 1983; Sadler, 1989), and literature focused on how instructors adapt their lessons (D. E. Brown, 1994; Carless, 2007; Novak, Garvin, Patterson, & Christian, 1999). Scaffolding is defined as the "supports that teachers provide to the learner during problem

solving – in the form of reminders, hints, and encouragement – to ensure successful completion of a task" (Shepard, 2005, p. 66). Scaffolding is an example of *bridge-focused formative assessment* because it focuses not on how the teacher collects the information but on the actions the teacher takes in response to the information gathered. In scaffolding, these responses come in the form of supports the teacher develops to organize the information or task being learned so that it is easier for the student. These supports can be tools such as graphic organizers, manipulatives, catchy phrases, or mnemonic devices. In the beginning, the student may not fully grasp the usefulness of the tools suggested by the teacher but as the student comes to fully understand the material being learned they will also become more adept at the use of the tool and become more aware of the usefulness of the tool (Wertsch, 2007a). In the beginning of the scaffolding process the teacher takes over some part of the task (usually an organizational element) that will be slowly returned to the learner as they become more proficient (which is determined based on further information gathered by the teacher in further formative assessment processes). An example of this type of scaffolding is the source/receiver energy diagrams of the Physics and Everyday Thinking (PET) curriculum (Goldberg, Robinson, & Otero, 2008). These are diagrams introduced in the curriculum to help students understand energy transfer. The curriculum begins by showing students examples of the diagrams and then having them fill out their own diagram using a simple energy transfer situation of a moving cart hitting a stationary cart. Throughout the curriculum, students return to the diagrams as they deal with progressively more difficult energy transfer situations. The diagrams are graphic organizers that help students to understand the difficult topic of energy transfer. They force students to be explicit about aspects of energy which many students struggle with, such as identifying the source, the receiver, and the type of energy. By starting with easy scenarios and then moving to challenging

situations of energy transfer, the students begin by learning about the diagrams in a physical context with which they are comfortable, such as two carts colliding. They then move to learning about complicated physical contexts, such as magnets, using a tool with which they are comfortable. Another example of *bridge-focused formative assessment* is the feedback teachers give students. This feedback can come in many varieties such as written comments, verbal comments, or numerical scores (Kluger & DeNisi, 1996). These can include the comments that teachers make to students in response to a student's question or answer during a discussion or the written comments teachers can make on students' work. These written comments vary from a simple grade, to an indication of what answers are wrong, to suggestions on how to improve. Only when this feedback provides students information about steps thay can make to advance their learning, is the feedback considered formative. As discussed earlier, Wiliam (2007) makes this distinction in his categorization of feedback. In another example of *bridge-focused formative assessment*, instructors can use the evidence from formative assessments to change their instruction. This may mean using analogical scaffolds, where a teacher uses a series of senarios and questions to lead students to the corrrect understanding of the material (D. E. Brown, 1994; Podolefsky & Finkelstein, 2007); deciding to reteach material (Novak et al., 1999); or deciding to further probe students understanding to inform later instruction.

Enactment of formative assessment.

A second way of organizing the literature is by considering the theoretical perspective that underlies the way the formative assessment is represented and the role the student plays in the process of determining the learning goals and/or sanctioning ideas. For instance some literature on formative assessment has the learning goals entirely determined by the teacher and the teacher is seen as the source of all information

and the one who validates correct answers. In other representations of formative assessment the entire community works together to negotiate the learning goals and ideas are accepted based on community consensus rather than a single voice of authority. Some of the literature discussed below considers itself to be part of the formative assessment research (e.g. Otero & Nathan, 2008; Shepard, 2005), while other research does not use this term (e.g. Kolb, 1984; Lave & Wenger, 1991), though its perspective on learning is aligned with the perspective of Black and Wiliam's definition of formative assessment. I consider it to be aligned with Black and Wiliam's definition because it focuses on using students' current state of understanding to inform instructional strategies.

Based on this literature I have created a spectrum that extends from research that focuses on formative assessment as a teaching strategy to research which focuses on formative assessment as a teaching philosophy. When formative assessment is seen as a teaching strategy it is considered one of many tools teachers have at their disposal. In these situations, formative assessment tends to be about efficiently teaching in the sense that teachers only teach material if students don't already know it and they continue to re-teach material until an acceptable percentage of students know the material. Formative assessment is still about collecting information about students' understanding and then using this information to make decisions about the next instructional move, but the information isn't used to decide what that instructional move is or to tailor the instruction to the specific understanding of the student. Under this perspective control of the learning process is almost exclusively with the teacher. The teacher is responsible for determining learning goals and for sanctioning certain ideas as correct.

At the other end of the spectrum, formative assessment is viewed as more of a teaching philosophy than a teaching strategy. This means two things. First, when watching an example of

this type of instruction, it may not be possible to separate out the exact steps of the formative assessment process. It also becomes impossible to separate formative assessment from the rest of the instruction. In these situations formative assessment permeates all aspects of the instruction. It may not be possible to point to an exact point where the teacher elicits' students prior experiences or begins a bridging strategy. Instead, the class can be characterized by a commitment to drawing on students' prior experiences and using these experiences to help students learn. Second, literature which views formative assessment as a teaching philosophy focuses on learning not just as a process of building concepts, but as a process of building identities. This literature focuses on learning as a process by which a person's identity is changed or shaped by their interactions with their community; this is a more holistic view of the learner than views of learning that focus only on changes in concepts. Under this perspective the student may play a critical role in the process of negotiating the learning goals. Since learning is now tied to shaping identities, the student's interests and values are part of the negotiation process. In this representation the sanctioning of ideas happens through community consensus. These perspectives are outlined in Figure 3. A scale of the enactment of formative assessment should be a continuum, not a series of levels. From the literature, I have identified seven discreet points along the continuum that are marked on Figure 3. The numbers shown on the scale are not intended to show units of development, but are simply to allow the reader to follow along in the explanations below. The ordering of these representations is only intended to represent increasing levels of student voice in determining goals and sanctioning ideas. Each enactment has its purpose within a classroom.

My scale of enactments begins with the *get it or don't* model of formative assessment, present in several of the articles I reviewed. This perspective views formative assessment as just

one of many teaching strategies that a teacher has in their instructional "toolbox." The "*get it or don't"* view of formative assessment is common among teacher candidates as documented by Otero and Nathan (2008). These future teachers would engage in formative assessment to see what students knew about the planned topic of instruction. If teachers were convinced by the assessment that students did not appear to already know the material, then the teacher would continue with the lesson as planned. Coffey, Hammer, Levin, and Grant (2011) describe a similar enactment of formative assessment. Their analysis of the literature found that researchers tended to highlight examples of formative assessment where the teacher was focused on student's use of scientific vocubulary and whether or not the student had the correct scientific idea. They contrasted this with enactments of formative assessment that focused on the disciplinary substance of students' ideas. Coffey et al. hypothesize that this type of enactment of formative assessment is due to an assumption of science as a body of correct information rather than a process of evaluating and explaining evidence. While this type of teaching has a place when the intention is to quickly convey lots of information, it is unlikely to provide deep conceptual understanding. In this representation the teacher determines the learning goals and sanctions ideas as either correct or incorrect. The student has almost no voice in this process. In this perspective, formative assessment is an efficiency technique – it prevents teachers from teaching material to students who already know the material.

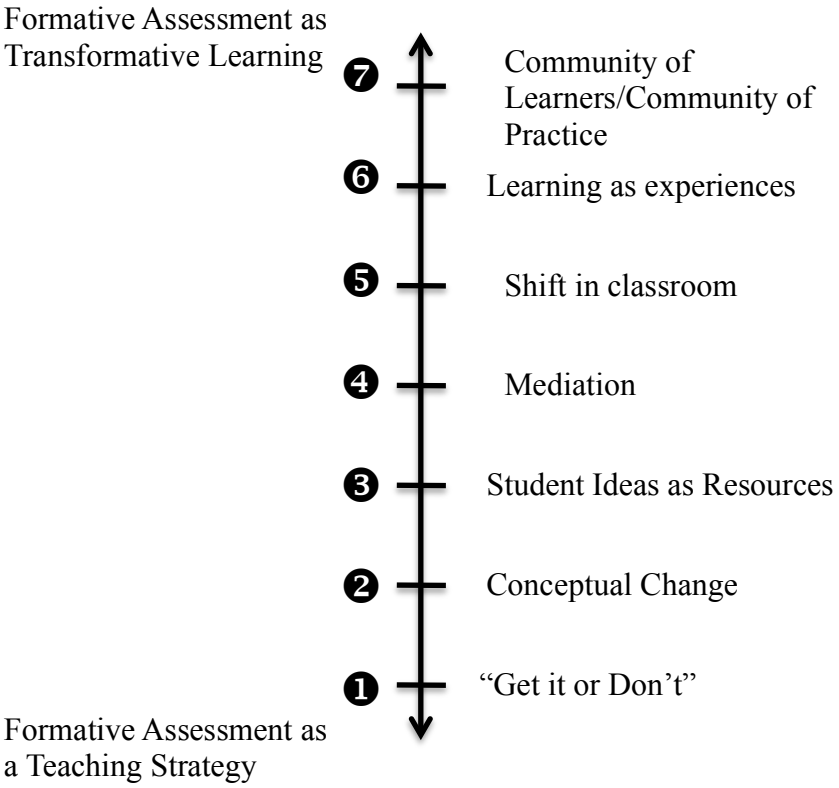

Figure 3. Enactments of Formative Assessment present in the literature, ordered according to student voice in negotiating goals and/or sanctioning ideas.

In the next point along the scale of formative assessment enactment is the *conceptual change model* (Posner, Strike, Hewson, & Gertzog, 1982) of formative assessment. In this perspective, instruction is designed to challenge students' ideas and to help them convince themselves of the correct answer. It is often manifested as the confront-resolve-replace or elicit-confront-resolve model of instruction (e.g. McDermott, 2001). According to this model, a teacher designs activities for students to confront their assumed misconceptions about a topic and discrepancies in their predictions and experimental results, to resolve these discrepancies, and to replace students' original ideas with the correct scientific concept for that topic (McDermott, 2001; Posner et al., 1982). As with all models of formative assessment, this type of instruction

begins with identifying a student's current understanding and responds to this with instruction specific to the students' current understanding. While the learner does not have much influence on the goals of the lesson, their ideas do help focus the instruction.

The third point in the scale of formative assessment enactment provides a more nuanced view of formative assessment. It sees the role of the instructor as one who elicits students' prior knowledge but recognizes that the ideas that students have are ones that can be built on as they work toward the scientific explanation. In other words, these ideas are not concepts to be proven wrong and replaced, but building blocks to a more correct understanding (diSessa, 1993; Hammer, 2000; Rumelhardt, 1980). Since the teacher is using student ideas to reach the target concept, the student has more power to control the direction of the lesson than under a conceptual change enactment. I will refer to this as the *resources* model of formative assessment. As with the *conceptual change* model of formative assessment, the *resources* model begins with identifying students' current understanding and then using this as a starting place of instruction. The *resources* model is different from the *conceptual change* model because it uses students' current ideas as resources or building blocks from which the scientific model can be developed. This model does not attempt to throw out students' ideas but to treat them as useful intuitions. Coffey et al. (2011) refer to this type of formative assessment as being focused on the disciplinary substance of students' ideas.

The fourth point of formative assessment enactment is the *mediation* model of formative assessment. The literature that discusses this point is based on Vygotsky's theory of learning (Shepard, 2005; Wertsch, 2007a). Under his theory of concept formation, the role of instruction is to help students mediate the relationship between their experiences and the academic concepts being taught. This mediation happens at two levels (Otero & Nathan, 2008; Vygotsky, 1986;

Wertsch, 2007a). Internally, the student is attempting to reconcile their experiences and their understanding of those experiences with the academic terms and concepts presented by the instructor. This means that the student works to interpret their experiences in light of the academic concepts. At the same time, the way the student understands the academic concept must be interpreted through the students' personal experiences. Externally, mediation happens as the student tries out certain words in certain contexts to see how the community responds. When the community responds as the student had expected, then he or she knows that they have successfully mediated their personal concept with the community's understanding and words. Because the student is interpreting the academic concepts in light of his personal experiences and testing this interpretation out on the community they have more influence over the process of sanctioning knowledge than student under other representations.

Moving upward on Figure 3 the enactments of formative assessment create more of a teaching philosophy than simply a teaching strategy, here the literature base is focused on *shifting the classroom culture*. This is the fifth point along the scale in Figure 3. This shift is aimed toward changing "our cultural practices so that students and teachers look to assessment as a source of insight and help instead of an occasion for meting out rewards and punishments" (Shepard, 2000). This differs from the *resources* perspective that focuses on the teachers' view of assessment and not on both the student and the teacher and therefore requires a shift in classroom culture and just a shift in the teachers' view of learning. Unlike other types of formative assessment, this philosophy of teaching focuses on teaching for transfer, sharing criteria for mastery with students, and teaching students to self-assess (Shepard, 2000; Wiliam, 2007). This type of instruction shifts the power structure of the classroom by involving students in instructional decisions and asking students to take ownership of their learning.

The next model that continues moving toward formative assessment as a teaching philosophy is the *learning as experience* model. The *learning as experience* model was first proposed by Dewey (1938) and was later expanded on by Kolb (1984) who combines the learning theories of Lewin, Dewey and Piaget. This model defines learning as "the process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 38). This perspective views knowledge as something that is created based not on instruction but on experiences where the learner interacts with his or her environment. As with all interactions, both the individual and the environment changed. As Dewey explains,

> Experience does not go on simply inside a person. It does go on there, for it influences the formation of attitudes of desire and purpose. But this is not the whole of the story. Every genuine experience has an active side which changes in some degree the objective conditions under which experiences are had. . . . The conceptions of situation and of interaction are inseparable from each other. An experience is always what it is because of a transaction taking place between an individual and what, at the time, constitutes his environment (1938, p. 39,43).

Under this enactment, learning is not something that takes place because of instruction but is the result of the interaction that takes place between an individual and his or her environment. Yet the perspective remains an enactment of formative assessment because this interaction is based both on where the student is currently and where he or she wishes to be. Many learning theorists have been influenced by the model of *learning as experience* and have taken it beyond this original model as shown below. Since the learner controls the experience he determines the learning goals, but under this perspective knowledge is solely sanctioned by the experiment or experience.

The final enactment of formative assessment shown on the scale is characterized by a redefinition of learning from the traditional acquisition model of learning to a model of learning as participation (Sfard, 2009). These perspectives all build off of Vygotsky's theory of concept formation. The *"community of learners"* perspective (Rogoff, Matusov, & White, 1996) and the *"community of practice"* perspective (Wenger, 1998) propose similar definitions of learning. Wenger (Wenger, 1998) begins by laying out two basic assumptions. First, "knowing is a matter of participating in the pursuit of such enterprises, that is of active engagement of the world" and secondly, "meaning – our ability to experience the world and our engagement with it as meaningful – is ultimately what learning is to produce" (p. 4). He then goes on to clarify what he means by *community of practice*.

> As we define these enterprises and engage in their pursuit together, we interact with each other and with the world, accordingly. In other words, we learn. Over time, this collective learning results in practices that reflect both the pursuit of our enterprises and the attendant social relations. These practices are thus the property of a kind of community created over time by the sustained pursuit of shared enterprise. It makes sense, therefore, to call these kinds of communities *communities of practice* (p. 45).

Similarly Rogoff et al. (1996) defines learning with a *community of learners* as "a process of transformation of participation in which both adults and children contribute support and direction in shared endeavors" (p. 389). Rogoff and Wenger's perspectives are examples of formative assessment for several reasons. First, traditional models of formative assessment begin by defining the goal for the learning experience. *Communities of practice* and *communities of learners* are formed around a shared goal or endeavor that defines, in some sense, a community. Therefore the learner works as part of the community to define the learning goals. Secondly,

formative assessment considers it vital to know about a students' prior experience and to use this information to shape instruction. *Communities of practice* and *communities of learners* are fundamentally shaped by the experiences their members bring to the community. These experiences help to shape the path taken by the community. Thirdly, feedback is often a key part of formative assessment as it is how teachers get information about where students are at in their understanding and it is how students get information about how to progress from the teacher. *Communities of practice* and *communities of learners* use feedback to shape their members' actions. If a new member does something that the community considers inappropriate, other members of the community will provide feedback in the form of explicit comments, veiled comments, or nonverbal reactions. New members then use this feedback to shape their behavior. Therefore ideas are accepted based on the negotiated consensus of the community.

The pedagogy course of the LA program tends to focus on teaching formative assessment with a *resources perspective*. This judgment is based on the readings of the course and discussions with the instructors. The reason for this focus is twofold. First, the learning environments that the LAs work in are typically not designed to allow for a redefinition of learning and are controlled by instructors or TAs who may not be comfortable with a shift in the classroom culture. Second, it was decided by the instructors that the LAs would find the *resources perspective* more intuitive based on their previous learning experiences and would therefore be conceptually primed for this perspective. This then provides the LAs an opportunity to develop a more sophisticated perspective on formative assessment and prepares them to encounter more advanced enactments of formative assessment in their later education courses or readings. Since the LAs have had the opportunity to develop a deep understanding of the resources perspective on formative assessment through their practice, they have a basis on which

to build understandings of later perspectives on formative assessment. The STEM courses in which the LAs work often enact formative assessment at a different level. For instance, the tutorials are based on a *conceptual change* model of formative assessment.

How do LAs learn?

While the LA program tends to *teach about* one level of enactment of formative assessment, it *teaches* formative assessment to the LAs *through* another level of enactment. The LA experience has many things in common with the *community of learners and community of practice perspectives*. The three pronged model of the LA program focuses on providing a rich learning experience that expects LAs to learn not only in the weekly seminar, but also in all parts of the experience. LAs also learn through becoming members of the education community at CU-Boulder. By interacting with their professors and experienced LAs, new LAs learn the vocabulary, values, and practices of the community and learn the values of this community. This learning is most obvious in the LAs who decide to enter the teacher certification program after serving as an LA, but it occurs with all LAs who learn to talk like an LA and to value and implement teaching philosophies like listening to students. This section will draw on much of the literature labeled as deep enactments of formative assessment to describe how LAs learn what good teaching looks like. The intention of this section is to flesh out the enactment of formative assessment used in the LA program. While this enactment draws heavily on the community of learners and community of practice perspectives, the resulting conceptual framework of learning will draw on theories of learning that are beyond a strict community of learners or community of practice perspective. For instance, this section will also utilize some of the literature that is specific to learning to teach.

Research has demonstrated the importance of integrating theory and practice. As discussed in the previous section, a *learning as experience* perspective (Dewey, 1938; Kolb, 1984) views learning as the interaction of a student with their environment. In this interaction both the environment and the student are changed. When applied to teaching as the topic of study, learners cannot simply engage in experiences about learning. Instead learners must participate in situations that allow them to experience teaching. As they teach, they change their ideas about what it means to teach well and they shape the environment in which they are teaching (Otero, 2004). As mentioned in the previous section, Vygotsky also describes how this interaction or mediation helps students learn (Vygotsky, 1986; Wertsch, 2007a). Vygotsky describes learning as the mediation of experience-based concepts with academic concepts (Otero & Nathan, 2008; Vygotsky, 1986). A student learns by interpreting academic concepts in light of their experience-based concepts and experience-based concepts are interpreted in light of the more general academic concepts. Yet these two types of concepts are not static. As the learner uses their experience-based concepts to understand the academic concepts, the academic concepts are altered. As the learner uses the academic concepts to recognize the generalized principles within their experience-based concepts, their experience-based concepts are modified usually to emphasize these generalized principles. When learning to teach, the academic concepts are the theories of teaching and learning or teaching strategies taught in education courses. From these courses, the learner is hopefully extracting generalized pedagogical principles that can be applied in their teaching. The experience-based concepts are the experiences the learner has had as a student as well as their experiences teaching. The learner is using these experiences to interpret and understand the generalized pedagogical principles.

Research has demonstrated that integrating experience and academics concepts is particularly important to learning to teach. The literature discussed above can be applied to learning to teach, but is not specific to learning to teach. The literature that follows considers what it means to integrate theory and practice *specifically* when learning to teach. Research on teacher learning has demonstrated the importance of situating teacher learning in actual teaching experiences (Borko & Putnam, 1996; Carpenter, Fennema, & Franke, 1996; Empson & Jacobs, 2008; Grossman & Williston, 2002; Putnam & Borko, 2000). This means that teachers are given the opportunity to test out new ideas for themselves while they are learning those ideas. This implies that it isn't enough for future teachers to learn about teaching; they must also experience teaching. These experiences allow the teachers to try out the theories of teaching and learning they are learning about and to ground these theories in actual experiences. Studies have demonstrated that teachers who learn new teaching strategies while being grounded in their students' thinking (Carpenter, Fennema, Peterson, Chiang, & Loef, 1989) and teachers who are able to try out new ideas with their students while they are engaged in professional development have students who learn more than those in control settings (Angrist & Lavy, 2001; Darling-Hammond, Wei, & Johnson, 2009). Smagorinsky, Cook, and, Johnson (2003) have found that Vygotsky's theory of mediation and concept formation, described above, can help explain why it is so important for teachers to be able to try out what they are learning while they are learning it. Korthegen (2010) uses Lave and Wenger's theoretical perspective on a community of practice (described above) to explain how teachers learn theories of teaching when the theories are grounded in their experiences of teaching. He cautions that introducing a theory of learning or teaching to a teacher before she sees the need for such a theory can cause her to reject the theory. For this reason, placing future teachers in a classroom not only gives them the opportunity to

practice what they are learning but it also provides the motivation for them to create theories of teaching and learning. For Korthegen a critical part of teacher learning is the opportunity to reflect on these experiences so that they can be used to motivate and create the theories of learning and teaching. Other research has also stressed the importance of reflection in teacher education (Rodgers, 2002; Schon, 1987; Zeichner & Liston, 1987).

The previously discussed *community of learners* (Rogoff et al., 1996) and *community of practice* (Wenger, 1998) theories stress the importance of the environment in learning. Because learning is seen as the process of enculturation or becoming part of a community, it is important that educators pay attention to the values of the community in which the student is participating. When applied to teaching teachers this means that if educators want future teachers to develop specific theories of teaching and learning then care must be taken to see that the entire community supports these theories. In other words all of the contexts within which the teacher is developing their theories and practicing their teaching must share consistent values (Darling-Hammond et al., 2009; Denton, 1982; LaBoskey & Richert, 2002).

Within a sociocultural perspective learning is defined as a change in one's level of participation in the community (J. S. Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991; Rogoff et al., 1996). This broad perspective doesn't view learning as the accumulation of information, instead learning is seen as a process of becoming part of a community as indicated by adopting the language, values, practices, and identity indicators of that community (Penuel & Wertsch, 1998; Sfard & Lavie, 2005; Sfard, 2009). It is not enough to be able to be able to use the same vocabulary of the community. A learner must also begin to notice the things the community values and to talk about these things. This is often referred to as a change in identity (Nasir & Cooks, 2009; Nasir & Hand, 2008; Wenger, 1998). Therefore, changes in the way a

person talks or behaves are evidence of learning (Sfard, 2007). This perspective is an interpretation and extension of Vygotsky's theory of learning discussed previously. Learning is not assumed to be a smooth linear process; learners tend to "test-out" words and "try-on" identities; meaning that people may use words or behaviors before they have fully accepted and understood their meaning (Erikson, 1968; Vygotsky, 1986; Wertsch, 2007a). This means this type of research focuses on the process of learning not on finding evidence that the learning is complete.

The entire process of learning described above is shown in Figure 4. This conceptual framework combines the theories of learning described above into a model of learning that can be applied to the LA experience. As described in the literature on situated learning, *learning as experience,* and Vygotskian concept formation, learning is a process of integrating a person's experience with the academic concepts. For the LAs, this means that they need to integrate their experiences teaching as an LA with the generalized pedagogical practices they are discussing in the LA seminar. These pedagogical practices include the teaching strategies, theories of learning, and learning goals that are covered in the seminar. This research will focus specifically on the generalized pedagogical principle of formative assessment. It isn't enough for the LAs to apply the generalized pedagogical principles to their teaching or to become interested in the generalized pedagogical principles because of their teaching experiences. For learning to take place at the deepest level, the LAs must interpret the generalized pedagogical principles in terms of their experiences and they must interpret their experiences in light of the generalized pedagogical principles. This means that both the generalized pedagogical principles and their experiences will be altered. Because of this need to go back and forth between the generalized pedagogical principles and the teaching experiences, the literature on situated learning stresses

the need for the teaching opportunities to happen at the same time that the generalized pedagogical principles are being taught. This process of negotiation also means that the teaching opportunities must be frequent and throughout the experience. For this reason, this type of teaching opportunity is labeled as an opportunity for sustained practice in Figure 4.

As described above, the way that LAs' sustained practice and the generalized pedagogical practices are integrated is through reflection. While this reflection can happen at any time in the process, the LA program provides opportunities for structured reflection during the LA seminar. By providing opportunities for reflection, the LA program communicates to the LAs the value the program places on teacher reflection, provides feedback to LAs on their reflection, and gives LAs the opportunity to participate in community reflection within class discussions.

This integration does not happen in a vacuum. The research described above indicates that the environment of the learner is critical to what he is able to learn. The research also stresses the importance of teachers learning to teach through an experience that is coherent. Given what the LA program is trying to teach LAs, they need to be in a community that values the good teaching described above. It isn't enough for LAs to be taught about good teaching in the LA seminar. Their teaching experiences also need to take place in environments that model what they are learning. This means that LAs work within transformed university courses. The LAs work with faculty who attempt to model a philosophy of formative assessment in their courses.

In keeping with this perspective on learning, this study used a socio-cultural perspective to investigate the learning which takes place in the LA program. This means that learning was considered to be the process of becoming a member of the community surrounding the LA

program. This process is revealed through changes in how LAs talk, act, and how they engage with the community. For instance, an LA who begins to use the vocabulary of the LA program has demonstrated that she is learning. Yet becoming engaged in a community is about more than just using the same language. A member of a community also learns to talk about the things that are important to the community, and to see the world from the perspective of the community. In Figure 4 this is described as adopting the values of the community. Becoming a member of the community also means beginning to engage in the practices of the community. While changes in a person's practice are critical to a socio-cultural perspective on learning, studying them can become problematic in the context of teaching. Observing a person's practice does not allow the researcher to know the reasons behind instructional decision or the effects of the context on those instructional decisions. Because so much of teaching happens away from sight, within the mental decisions about interactions that teachers make in a split second, this research focuses on how LAs describe and talk about their practices rather than attempting to draw inferences about instructional decisions based on observations of teaching. Therefore the practices shown in Figure 4 will not be included in the research described here and the languages shown in Figure 4 will include both the way LAs talk about teaching and learning and the way they describe their own practices. This understanding of learning leads to the following methodologies for studying the LA program.

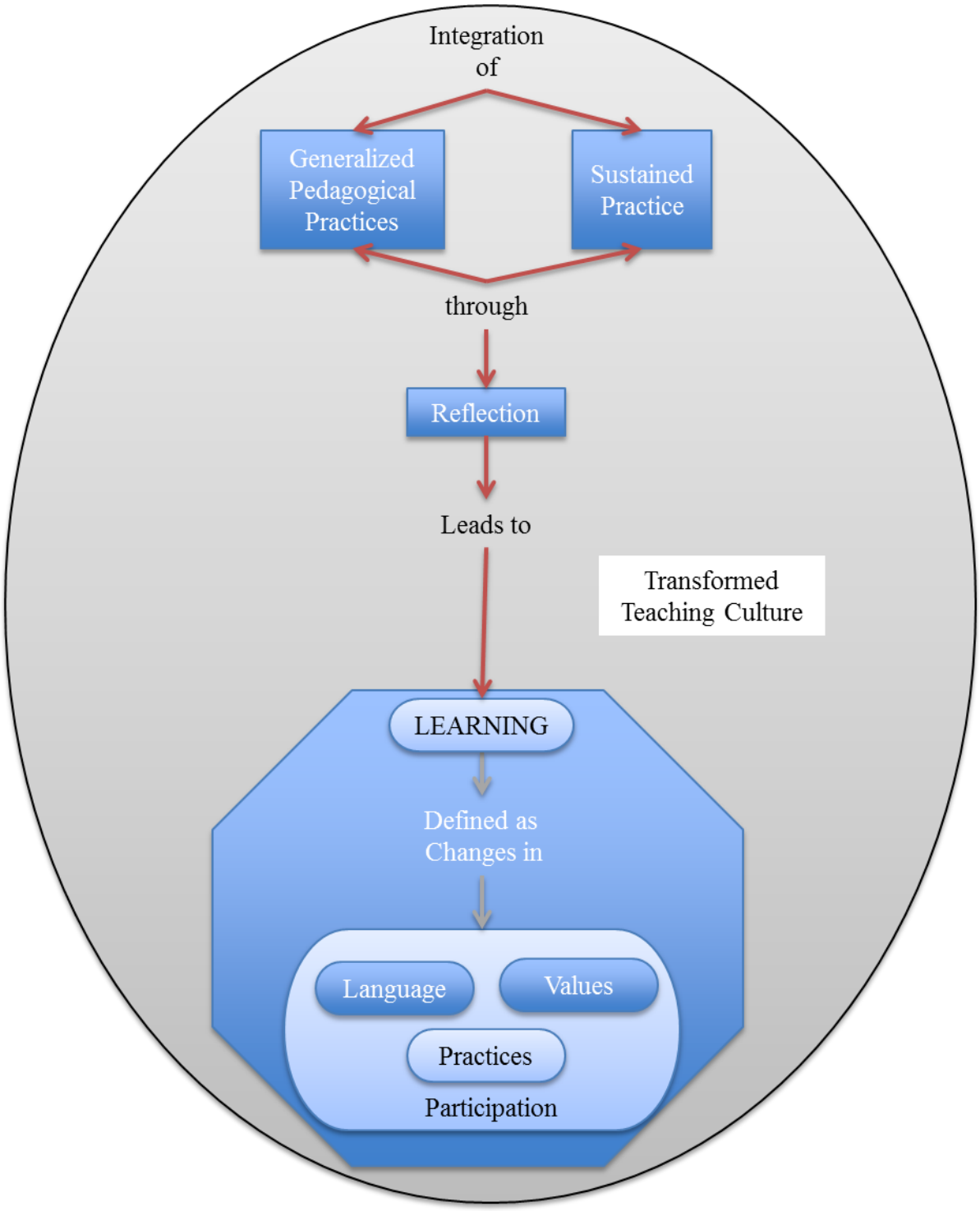

Figure 4. Conceptual Framework of LA Learning.

Methodology

Purpose

The purpose of this study was to understand how the Learning Assistants (LAs) have developed their views of learning during their first semester in the LA program. This study employed a qualitative research methodology, which has been defined as a process that builds a "complex, holistic picture, analyzes words, reports detailed views of informants, and conducts the study in a natural setting" (Creswell, 1998, p. 15). This methodology was used for two reasons. First, it allowed me to develop a descriptive model of how LAs learn about learning. Second, it allowed this process to be described in the words of the LAs. In order to capture the ways LAs talk about learning, I collected the following data – interviews with the LAs from the beginning and end of their first semester, LAs' weekly writings about their experience, and the three larger papers that LAs write as part of the pedagogy course. Using the data from these three sources I developed case studies of the four LAs studied, which described the LA's views of learning. From these case studies, two generalized models of learning were developed which described, in general, how these LAs tended to think about learning. The Colorado LA Program, participants, data sources, and analysis are described in more detail in the sections below.

Colorado LA Program

The University of Colorado Boulder (CU-Boulder) established the Colorado LA Program in 2003 to engage STEM research faculty more comprehensively in the recruitment and preparation of future secondary math and science teachers. This has been done by coupling these efforts with initiatives to transform the faculty members' own large-enrollment, undergraduate mathematics and science courses. The idea behind the program was to hire talented STEM majors to serve as *Learning Assistants* or *LAs* to make transformations in large-enrollment math

and science courses possible. These transformations were based on research in science and math education, in particular making courses more student-centered and interactive (McDermott, 2001; National Research Council, 2000, 2001; Posner et al., 1982). LAs help facilitate collaboration, discourse, and problem solving among small groups of enrolled students who would otherwise be listening to lectures, taking notes, and reviewing solutions to problems. At the same time, these LAs make up the pool from which future K-12 teachers are recruited into math and science teacher licensure programs. The idea is to tap into the pool of talented mathematics and science majors who have not previously considered teaching as a career option, but who might start thinking of K-12 teaching as a legitimate career path as a result of their experience working with students and the encouragement and support of STEM faculty. Meanwhile, STEM faculty members would increase their awareness about research-based instructional strategies, the scholarship of teaching and learning, and issues in K-12 math and science education. The program also benefits the students taking LA supported introductory STEM courses, as shown by dramatic differences in student learning gains compared to national averages (Otero et al., 2010; Pollock & Finkelstein, 2012). To date, the program includes participants from 11 departments, in 3 colleges and schools at CU-Boulder and the model is emulated at over 35 universities throughout the nation.

Figure 5. Three-pronged learning experience of the Colorado LA Program.

The main differences between the Colorado LA program and standard models for undergraduate teaching assistants include: (1) explicit focus on teacher recruitment and preparation, (2) concurrent enrollment of LAs in a seminar targeted at helping them integrate content (that they are both learning as undergraduates and teaching in their LA placement), pedagogy, and their practice as an LA, (3) collaborative educational research program designed to evaluate the effects of the LA model, and (4) involvement of STEM research faculty in the recruitment and preparation of future teachers.

LAs engage in the three-pronged experience shown in Figure 5. First, *content* - LAs meet weekly with the lead instructor of the STEM course in which they work. In these meetings they review course content, plan for the upcoming week, reflect on the previous week, and discuss common student difficulties with the content. Second, *pedagogy* - all new LAs enroll in a semester-long education course that meets weekly and focuses on theories of learning and research-based strategies for teaching. Weekly topics included questioning, constructivism, multiple intelligences, metacognition, student epistemology, argumentation, and the nature of

mathematics and science. For the seminar LAs are required to submit weekly teaching reflections based on a series of prompts. These prompts ask LAs to consider their interactions with students and the application of their readings to their teaching experiences. The LA seminar is described in more detail in a later section. Finally, *practice* - LAs lead "learning teams" of 4-20 students in the courses in which they work. Although the LA experience is different for each transformed course, all transformed courses have opportunities for students to work in their learning teams. In some courses these learning teams meet during lecture, other courses restructure recitations, and others cancel one hour of lecture each week to have students meet in their learning teams. For instance, the CU-Boulder Physics department chooses to restructure the weekly one-hour recitation. During these weekly recitations, students work in groups on problems designed to address many common conceptual difficulties in introductory physics. These problems come from the research-based, research-validated University of Washington's Tutorials in Introductory Physics (McDermott, Shaffer, & Univeristy of Washington Physics Education Group, 2002). The recitation sections are co-led by an undergraduate LA and a graduate TA. The physics department's implementation of the Colorado LA program is described in more detail in a later section. The Applied Mathematics department restructures the weekly one-hour recitations into LA-led problem-solving sessions. During this time small student groups collaboratively construct problem solutions. The Applied Mathematics department has also instituted optional oral exams for their students. These oral exams provide students the opportunity to work aloud through sample exam problems with the oversight and support of an LA. In the Astrophysical and Planetary Sciences department, students work in learning teams, which are headed by an LA who facilitates student collaboration as students analyze real astronomical data to generate and compare scientific models. While the Colorado LA program introduces undergraduates to

pedagogical theories and strategies, it is not the teacher preparation program at our university. LAs interested in a teaching career later enroll in the teacher certification program. In fact, only about 12% of the 792 undergraduates who have served as LAs from 2003 to 2012 have pursued K-12 teacher certification. Others continue on to graduate school in their STEM discipline or pursue non-teaching-related careers.

Throughout the implementation of the LA program, the Discipline-Based Education Research group at CU-Boulder has conducted extensive research on the impact of LA-supported course transformations on enrolled students' and LAs' content knowledge. These replicated studies (Otero et al., 2010; Pollock, 2009) demonstrated that learning outcomes in LA-supported courses were more than double those of traditional courses on standardized, nationally-normed physics assessments such as the Force and Motion Conceptual Evaluation (Thornton, 1998) and the Brief Electricity and Magnetism Assessment (Ding, Chabay, Sherwood, & Beichner, 2006). Further, these studies showed that after one semester of serving as LAs, LAs' scores on these assessments were more like graduate students' than like their peers (Otero et al., 2010). In LA-supported Calculus I courses, more than three times as many at-risk students passed the course as compared to at-risk students in the control courses (Nelson, 2010). One study showed that in a junior-level electricity and magnetism course, physics majors who had taken a transformed electricity and magnetism courses as freshmen outperformed those who had a traditional freshman electricity and magnetism courses, and the LAs outperformed all students in the junior level physics course (Pollock, 2009). These are the students who are being recruited to K-12 teaching through the Colorado LA program.

CU-Boulder Physics Department's LA Program

LAs in the introductory physics courses work with students during the students' weekly one-hour recitation sections. Each LA works in three to four recitations a week. All recitations met on Thursdays during the semester included in this study. Each recitation section includes approximately 28 students, one graduate teaching assistant (TA), and one to two LAs. Students sit in groups of three to five students to work through the recitation activities. Attendance in recitation counts toward students' course grades. They also have weekly recitation homework that is based on the activity from the previous week and is graded.

Within the recitation classroom, LAs and TAs share the same responsibilities, but their experiences outside the recitations are very different. Most TAs are first-year physics graduate students. They receive two days of pedagogical training right before classes start for fall semester. They also attend weekly content preparation sessions with the LAs and the course instructor. Therefore, TAs tend to have less pedagogical instruction than LAs. TAs are also required to grade homework and proctor exams unlike the LAs.

LAs guide tutorial sections that use the University of Washington Tutorials (McDermott et al., 2002). The University of Washington Tutorials are a series of research-validated worksheets designed to supplement traditional physics lectures. The worksheets are designed around common conceptual physics topics with which college students in introductory physics courses are known to struggle. Each Tutorial is designed to draw students' attention to contradictions in their own reasoning through a series of questions asking students to rank order situations or explain their reasoning. The Tutorials are designed to then help students develop the correct scientific explanation through Socratic dialog-like questions. At various points in the Tutorials students are instructed to check-in with their instructor about their reasoning. LAs

assist students in the development of conceptual understanding by asking probing questions based on their evaluation of students' ideas as they work through the activities (Finkelstein & Pollock, 2005). The Tutorial topics for each week are listed in Appendix 5.

Participants

I chose to focus on LAs in the first semester, calculus-based Mechanics course of the two-semester introductory physics sequence (PHYS 1110). All four of these LAs agreed to participate. The gender, year, major, and career plans of each LA are presented in Table 1. In the second column labeled Year, the LAs' year in college is based on the number of years they have attended college and not on the number of college credits they have received. Gen was in his first year of college during the semester of the study but had enough college credits to be classified as a junior. Andy was in his second year of college but completed his first year of college at another university. Leah completed a bachelor's degree in Political Science at another university and had returned to complete her pre-requisites for medical school. The LAs' career plans are based on the careers they gave during the first interview. Gen's career plans became more nebulous by the end of the semester. Andy and Jamie's career plans remained undecided.

Table 1. Description of LAs.

	Gender	Year	Major	Career Plans
Leah	Female	Pos – bach	Poli Sci / Pre med	Doctor
Andy	Male	Sophomore	Mechanical Engineering	Undecided
Jamie	Female	Freshman	Physics	Undecided
Gen	Male	Freshman	BioChemical Engineering	Doctor

LA Pedagogy Seminar

First-time LAs from all departments attend a weekly education seminar focused on pedagogy in which they explore literature about research-based teaching strategies, learning theories, formative assessment, student-centered instruction, and other topics in education. The

seminar includes activities intended to extend the readings or apply the readings to LAs' particular teaching situation. LAs are also required to submit weekly online teaching and reading reflections. These reflections not only help LAs be reflective about their teaching but allow instructors to stay informed about LAs' experiences and obtain formative feedback about how LAs are interacting with the content of their course. The following sections provide more detail about the content of the seminar and the course assignments.

During the semester of this study the LA seminar included thirty-one first time LAs from seven different departments. Dr. Iona, a retired high school math and science teacher, and Prof. Otero, a professor of science education, co-taught the course for the entire semester. I served as a teaching assistant for the course. I posted the online reflections and attended the weekly meetings with Dr. Iona and Prof. Otero to plan the seminar. Several times during the semester, including week five, I stepped in as a substitute co-instructor when Prof. Otero was gone. The syllabus for this semester is included in Appendix 6, though all dates have been removed.

Pedagogy Seminar Content

Table 2. The LA Seminar units and their related lesson topics.

Unit	Lesson Topics
1. Teaching Strategies - Questioning	Open and closed questions Dialogic and univocal discourse
2. Theories of Learning	Mental Models Resources model of learning Formative assessment
3. Meta-Issues in STEM classes	Cooperative learning Argumentation Metacognition Nature of Science/Math
4. Teaching Strategies for all students	Multiple Intelligences Differentiation Qualities of Effective Teachers

There are four units covered in the LA seminar (see Table 2). The first two weeks cover the first unit on questioning strategies. Because the LAs begin working with students as soon as the semester starts, it is important that they receive some training to help them successfully work with students. Because questioning is critical to the teaching philosophy of the LA program and the transformed STEM courses, it was taught first. During these two weeks LAs discuss the differences between open and closed questions, how to recognize dialogic and univocal discourse styles (Knuth & Peressini, 2001), and how to use Bloom's taxonomy to diversify their questions (L. W. Trowbridge, Bybee, & Powell, 2000). The second unit focuses on theories of learning. This unit extends from week 3 to week 5. This three-week unit focuses on helping LAs develop a theory for how students learn and how teaching helps students while also providing a common vocabulary for the seminar. The unit begins by developing a theoretical perspective on students' knowledge as mental models or resources. The second week focuses on building a model of formative assessment. Formative assessment is used in the seminar to mean a type of responsive teaching that focuses on the teachers' goals for the lesson and the students' current understanding of the topic and then creates instructional strategies or learning experiences to serve as bridges between the two ideas. Finally, the last week focuses on applying these ideas to LAs' specific content areas. The third unit of the LA seminar focuses on the meta-issues of STEM courses. This unit refers to the skills most STEM instructors want students to develop during their course, but that are not included on the course syllabus. These skills include cooperative learning (Johnson, Johnson, & Smith, 1998; Johnson & Johnson, 1999), argumentation (Jimenez-Aleixandre, Rodrigues, & Duschl, 2000), metacognition (Schoenfeld, 1987), and the nature of science (Lederman, 1998). The final unit of the LA seminar returns to teaching strategies but with a focus on how to reach all students. In this unit, the LAs talk about

the importance of recognizing students' multiple intelligences (Armstrong, 2000) and using differentiation (Tomilson, 1999) in their instruction. The LAs also discuss the qualities of effective teachers. The readings and related class discussions on the qualities of effective teachers are very influential for many of the LAs. The seminar approaches the topic from two different perspectives. First, the seminar discusses the topic from the perspective of research that attempts to document the common characteristics of highly effective teachers (Stronge, 2002). Second, the seminar considers the importance of an instructor's integrity rather than their instructional strategies as discussed by Parker Palmer (Palmer, 1997).The topic of the last week of reading for the LA seminar has varied across semesters. During the semester of this study, the final week of the seminar discussed the importance of teaching as a profession in the future (Berry, 2009). While this was not a topic that related directly to the LAs' teaching experience, it was relevant for those LAs who were considering future careers in teaching. Also, the instructors considered it relevant to other LAs in their role as informed citizens. The topics for each week of the LA seminar are listed in Appendix 5 under LA seminar topics.

During the semester the LAs also engage in a series of class activities that are independent of the four units discussed above. The LAs collect and analyze anonymous feedback from students. Surveys are given to students partway through the semester. The LAs read and discuss the feedback in the LA Seminar. The LAs also observe another LA and then provide feedback in class to that LA. The LAs do two of these observations during the semester. For the first observation, the LAs observe a fellow LA who teaches the same course or in the same department as they do. For the second observation, LAs observe an LA from a different department than themselves. During these observations, the LAs took notes using the template

shown in Figure 6. Following the observation the LA responded to the following reflection questions:

1. What were specific actions or questions, by the Learning Assistant that increased student involvement, attention, participation, and thinking?

2. What were specific questions or actions that the Learning Assistant did to elicit or clarify student ideas?

3. What were specific ways or examples of the Learning Assistant responding to student questions, statements, or answers?

4. What did the Learning Assistant do well during the teaching session?

5. What suggestions to you have for the Learning Assistant for improvement?

During the pedagogy course the following week, the LAs share their notes and reflection responses with the LA they observed and provide constructive feedback for that LA. The LAs also spend one class period of the semester talking with perspective LAs about their experience at the LA Information Session. The dates of these activities are listed in Appendix 5 under LA Seminar topics.

What the LA did	What the students did	Personal comments

Figure 6. Template for LA Observations

Written Assessments

LAs' grades in the LA pedagogy seminar are based on the completion of a series of written assessments throughout the semester and class participation. There are four types of assignments – reading reflections, teaching reflections, article reports, and a final paper. Most of

these assignments have been used as a source of data in this study. The due dates for each of the written assignments are listed in Appendix 5 under LA Seminar Assignments.

LAs are required to submit teaching reflections on-line each Monday. These teaching reflections focus on the LAs' general impressions of their experience that week, specific issues that arose during their teaching, and specific applications of the topics covered in their pedagogy course to their teaching experiences. An example of a teaching reflection form that the LAs fill out online is shown in Figure 8. Each week, the LAs answer different questions, though many questions are repeated during the semester. LAs who miss a reflection are asked to turn in a one-page reflection about their teaching. All of the questions that were asked over the course of the semester of this study are listed in Appendix 3. Appendix 4 lists which questions were asked as a part of which weekly reflection for the semester of this study.

LAs are asked to write three papers during the semester. The first two papers are referred to as Article Reports. The Article Reports are four page papers that ask LAs to summarize two of the course readings, synthesize the two readings to create a common theme about teaching, and then apply this theme to their LA experience. At the end of the semester LAs are required to submit a final paper that summarizes what they learned that semester. This paper is intended to be a written summary of the poster they present at the final pedagogy class. The posters are designed and presented by individuals or pairs of LAs. The posters are typically formatted based on what LAs feel they have learned from the LA experience. While the LAs tend to work on the posters in pairs, they are required to submit their own paper. The papers range in length from two to four pages.

Data Sources

In order to understand these LAs' views on teaching and learning they were interviewed at the beginning and end of the semester and their weekly writings and course papers were collected and analyzed. These data sources are explained in more detail below. All data sources and their timing within the semester are shown in Figure 7.

Interviews

The LAs were interviewed about their views on teaching at the beginning and end of the semester. In the first interview I asked about their previous experiences with tutorials and LAs, their expectations for the semester, how they planned to help students, and what they considered to be good teaching. The interviews were conducted in the first week of the semester before the LAs attended their first pedagogy class or physics tutorial. In the second interview, I focused on LAs' experience as an LA, how they thought they were able to help students, and their future plans around teaching. The interviews were conducted during the last tutorial session of the semester while the students were busy completing end of the semester conceptual inventories. The interviews lasted between thirty and fifty minutes. The interview protocols are included in Appendices 1 and 2. The dates of the interviews are included on the weekly schedule for the semester in Appendix 5. Within this study the interviews are referenced by giving the LA's name, listing pre or post based on which interview is being referenced, and the line number of the relevant text of the interview transcript (e.g. Gen, pre, 191 – 220).

Weekly Writings

LAs were required to submit teaching reflections on-line each week as part of the LA pedagogy course. In these reflections, LAs responded to a series of questions about their experience that week. The questions on the weekly teaching reflections varied each week though

some questions were repeated during the semester. The weekly reflections' questions that were asked in the weekly reflections are listed in Appendix 3. The questions, which were asked each week, and the order of the questions on each weekly reflection are listed in Appendix 4. In this study, weekly reflections are referenced by listing the LA's name, the week the reflection was submitted, and the number of the question to which the LA was responding (e.g. Andy, wk04, 2). If a student missed a teaching reflection, they could submit a one-page reflection on their teaching experience that week. The makeup reflections have been referenced by listing the LA's name, the week of the makeup assignment and the word makeup (e. g. Gen, wk10, makeup).

In the semester of this study the LAs were assigned 13 weekly reflections. Two of the LAs (Leah and Jamie) completed all 13 weekly reflections. One LA (Gen) missed the week 12 reflection and submitted a makeup assignment later that week. The final LA (Andy) missed three of the reflections (wk6, wk8, and wk14) and did not submit any makeup assignments.

Course Papers

As part of the LA weekly pedagogy course, LAs are required to write three papers. The first two papers are referred to as Article Reports (AR). Quotes from LAs' article reports are referenced in this study by referring to the name of the LA, the number of the article report, and the line number of the referenced text (e.g. Leah, AR1, 19-25). At the end of the semester LAs were required to submit a final paper that summarized what they learned that semester. This paper was intended to be a written summary of the poster they presented at the final pedagogy class. Quotes from the LAs' final papers are referenced in the study by giving the name of the LA, the word final, and the line numbers of the quoted text (e.g. Jamie, final, 31-35).

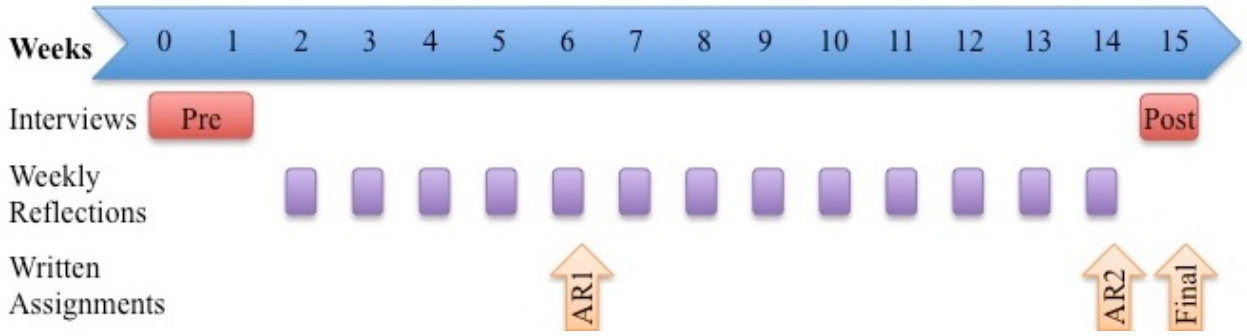

Figure 7. Visual Representation of all data sources collected for the study.

Data Analysis

I analyzed the LAs' interviews and writings to understand the LAs' views toward teaching and learning. I used emergent data analysis strategies – allowing the categories, themes, and codes to arise from the data - to make sense of the data. This does not assume that my prior experiences did not shape my data analysis focus. My focus, when I began the analysis, was on formative assessment strategies since I considered these to be a learning goal of the LA program and a critical component of the LA experience. Research has also demonstrated that this was a difficult concept to teach. While this was my focus in the analysis, I also looked for what LAs' talked about being important to their teaching and learning.

This analysis process proceeded in four phases. In the first phase I focused on excerpt selection using four selection questions. In the second phase I developed a series of emergent codes for the excerpts chosen in the previous phase. In phase three I refined the 21 codes developed in phase two into seven codes that were separated into two categories. In the final phase I used the coding scheme developed in phase three to create generalized models of the LAs' views and case studies for the four LAs. The two categories developed in phase three represented the two views of teaching and learning that were prevalent in the LAs' talking and writing. The generalized models developed in phase four provide an overview of these views and

focuses on the similarities across the LAs. The case studies developed in phase four demonstrate the nuisances the LAs exhibited in the individual views. These four phases are described in more detail below.

Phase One

I began the process of analyzing the data by selecting excerpts from the interview transcripts, written assignments, and weekly reflections that addressed at least one of four *selection questions* –

1. What influences LAs' learning?
2. How do LAs talk about struggling students?
3. How do LAs define teaching?
4. How do LAs define learning?

The selection questions served as a priori codes for the data. These questions were developed from the research questions. I coded the data using NVivo software. This allowed me to highlight excerpts of text from the data and label them using the four questions above. I was then able to extract all of the text coded under each question. While I began the excerpt selection process with four selection questions – *influences, struggling students, teaching, and learning* – I found only the last two to be particularly helpful. The first question, influences on LAs' learning, was intended to capture statements from the LAs that focused on the experiences that appeared to help them learn. Unfortunately the excerpts chosen were either based on highly inferential selection decisions or appeared to be too sensitive to cueing from interview questions. Therefore this question was abandoned for excerpt selection purposes. The second question – *how do LAs talk about struggling students* – focused on the statements LAs made about how they would help or had helped students. This question

turned out to be redundant since these excerpts also addressed either the third or fourth question – *how to LAs define learning* and *how do LAs define teaching*. Therefore these excerpts remained important in later analysis since they often provided concrete examples of LAs' views on teaching and learning, but it was not helpful to group them together independent of the strategy being described. All excerpts that were originally selected under this selection question were regrouped under the question of *how LAs define learning* or *how LAs define teaching*. I ended this phase of the analysis with two groups of extracted text that served as my data for the remaining phases of the study.

Phase Two

Once I had selected the excerpts that I felt related to the section questions about teaching and learning I began the process of further coding the data. For this phase I used a series of emergent codes. Emergent codes are developed from the data rather than from prior research questions. This is a process similar to that described by Coffey and Atikinson (1996). I used emergent codes at this point in the process because I wanted to focus on understanding the data from the LAs point of view. In the a priori codes the LAs' views on teaching and learning were divided based into two selection questions because I predicted that LAs might talk about how people should be taught differently than they talked about how people learned. Therefore excerpts selected by each selection question were kept separate for the second phase of the coding process. This resulted in two categories of codes based on the question used to select the excerpt. The list of codes under each category turned out to be very similar. This was because there did not appear to be a difference in how LAs talked about how people should be taught compared to how people learned. Instead, the excerpts were grouped into one of the two categories – *teaching* or *learning* – based on to what question the LA was responding. Table 3 lists the codes

developed from this original excerpt selection. The codes are grouped based on which question the excerpts were chosen under – *how do LAs define learning* and *how to LAs define teaching*. The table includes the name of the code, a brief description, and an example of an excerpt from that code. Also, when creating the codes shown in Table 3 I chose to err on the side of making codes that were too specific and focused on the distinctions between excerpts resulting in a large number of codes rather than erring on the side of emphasizing the similarity between excerpts and having fewer codes.

Table 3. Emergent Codes for the Groups "How do LAs talk about Learning" and "How do LAs talk about Teaching.

Codes	Definition	Example
How Do LAs Talk about Learning		
Discovery	give students the opportunity to learn on their own.	My job as an LA is to help the students learn. I give them them the tools and the opportunity to learn and guide them through.
Discussions are important	Important for students to talk with each other	The tutorial is a great way to do this through discussion. One of the things I have been good at doing is encouraging group discussion of the topics. If a student has a question, I try to see if one of the other students at the table can answer it before I try to answer it
Explaining	telling students the answer to a problem or question	Sometimes, if the students' ideas were very off track, I just had to state right out that acceleration is perpendicular to velocity on a curved path. If I had to do this, I would try to explain it with a physical situation (i.e., spinning a ball around on a rope) and if they still didn't understand, I told them to accept the answer for now and to keep trying to figure out why that was true.
Groups - Additive	Groups work because if you don't have the answer someone else might.	Well. I mean it was really helpful to go through our tutorial sets with other people because, I think, a lot of times group learning can be better because if you don't know something, somebody else is there to fill in those gaps.

	Groups - Synergistic	Students' can build off of each others' ideas in a group therefore knowing more than they would individually.	Instead, I increasingly believe that the value of discussion lies not in the information itself, but in the way that students learn to generate ideas and understanding within a small group. Creativity increases significantly when students combine and develop their individual ideas as a group.
	Learning Styles	Students learn in different ways or prefer one way to another.	Occasionally, I will explain a concept in a way that I think will make sense to the student, only to see blank stares. I often have to try several ways of explaining something before one "clicks", and this is probably doe to the individuality of each student's learning style.
	Mental Models or Resources	students come to class with experiences that can be useful (or detrimental) to understanding physics concepts.	Because especially in physics, I mean, physics, everybody kind of has an innate understanding of physics, it's just its hard to get there from just dry lecture or reading the book and stuff.
	NOS	There are skills we want students to learn beyond just physics concepts.	Lectures and answer-giving will not advance an understanding of the nature of science because students need to be able to produce their own creative ideas and thoughts regarding a specific problem. It is not simply scientific knowledge that students must learn, but scientific skills.
	Questions important	It's important to help students learn by asking them questions rather than telling them something.	Next week, before the tutorials, I am going to think ahead for questions I can ask students to get them to think about the concept without telling them the answer. This way, I will be more prepared for the specific places that I can help push the students to understand the idea on their own.
	Real World examples	LA uses examples from real life to help a student understand	Students who had trouble understanding the physical meaning behind the vectors struggled with the concept because many could find no bridge to connect this idea with one they already understood. In an attempt to engage a physical understanding of acceleration, I asked one student to imagine driving a car.
How Do LAs Talk About Teaching?			
	Adaptable	A teacher should be prepared to change the instructional strategy based on the student.	I have encountered the necessity of adaptability in teaching style both as a learner and a teacher. As a learner, I am keenly aware of situations in which a small change in

			teaching style or lesson can greatly enhance my understanding of a subject.
	Alternative Explanations	Teachers should present material in multiple ways.	As a teacher, I think it is important to try to understand how each student prefers to learn, and spend equal time on detailed examples and the general concept.
	Applications	It can be helpful for students to help them apply the concept to another situation.	Giving the students further applications and examples seemed to help them understand the concepts much more. Trying to explain or define something straight out wasn't very effective,
	Approachable	It's important for students to feel comfortable talking to a teacher.	know I've had teachers like that who are just really dry and really strict and you really don't want to ask them questions because you're afraid to look stupid and I think that that's kind of sad because how else are people gonna learn
	Authoritative	Good teachers have authority over their classroom.	My main goal was to try to get myself comfortable with being an "authority figure" for a class of students. I felt that I met this goal, because I was able to maintain a reasonable presence
	Check for right answer	The LA's main job is to make sure that students have the correct answer on the tutorial.	I tried to pinpoint the groups that I knew had struggled in the past, and make absolutely sure that they knew the material. If a group understood a concept thoroughly, and it was evident in their answers to the tutorials, I tried not to bother them too much.
	Comfortable with students	LAs should be comfortable working with students	My main goals for this week were: 1 getting comfortable helping the students with tutorials
	Content knowledge	The LA focuses on students' conceptual understanding of the topic.	Both motivational and conceptual. I feel I met my goals. The students definitely have the concepts of conservation of momentum down!
	Encourage interaction	The job of the LA is to encourage students to work together.	I wanted the groups to feel comfortable discussing the topics and also discuss more with each other. This was partially accomplished, but I feel I didnt prompt nearly as much discussion as Id hoped. The students were more shy than I thought and werent as willing to discuss with one another.

	Engaging_fun_ relatable	Good teachers are engaging, fun, and relatable	I think the most general thing I can come up with is somebody who teaches in a style that is just not relatable I guess or something you just can't pay attention to.
	Explain	The LA responds to questions by explaining the concept.	I started changing my methods a bit and asking less questions then telling them my interpretation and asking them how theirs' has changed.
	Group dynamics or off task students	One job of the LA is to help students deal with group dynamics and stay on task.	Last week worked generally well. For the groups that tend to get distracted I really worked to focus them more, though there was loads of discussion relating to how students did on the test that took up far too much time. I tried to ask them to focus on their work, but it seemed unavoidable.
	Helpful	The job of the LA is to be helpful.	Like they both walked around the room and helped as you were going through the tutorial. Just helped you understand what was going on,
	LAs better	LAs are more helpful than TAs	And it was just really great to be able to learn from other students because I think that other undergraduate students sometimes have a better idea of what their fellow undergrads need to be able to learn the material.
	LAs don't teach	LAs don't teach students.	Is that the LAs weren't really teaching you but like sort of pushing you to understand the concepts better. Is that the LAs weren't really teaching you but like sort of pushing you to understand the concepts better.
	More than Right answer	There is more to learning than just getting the right answer.	I have noticed that the more I teach and learn about teaching, the more I have realized the importance of allowing the student to reach his or her own answer. A student learns much better through thinking, and that process is much more important than the answer itself.
	Motivating	Part of the LA's job is to help students become more excited about physics.	I hope to help them to become more motivated to explore physics this week. Since motivating more people to be interested in physics was one of my reasons for being interested in becoming and LA,
	Not give answer	The LA should never just tell students the answer.	It was really helpful that none of the LAs that I had have ever given me the answers or anything which a lot of people want. And I know a lot of times I've wanted them too.

	PCK	The LA is developing an understanding of where students are likely to struggle and is devising strategies to address these issues.	Next time I will spend more time looking over the tutorial beforehand to get a good understanding of places where the students may have problems.
	Start conversations	The LA is working on how to enter or start conversations with students.	My main goals for this week were: . . .2 Figuring out what was the best way to start a conversation without giving the answer.
	Teaching more than content	LAs help students learn more than just content.	So, yeah, just sort of there as the guide to help you figure out what's the best way for you to learn

Phase Three

As mentioned above, the distinction between the excerpts grouped under the selection question *how do LAs define teaching* and those grouped under *how do LAs define learning* differed mainly based on the interview question or reflection promote to which the LAs were responding. It did not appear that the LAs were making a distinction in how they talked about learning and how they talked about teaching. This was evidenced by the similarity in the emergent codes developed for each group in phase two of the process. Therefore, for phase three of the analysis, I combined all of the emergent codes into one large group. This resulted in a lot of redundant codes (e.g. explain and explaining). I then merged codes for a more concise series of codes. Many of the codes were also specific examples of teaching strategies or LA statements. To make the coding scheme more concise, I therefore merged codes to create a more abstract series of codes. At the end of phase two there were 21 codes, during phase three of the analysis I merged these codes into a final seven codes. These seven codes will be described in detail in the results chapters. Three of the 21 codes were dropped. These codes and this process will be described in a later section. I then further grouped these seven codes into two categories – *formative assessment* and *student/teacher relationships*. The first category, *formative assessment*,

included all the codes that related to the cognitive aspects of how people learned and the teaching strategies teachers used to facilitate the cognitive aspects of learning. I referred to this category as *formative assessment* since most of the ideas expressed in this category aligned with the literature on formative assessment teaching strategies. The second category, *student/teacher relationships*, included the codes that were focused on the affective aspects of learning and the teaching strategies teachers used to address these affective aspects of learning. I referred to this category as *student/teacher relationships* since these excerpts were focused on how to build relationships and why these relationships were important. Later in the analysis these two categories came to represent the two themes I developed from the LAs' talk and writings and therefore the major findings of my analysis. This process of grouping and merging codes is visualized in Table 4.

Phase Four

Once I had developed the two themes and their seven codes, I used two methods for portraying the information – *generalized models*, explained below, and *case studies*, explained in the next section. The two methods of describing the data were intended to portray two different aspects of the information. The *generalized models* focus on the points of similarity in the experiences of the four LAs. They are intended to suggest the possible outcomes that may be expected from the LA experience. The *case studies* highlight the uniqueness of each LA's experience. They are intended to demonstrate the range of LAs' experiences though I do not suggest that these four case studies have completely mapped the entire terrain of possible experiences.

generalized models. I developed the two generalized models for the two themes differently in order to highlight the most important aspects of each theme. For the theme on

formative assessment, I focused on explaining the relationship between the four final codes of the theme. In order to do this I compared excerpts across the four LAs and across time. I looked for the most articulated descriptions of what each code meant. By looking at when the LAs brought up each code, I found that the four codes in the *formative assessment* theme tended to appear in the same order across the semester for each of the four LAs. I also found, based on my understanding of the codes and the related literature that the four codes built on each other conceptually. Therefore the diagram of this model is designed to portray the building up of the concepts in both time and conceptually. The generalized model also includes the most articulated descriptions of each code based on excerpt from across the LAs.

Table 4. Coding Scheme used for Data Analysis.

Original Emergent Codes	Final Codes/Model Components	Categories/ Themes
Discovery	Construction	Views of Formative Assessment
Discussions are important		
Questions important		
Applications		
Check for right answer		
Content knowledge		
Explain		
Explaining		
LAs don't teach		
Not give answer		
NOS		
More than Right answer		
Teaching more than content		
Mental Models or Resources	Prior Knowledge	
Real World examples		
Learning Styles	Individuality	
Alternative Explanations		
Adaptable	Adaptable	
PCK		
Approachable	Approachable	Views of Student/ Teacher Relationships
Comfortable with students		
Encourage interaction		
Engaging_fun_relatable		
LAs better		
Start conversations		
Authoritative	Authority	
Group dynamics or off task students		
Motivating	Motivation	
Groups - Additive	Dropped	
Groups - Synergistic		
Helpful		

For the generalized model of the *student/teacher relationship* theme I chose to focus on creating descriptions of each of the three codes for the theme. These descriptions were

summaries of the most common and well-articulated excerpts across the four LAs. I also created a diagram for one of the codes – *approachability* – within this theme. I chose to treat the *approachability* code differently because almost all of the excerpts in this code described a process for how being approachable would lead to student learning. Therefore I created flow charts for each of the excerpts to visualize what the LA was describing. I then created the generalized flow chart to depict all the common aspects of the excerpts.

The generalized models were not intended to accurately depict the views of any one LA. Instead the models provided a general picture of the similarities across all four LAs. Therefore these models have worked very similarly to a scientific model. A scientific model may not perfectly predict a single experimental trial but does provide a helpful approximation of that single trial. The models provided a helpful way of talking about the views of LAs. For instance, all LAs talked about the individuality of their students, but the value they placed on this individuality varied across the LAs and across time.

case studies. The case studies were intended to describe the nuances between the views of the individual LAs and the generalized models. While the generalized models have been useful, it has been also informative to consider the variations in LAs views. The case studies have shown how LAs' views evolved over the semester.

Limiting Bias in the Analysis

Throughout the data analysis process I worked to limit the bias I brought to the data. I did this in several ways. During the excerpt selection phase, I chose excerpts based on the four questions stated above, but I also used two other questions to broaden my selection – what do I find interesting about what this LA is saying here and what appears to be important to this LA here. These questions allowed me to consider both excerpts that I considered to be relevant to the

literature on teaching and learning and that captured the views and interests of the LAs. The two themes that developed from this analysis demonstrate this dual focus. The theme on *formative assessment* aligns with my original interest in formative assessment. The theme on *student/teacher relationship* aligns with a topic I had not focused on prior to the analysis, but which I came to recognize as being very important to the LAs. Another way I attempted to limit bias in my analysis throughout all four phases, was to frequently return to the original data sources while I was analyzing the data rather than relying solely on the excerpts I originally chose in my analysis or the codes I created. As I refined my codes I returned to the transcripts and writings to check for other excerpts that would align with the code, help to clarify the code, or would discredit the code.

As I created and merged codes in phases two and three of the study I attempted to emphasize both similarities and differences across LAs and data sources. In other words, I abandoned or merged codes if they did not meet one of the following criteria

1. A code needed to be repeated multiple times within a single data source (an interview, written assignment, or weekly reflection) for a single LA and in response to multiple questions (for the interviews and weekly reflections) or mentioned in multiple sections of the written assignments.
2. A code needed to be repeated multiple times across multiple data sources for a single LA.
3. A code needed to be repeated across multiple LAs but within in the same type of data source (e.g. pre interviews, final paper, week 3 reflection).

These criteria allowed me to select codes that characterized ideas that were common to the LAs or that were important enough to a single LA to mention multiple times.

When I merged codes in phase three of the study I attempted to maintain the focus and

integrity of what the LAs were saying in their interviews and writings. This meant making sure that codes and their excerpts were not dropped from the analysis. I did choose to drop three codes, though, because I did not feel that they contributed to an understanding of how LAs thought about teaching and learning. The two Groups codes, *Groups-Additive* and *Groups-Synergistic*, were dropped because the distinction between the codes was not a distinction made by the LAs but one that I was reading into the LAs' statement and was therefore of higher inference than the other codes. The excerpts that had been grouped under these codes were moved to *Discussions are important* so the excerpts themselves were not lost from the analysis. The third code that was dropped was the *Helpful* code. This code included all the excerpts where the LAs described the job of an LA or a teacher as being helpful to students. It was unclear what the LAs meant by the word helpful or if they meant the same thing every time the word was used. Since the code did not shed any light on how the LAs thought people learned or how the LAs thought they should teach the code was removed. Any of the excerpts originally grouped under this code were moved to other codes if at all possible and were otherwise dropped from the coding scheme if they were too vague to be grouped elsewhere.

Limitations of the Study and the Generalizability of the Research

The purpose of this research is to develop a detailed understanding of four LAs' views of teaching and learning. The resulting case studies and the generalized models should help to inform the understanding of how the Colorado LA program helps LAs learn and how pre-service teachers learn to teach. While this study should inform our future understanding, there are several limitations that must be taken into account based on the specific context of this study.

The LAs who participated in this study were working within the physics Tutorial environment. They were therefore part of an established program that included faculty, TAs, and

returning LAs who were familiar with how the Tutorials should be run and who were able to offer support. LAs who are part of a new program may not have these advantages.

These LAs were also working with the University of Washington Tutorial activities. These are research-based and research-validated activities designed to elicit students' ideas and address common problems students have with introductory physics concepts. Because of this these four LAs were in an optimized environment where the teaching philosophy of their practice context was congruent with the philosophy of their pedagogy course. Other LAs may be in contexts that do not have well designed activities or that have a teaching philosophy that is not closely aligned with the philosophy of the LA program.

Because these LAs were part of an established LA program, they all had previous experiences with LAs. All of the LAs were students the previous semester, in the same course in which they were teaching. Therefore the first-time LAs already had many ideas about the LA experience because of their opportunities to observe LAs when they were students. This experience shaped the LAs' opinions as evidenced by the frequency with which the LAs referenced their former LAs during the pre-semester interviews. Other LAs who are part of a new program, will not have the opportunity to learn from their own LAs.

The physics LA program at CU-Boulder is in the advantageous position of having more LA applicants than they have LA positions. In the semester that these LAs applied, there were four applicants for every one position. This meant that the physics faculty were able to interview applicants and select students who were likely to be successful LAs. Therefore the LAs who participated in this study were some of the best applicants for the positions. Based on my observations of LAs over several semesters in the LA pedagogy course, however, these LAs were representative of the students chosen as LAs at CU-Boulder.

Finally, this study must be placed in its historical context. The semester of this study was the first time that the LA pedagogy course explicitly addressed formative assessment. While the concept of formative assessment has always been an important part of the LA program, the concept has been taught to LAs implicitly as a part of the resources perspective (Hammer, 2000) on student learning. During the semester of the study the concept of formative assessment was introduced in week four and the term was used several times during week five of the course. However the term did not become a common part of the language of the course. At the end of the semester, none of the LAs could define the term when asked about it in the end-of-semester interviews. Since this semester, formative assessment has remained an explicit topic of the course, but the way it is taught has continued to evolve. Later iterations of these lessons tended to stress the term formative assessment so that it became a more common part of language in the course. Therefore some aspects of the LAs' views on formative assessment may be unique to this particular semester.

Despite these limitations, I believe that the models and case studies developed in this study have relevance to the experiences of other LAs and pre-service teachers.

1. LA Job Descriptions

(Points: 5)

In what course are you working? What is your main responsibility (Do you help with clicker questions during lecture; run a co-seminar, help with tutorials, labs, or recitations; work in the helproom; etc?)? Are students required to participate in the part of the course in which you are working? Are you working with a TA or fellow LA? Do you have grading responsibilities?

Paragraph

New Insert equation Go

Save Answer

2. Goal

(Points: 5)

What was your main teaching goal(s) for this week? These can be conceptual, motivational, metacognitive, etc. Do you feel you met this goal(s)? Why or why not?

Paragraph

New Insert equation Go

Save Answer

3. Evaluation of group interactions

(Points: 5)

Did all the students appear to be participating? Any good discussion? Any problems with the group, and if so how do you plan on addressing that problem in the future?

Paragraph

New Insert equation Go

Save Answer

Figure 8. Example of Weekly Reflection that LAs fill out on-line and submit.

Results Chapters

The following three chapters present the results of this research. The first two chapters present the two themes that were developed from the analysis of the data of all four LAs. These themes are formative assessment and student/teacher relationships. Each chapter begins with a description of the generalized model developed for that theme. Following this is description of the analysis done on the data that led to this generalized model. The third chapter presents the individual case studies of the four LAs. Each case study describes that LA's nuanced views on the two themes. Each of these sections begins with a table that summarizes that LA's views on the theme at various times in the semester.

Theme 1: Views of Formative Assessment

My analysis of the LAs' writings and interviews showed that over the semester the LAs developed common views of teaching and learning. Because these views have so much in common with the literature on formative assessment, they will be referred to as the LAs' views of formative assessment. These views include four constructs that build on each other. A model of these views is shown in Figure 9. The following section will describe the generalized model and the analysis section will deconstruct relevant excerpts from the LAs' writings and interviews to demonstrate each aspect of this model.

Generalized Model

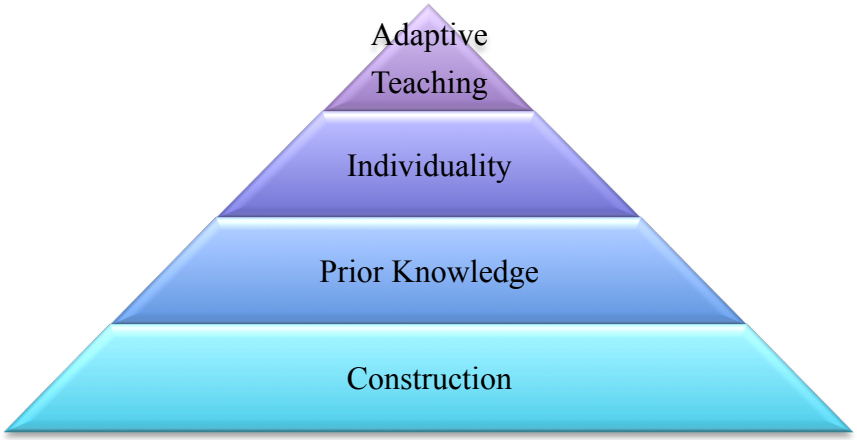

Figure 9. A model of the Generalized Views of Formative Assessment.

The first element of the generalized model of the LAs' formative assessment views is the *construction* of knowledge. The construction of knowledge refers to allowing students to build up a scientific concept using their own experiences or first principles rather than learning concepts in their final form from lectures or textbooks. The construction of knowledge is therefore an active, rather than passive, process for the student. According to the model, it is very important for students to construct their own understanding of a concept rather than being

passively given the concept by an instructor. The general model considers lectures to be a passive form of learning while the Washington tutorials are designed to make the students active in their learning process. The reason the model emphasizes having students take an active role in their learning is because the resulting understanding will be more durable and robust.

Since students are expected to construct their own understanding, according to the model, the instructor must take on a different role within the model when compared to traditional teaching. The model expects the teacher to take a facilitating role where her job is to help students construct their understanding but to not develop the concept for the students. A facilitating role means that the teacher assists students when they are struggling with the material. Yet, the student remains in control of the process and he is expected to do the mental work of building the idea. According to the model there are two general methods that instructors can use to facilitate learning – questioning students and providing explanations or hints. The questioning strategies can include asking students to explain their reasoning or asking students to consider the question in a slightly altered context. By explanations the model is referring to brief descriptions that clarify some aspect of the tutorial problem or the physics concept. It is not talking about providing student with the answers to the problem or derivations of the concepts.

The second construct in the model of formative assessment is an awareness of students' *prior knowledge*. This awareness includes two aspects. First, the instructor recognizes the ideas and skills that students bring from their experiences to the physics content. This means the instructor is able to describe how the student is thinking about a concept. An instructor who did not recognize students' prior knowledge would assume that students approach all physics concepts as blank slates with no thoughts on the topic. Second, the instructor value these ideas and skills as being useful for the students when they're learning the content. This means the

instructor is not only aware of what ideas a student has on the content but realizes that these ideas can be useful in helping the student deepen their understanding of the topic and work toward the correct scientific model of the concept. An instructor who recognized students' prior knowledge but did not value it would attempt to make students abandon their prior ideas before they worked to learn the new material. Students' prior knowledge can include their everyday experiences, their prior knowledge of physics concepts from earlier in the semester or a previous physics course, and their knowledge from other subjects such as math. Besides conceptual prior knowledge, the model also recognizes that students bring to their learning their learning preferences and the learning strategies that they have previously developed.

The third construct of the model of formative assessment is the awareness of the *individuality* of students. This construct refers to the recognition that each student is different from all other students and that these differences should be acknowledged and not glossed over or destroyed. In many ways this construct builds off of the previous construct of prior knowledge. This is because the model talks about differences between students in terms of differences in prior knowledge as opposed to ability, motivation, or static characteristics of the students. A recognition of students' individuality does not only acknowledging that students come to the topic with different ideas but that they also respond to instruction (e.g. questions) in different ways. This means that a question may trigger one student to change the way he is thinking about a concept. Yet that same question may not bother a different student and therefore it will not trigger that student to rethink his ideas.

The final construct in the model of formative assessment is really a culmination of or response to the other three constructs. While the other three constructs refer to characteristics of learning or of the students, the final factor refers to how one should teach in response to these

characteristics. Because students need to create their own understanding utilizing their prior knowledge, and because students have different prior knowledge, an instructor needs to *adapt her teaching* to meet the unique situations of each student. Examples of teaching adaptations include asking different questions, using a visual representation instead of a verbal analogy, using an example from sports to demonstrate the concept, or helping the student to construct a conceptual explanation rather than the mathematical explanation used in the book. The model states that adapting one's teaching is critical to good teaching and to the job of an LA. The model holds that good teachers teach to the students and not to the content or to an idealized student. It is not enough to teach the content following the path used in the textbook or in the way that makes the most sense to the instructor. The teaching strategy that is used has to be the best strategy for the particular student. The LAs find that this need to constantly adapt their teaching makes teaching fun and challenging.

Analysis

The above section has presented generalized model of the LAs' views of Formative Assessment. This model was developed based on the writings and interviews of the LAs and evidence for this model can be found in the writings and interviews of all four of the LAs. The following sections will consider evidence for each of the elements of the generalized model. The later case studies will consider the views of formative assessment developed by each of the four LAs and how these models compare to the generalized model. The sections below will consider excerpts from all four LAs to demonstrate the generalized model.

Construction of Knowledge

The first element of the generalized model of formative assessment is the view that students should construct their own understanding instead of receiving knowledge passively from teachers. Leah explains this idea during her mid-semester reflection,

> I have noticed that the more I teach and learn about teaching, the more I have realized the importance of allowing the student to reach his or her own answer. A student learns much better through thinking, and that process is much more important than the answer itself (Leah, wk08, 1).

Leah begins explaining her views by stating that she "allow[s] student to reach his or her own answer". This excerpt indicates that it is not enough to give students answers. Instead students have to come to the answers on their own and then that answer becomes not simply the "correct" answer, but their "own" answer. Therefore the construction of learning, as described in the generalized model, allows students to claim ownership of the content. Leah goes on to explain that students learn "better through thinking" a phrase that refers to the concept of active learning.

The construct of students constructing their own knowledge is also evident in the tutorial environment. By design the University of Washington tutorials are intended to elicit students ideas and to then help students construct the physics concepts. It is unsurprising that the tutorials are aligned with the theories of learning taught in the LA pedagogy course or with the views of formative assessment developed by the LAs since the tutorials were designed based on research in student learning of physics by the University of Washington Physics Education Group. Gen describes how the tutorials create an environment that allows students to construct their own understanding in the excerpt below,

> The purpose of the tutorial is to kind of like explore the idea of physics. If we, like even if it's a small thing, like even if it's a small question, you actually have to find, like, signs that would lead you to the answer. So, if I just blatantly say, "Hey this question is going to use this thing and that thing," then they're not thinking about what they know of that would lead them to the answer, it's going to be like, "Hey do this, do this." It's going to be, like, guided. If it's guided, if it's something guided, then why don't we have another lecture. Because like I said, "Okay for this tutorial do this, this, and this. Okay, I'll give you 15 seconds to do it. Okay, are you done? Alright, let's go to the next question." That would be the same thing. So, like, the point about the tutorial is we actually have to let them navigate and let them think of what they're doing. (Gen, pre, 238 – 248).

In this quote, Gen tends to credit the tutorials environment and the assigned task with the successful learning of the students but he recognizes that the TA or LA could easily disrupt this environment. He describes how the purpose of the tutorials leads students to develop their answers and requires them to think through the materials. He contrasts this with lectures, which he feels tend to be too guided for students to actually think through what is happening. Gen's phrases "you actually have to find", "what they know", and "leads them to the answer" indicate that Gen is focused on students constructing their own answers. Gen recognizes that it is not enough for students to simply do the manual work of writing out an answer as they are directed by a teacher. Instead, students have to do the mental work of constructing the process. Though Gen is using every-day language to make his argument, it is also possible to express this idea in terms of academic jargon. What Gen is saying is that it is not enough for the activity to be hands-on; it must also be a minds-on activity for the students.

The reason the general model emphasizes having students take an active role in their learning is because it leads to more robust knowledge. Leah references this idea in the following excerpt,

> . . . directed questions and carefully constructed questions can really help the students come to their own understanding of the concept which is going to be a lot more lasting and a lot more solid than just hearing an answer from somebody else (Leah, post, 106 – 108).

Leah begins by emphasizing the effort LAs put into their questioning. For Leah, it is not enough to just question students; the questions must be directed and carefully constructed. She then goes on to explain why construction is important – the knowledge is "more lasting" and "more solid". Leah is explaining that the knowledge that students' construct for themselves will be remembered beyond the homework or tests and that the knowledge will be at a deeper level than the surface level knowledge students develop when they are just told the answers.

As expressed in the generalized model, the job of the LA is to facilitate students' construction of knowledge. Both Leah and Gen, in the excerpts below, reference this idea by contrasting the job of an LA with teaching. When talking about the job of an LA they define teaching as giving students information – as done in more passive learning environments. Therefore, Gen and Leah explain that good LAs do not teach.

> [The LAs are] there to help you learn and so that I think to me sums it up. It's that the LAs weren't really teaching you but like sort of pushing you to understand the concepts better. It was really helpful that none of the LAs that I had have ever given me the answers . . . [They're there] as the guide to help you figure out what's the best way for you to learn and help you understand the concepts (Leah, pre, 109 – 115).

Leah uses the phrases “help you learn” and “pushing you to understand” to describe the facilitation role of LAs. She contrasts this with teaching which she equates with giving answers. Gen also references this point when he explained what good teachers do,

> A good teacher doesn't teach like they actually facilitate learning, so teaching is something like reading out of the book, asking them to take notes, that would be teaching as well, but facilitating knowledge is having the students understand why, . . . So like hands on basis, facilitating knowledge, I think that's the most important part about teaching. (Gen, pre, 291 – 300).

In this excerpt Gen creates a dichotomy between facilitating and teaching. To facilitate learning means to have students develop a deeper understanding that goes beyond just getting the answers – as indicated by Gen’s description of “having the students understand why”. Gen equates teaching with “reading out of the book” and having students “take notes” which basically refers to lecturing.

According to the general model, one reason for having students construct their knowledge is because the process of finding the answer is as important as the answer itself. Jamie describes this in the excerpt below,

> The job of an LA is you know, of course, it's in the title, we assist them in learning, but I think it's a bit more than that. I mean it's being a teacher but it sounds simplistic at first but when you really go into it it's all of those aspects, getting to know them, helping them through, not step by step through a problem but giving them the right thought process, you know, so it doesn't matter if they get it done it just matters if they learn the process as long as they get some benefit out of it, because getting the right answer often doesn't benefit anyone. . . . That’s what being an LA is, is kind of being that little step to helping

> them understand it because it doesn't seem like the teachers are willing to do that sometimes, and I think that's what our job is (Jamie, post, 114 – 132).

Jamie's description of teaching as sounding simplistic at first indicates that she now recognizes the extensive amount of work that goes into teaching "behind the scenes". Like Gen's previous quote, Jamie also recognizes the danger in teachers providing too much guidance in stepping students through a problem. Instead she wants teachers to help with the thought process since this is what matters.

In order to help students construct their own knowledge, LAs most often rely on questioning strategies. LAs often talk about improving their questioning skills in their reflections - "My main goal for this week was to try to give the students multiple ways of thinking of the problems that they faced, by asking them questions that would prompt discussion" (Jamie, wk03, 2). Jamie's main focus here is finding ways to "prompt discussion" since she believes this will give students multiple ways of thinking about a problem. She plans to use her questions to achieve this. The LAs often write about using questions to guide students –

> This week, students were given a situation of two blocks moving at constant velocity, and were given the task of ranking the magnitudes of the forces involved. Many students had difficulty with this concept. Generally, what worked for most students was when I went through each force and asked them to determine the magnitude relative to another force. After doing this for all of the forces, I then asked the students to compare all of the forces using what they had just learned. I think that for students who do not understand the general idea immediately, it is helpful to take them through the problem step-by-step. I have found that most students know the answers to each step, either intuitively or from instruction, but sometimes have trouble putting it all together (Leah, wk06, 2).

In this excerpt Leah describes breaking down a complicated problem for students so that they do not have to keep track of so many ideas at once. Leah's students were able to explain how pairs of forces relate to each other, which was the goal of this problem, but they struggled when they tried to keep track of so many forces at once. Therefore Leah scaffolds the students by keeping track of the forces for them while they do the actual calculations or comparisons between the pairs of forces. Leah's explanation that "student know the answers to each step" but struggled "putting it altogether" indicates that she was aware of the scaffolding or organizing role of her questions even if she did not use the education jargon. Another example of LAs talking about using questions to help students comes from Andy's description of helping students with acceleration vectors. Andy wrote the following vignette based on his many interactions with students that week over a difficult part of the tutorial. In the problem students had been asked to draw the acceleration vector of a particle traveling around an oval track –

I: "why do you think that the acceleration is way that you drew it?" (the angle between the velocity and acceleration was greater that 90)

Student: "well acceleration points towards the center of the oval".

I: "does it?" (Sometimes that was enough for them to see their mistake)

Student: " yes when an object moves in circular motion, the acceleration points towards the center of the circle"

I: "is the track a circle?"

Student: "no." (often they would get a puzzled look)

I: "how does radial acceleration work? how is it related to velocity?"

Student: "acceleration is change in velocity over time"

I : "is the velocity changing here?"

Student: " there is constant speed, but the direction changes"

I: " so the object is not speeding up or slowing down, right?"

Student: "yes"

I: "how do u think acceleration would have to act on the object to make it turn but remain at a constant speed?"

Student: " oh. it would have to be 90 degrees?"

I: "do you think it would?"

Student: "yes, because if it was not then the object would either speed up or slow down. this makes sense now. thank you"

This one kind of conversation I had with students. (Andy, wk04, 2).

Students often struggle with this particular problem because they tend to over generalize from their experiences with particles on circular tracks instead of thinking about the relationship between the acceleration vector and the instantaneous velocity vector. Andy's focus in this interaction is on getting students to talk about their ideas. As he had explained previously, he thinks that students will recognize inconsistencies in their thinking if they voice their thinking to others. Therefore Andy begins the encounter by asking students to explain their answer rather than simply asking them to tell him their answer. Andy keeps his questions very brief and focuses on encouraging students to keep thinking about the problem. He also focuses them on key aspects of the problem like the fact that the track is not a circle. Therefore Andy is helping the students construct their own understanding by encouraging them to continue thinking about the problem and directing their attention to important aspects of the problem. Andy explains this view later in the semester –

> I try to use indirect questions when I am discussing concepts with students. Indirect questions give the students an opportunity to develop the concept by themselves and that makes the learning process exciting and also more effective. For example, "What do you think about this diagram?", "Why have you answered the question like that?" and so on (Andy, final, 49 – 53).

For Andy, the key to his vague or indirect questions is that they provide students with opportunities to develop concepts on their own which he realizes is more effective.

The LAs recognize that questions are not the only way for them to help students construct their own understanding. The LAs also recognize that explanations can sometimes be equally effective in helping students construct knowledge –

> There are two ways that I normally help the students. I either ask a question or explain the concept. I try to find ways to ask questions, as a question gives more room for thought generation than an explanation and can lead to a discussion. However, a simple explanation can do wonders at times. (Andy, final, 25 – 28).

While Andy prefers to use questions because they allow students to be more active in their learning he acknowledges that explanations can be powerful. It is important to note that Andy specifies "simple" explanations, though. Earlier in the semester, Andy is more specific about the types of explanations he uses –

> I found that the combination of questions and explanations did the trick. But when I only asked questions, some of the students did not seem to know where to start. When this happened I would give some hint or read the question again (Andy, wk07, 2).

When Andy uses the word explanations he is not describing long reviews of the material or derivations of the concepts. Instead, Andy uses the word explanations to mean hints or rereading the question.

Prior Knowledge

The second construct of the generalized model of formative assessment was the prior knowledge that students bring to any topic. Andy demonstrated his awareness of students prior knowledge in his teaching goals - "my goals for next week are to build off of students' misconceptions. I plan to do this by asking broader questions or more open questions" (Andy, wk05, 3). In this excerpt, Andy indicates that he is not only aware of students' prior knowledge but views this knowledge as something worthy of being brought into his discussions with students. He plans to elicit these ideas using questions, especially questions that are broad or open. Leah also described eliciting students prior knowledge,

> Well, definitely something that I try to do was to get students to think about problems first from things that they already knew about because physics is one of those subjects, especially mechanics, where people have pretty intuitive understandings of some concepts and sometimes not or sometimes their intuitions can be a little bit misguided but I think it can definitely be a good starting point (Leah, post, 173 -178).

In this excerpt Leah's references to "intuitive understandings" and "intuitions" indicate her recognition of the value of everyday experiences that students' bring to the classroom. For Leah, the idea of prior knowledge is especially relevant to her current teaching situation since mechanics is a topic with which students have a lot of personal experience. In an early excerpt, Leah also references students' intuitive or innate understandings, "Because especially in physics, everybody kind of has an innate understanding of physics, it's just its hard to get there from just

dry lecture or reading the books and stuff" (Leah, pre, 154 – 156). In this excerpt Leah references the importance of teachers eliciting students' ideas. It is not enough for students to have had relevant experiences, if the classroom environment does not encourage students to refer to these experiences. Leah's comment explains that it is hard for students to apply their "innate understanding" to physics concepts when it is being taught passively using books and lectures. In this way Leah is tying the ability to elicit students' prior knowledge to the teaching strategies used to help students actively construct their knowledge as was discussed under the first construct.

LAs recognized multiple types of prior knowledge that students could apply to their physics instruction. The excerpts from Leah's interviews mentioned above refer to students' everyday experiences as a useful type of prior knowledge. Jamie refers to a second type - "I noticed that they applied their previous knowledge in order to understand and explain the problems better. They applied previous knowledge of geometry and thought about the attribute of a circle" (Jamie, wk04, 1). In this excerpt Jamie describes concepts that students had previously learned in geometry courses as useful prior knowledge for their physics classes. A third type of prior knowledge is the learning preferences that students have developed over their years of schooling. Jamie describes this type of prior knowledge here -

> I also recognize ways they learn better and try to find their primary intelligence. This helps me to assist them in learning the concept. By figuring out their primary intelligences it is much easier to relate the concepts to the students and make the material feel much less intimidating (Jamie, final, 15 – 21).

In this excerpt Jamie describes understanding students' primary intelligences as critical to helping students. In order for her to teach well, Jamie needs to know about how her students learn best so that she can relate the material to the student.

The LAs not only mention the general idea of prior knowledge, but they also give examples of students' prior knowledge. In the following excerpt Jamie describes a common instance of prior knowledge that she saw in her classes,

> The second problem the students were having trouble with was involving the direction of the acceleration along the curve. Due to previously being told that the acceleration always points to the center of a circle, most students just assumed that was true of the oval, not realizing that would affect the velocity . . . Most students understood that the acceleration can't have a component in the same direction as velocity, but some of the other students were baffled by the sudden challenge of their "acceleration is always towards the center" theory (Jamie, wk04, 2).

In this situation, students struggled to talk about an object traveling along an elliptical path because they were over generalizing their knowledge of circular paths. Students thought that the acceleration vector would always point to the center of the track because of their prior experience with circular tracks. Jamie describes this prior knowledge as a "theory" that the students have developed.

Individuality

The third construct of the generalized model of formative assessment is the awareness of students' individuality. The LAs talk about students' individuality in two ways – differences in prior knowledge and differences in how they respond to instruction. Gen refers to differences in prior knowledge when he states, "Everyone comes from [a] different starting point; therefore we

have to accept the different views and try to build upon it" (Gen, wk05, 1). Gen refers to students' pior knowledge as their "starting point" and their "view" of the concept. He then states that LAs have to not only accept this prior knowledge but use this prior knowledge when working with students. Leah describes how students will differ in how they respond to instruction in her final paper,

> It is all too easy for a teacher to view students as identical "learning units" that must be filled with a particular subject. Analyzing these two articles at the beginning of the semester helped me to understand that students necessarily learn in distinct ways. A particular form of discussion may enhance one student's understanding of a concept, but could do absolutely nothing for another student (Leah, final, 29 – 33).

In this excerpt Leah doesn't mention students' prior experiences but instead focuses on how students will learn given a particular discussion. Leah contrasts her current understanding with the teaching pitfall of seeing all students as identical.

The LAs also talked about students' individuality in more implicit ways as well. For instance, when describing students' ideas or difficulties some of the LAs talked in terms of *most* students or *some* students – "Most understand that force always acts at the center of mass" (Leah, wk12, 2) and "some of the people thinks that they are suppose to add the vectors . . ." (Gen, wk04, 2). Most of the LAs also talked this way when describing successful interventions - "Sometimes when I was trying to help a student with something, I went about it the typical way I'd seen myself or other students do, but this lost a student a tad" (Jamie, wk07, 2) or "Generally what worked for most students was when I went through each force . . ." (Leah, wk06, 2). This language indicates that the LAs recognize that while there were common issues with which many

students struggled and that there were common strategies that helped these students, these were not universal and other students had other ideas or learned from other strategies.

Finally some of the LAs saw the individuality of students' as one of the key reasons they found teaching to be challenging or frustrating. When asked what aspects of his LA experience went well, Andy responded,

> I mean I enjoyed working with students and it was always interesting to see the concept from their perspective, 'cause I tried to do that. So I would be able to explain it to them. And it was cool seeing what different kinds of questions could do. Like, in order for me to get information about what or how they're doing or in order for them to build on it, talk about it more. To discuss with them and some points, it was a challenge because I'd have to sit there and then everybody's different so some people would get the concept if I explained it one way, but other's wouldn't so I would have to think of a new way to explain it that I hadn't done before if I had tried the techniques. (Andy, post, 10 – 19).

Andy describes understandings students' ideas about a topic as "see[ing] the concept from their perspective". He then goes on to mention the differences in how people respond to questions and explanations. Andy also implies that seeing the different perspectives and having to develop new questions or explanations helped him to learn the content better.

Gen gave a more ambivalent comment when asked how his semester went, he replied,

> Frustrating but fun. Like, I enjoyed it so much that I want to do it again. I say it's frustrating because it's hard to see, hard to make the students do one thing and because there are like 15, there are as many answers to one question as the students. You could ask someone a question and they'll give you a different answer from a person you asked a day before. So it was frustrating but fun. (Gen, post, 6 – 10).

In this excerpt Gen refers to the wide variety in how students respond to questions. He considers this aspect of teaching to be frustrating because he cannot predict how students will respond to a question based on how previous students responded. At the same time the unpredictability makes teaching fun as well.

Adaptive Teaching

The final construct in the generalized model of formative assessment is the culmination of the other three constructs. Gen demonstrates how these constructs come together to shape his teaching,

> I have learned that there are many teaching methods that exist. Since all students are starting at different starting points, everyone has their own way of learning the same material; therefore, I need to change my way of teaching from student to student (Gen, wk08, 1).

In this excerpt Gen refers to both the prior knowledge of students and students' individuality in this prior knowledge when he states that students have "different starting points" and "way of learning". In response to these differences in prior knowledge Gen recognizes that he has to change how he teaches in response to each student with which he works.

All good teaching and especially LAing requires that the instructor adapt the teaching to the students. Leah describes adaptability as necessary for successful teaching –

> "While both articles [(Knuth & Peressini, 2001; Redish, 2003)] present the learning experience in a different manner, they each emphasize the necessity of adaptability of teaching style. Certain students and situations will require the teacher to guide the learning process differently. I support the general argument of both articles – a successful

> teacher must be able to alter lessons or concept explanation based on the individual situation and student" (Leah, AR1, 19 – 23).

In this excerpt Leah explains that a teacher must adapt both the "lessons" and the "explanations". These two categories can be interpreted as describing both large scale changes that teachers make to their lesson plans and moment to moment changes they make in their discussions with students. Leah's phrase "based on individual situation and student" indicates that she does not expect one teaching strategy to always be effective for the same student. Instead a student may learn different material better using different methods. In other words, just because a visual analogy helped a student understand force pairs, does not mean that a visual analogy will help that same students understand angular momentum. Therefore the teacher has to adapt not only to the individual but also to the specific situation of that individual.

Leah later applied the concept of adaptable teaching specifically to LAs,

> "I found that one of the most important roles of the learning assistant was to identify the ways in which these students struggled and to try to find alternative ways of understanding the material that did not rely so heavily on logical and mathematical intelligence" (Leah, final, 60 – 63).

In this excerpt Leah describes the process of eliciting students' ideas using the phrase "identifying the ways in which these students struggled" and then describes the task of the teacher as "find[ing] alternative ways of understanding". Leah then goes on to mention a common type of adaptation she saw as necessary. Leah found that tutorials relied heavily on logical and mathematical intelligences but that these types of intelligences were not strengths for many of her students. Therefore she often worked to better align her students' learning preferences with the way the concepts were being explained.

In his final interview Andy described adaptive teaching as not only necessary for student learning but also fun for the teacher,

> . . . teaching something like physics is definitely challenging because you have to, it's not just you understanding, you get other people to understand and a lot of times they don't see it the same way you see it. So, it's sometimes like a puzzle, you're like 'ha' after you get them to understand and how do I get them to understand – I tried that, I tried that, it didn't work, so now I'll try this. Yeah, I definitely consider teaching as an option (Andy, post, 322 – 327).

In this excerpt Andy refers to the differences in students' prior knowledge when he states that "they don't see it the same way you see it". He then talks about trying out different teaching methods to find what is effective in a "guess and check" style. For Andy this process of finding the effective teaching strategy for each individual is like solving a puzzle. Because of this puzzle aspect of teaching and because he finds so much joy in seeing students finally understand, Andy ends the semester considering a career in teaching and eventually pursues his teaching certification.

Theme 2: Views of Student/Teacher Relationships

The Learning Assistants place a great emphasis on developing their relationships with students. They talk or write about these relationships in both their interviews and their writings throughout the semester. This chapter presents a generalized model of student/teacher relationships based on these views expressed by the LAs. The LAs talk about student/teacher relationships in similar ways whether they are talking about their relationships with their students or with their previous LAs or with their previous instructors. Therefore the views described here are created from LAs' comments about both their own teaching and their experiences with other teachers. This leads to a generalized model of teacher/student relationships. As will be discussed later, the LAs are at a particular advantage with respect to this model because of their unique relationship to students. The following chapter considers first the generalized views of student/teacher relationships that I have drawn from the LAs interviews and writings. Then I present an analysis of the data that was used to create these generalized views.

Generalized model

Generally, when LAs talk about their relationships with students they are focused on one of three elements of the relationship

1. Being seen as approachable by students
2. Being seen as an authority figure by students
3. Being able to motivate students

While the LAs' views on student/teacher relationships include all three elements, this does not mean these views necessarily form a coherent perspective. Sometimes one of the elements of the LAs' views on relationships comes in conflict with another element of their views. These elements of student/teacher relationships will be considered in the sections below.

Approachable

The most common construct of student/teacher relationships that the LAs talked about is being seen as approachable by students. For the LAs, being seen as approachable is important because it allows them to know what their students need. Over the course of the semester, the LAs explain how being seen as approachable by their students allows them to help their students learn. This process is modeled in Figure 10. First, a teacher must care about her students and make students aware that she cares about them. If the teacher cares about her students, then she will get to know them. This includes knowing her students' prior knowledge, their personal interests, their learning preferences, and with what they are currently struggling. When a student recognizes that the teacher cares about him and is willing to get to know him, the student can be comfortable with the teacher and with the classroom environment. Only when the student is comfortable is he willing to be vulnerable and share his ideas with the teacher or admit his struggles to the teacher. This type of vulnerability is necessary for the student to be able to learn. Vulnerability is used in the model to talk about a student being in a mental or emotional place where they can share with the teacher how they are doing, admit when they do not understand something, share their ideas, and ask questions when necessary. A student who is willing to be vulnerable is able to be honest about their knowledge and their learning. Vulnerable is therefore being used in a positive light to mean a student who is willing to be open as opposed to in a negative light to refer to a student who thinks they are under attack.

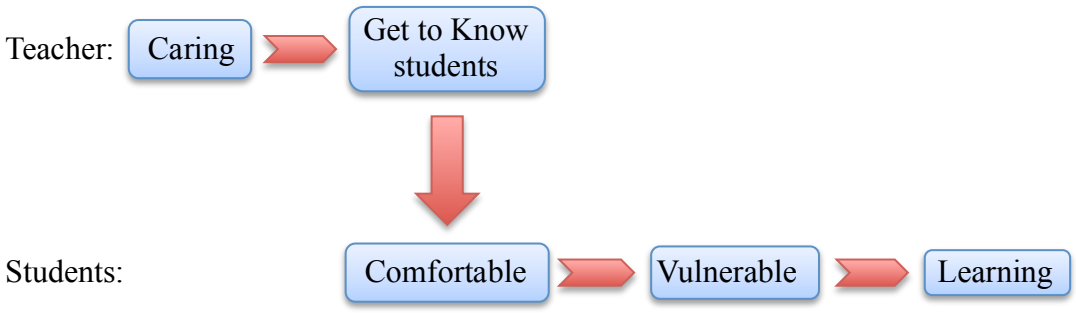

Figure 10. A model of the Generalized Views of Approachability.

While the above model creates the conditions necessary for students to learn, it does not necessarily help the student to learn. Instead, helping students to feel comfortable and willing to be vulnerable is a prerequisite for learning. The LAs recognize this and describe how their views of approachability fits with their views of formative assessment. Being seen as approachable by students means that the teacher is able to learn about a students' prior knowledge because the student is willing to be vulnerable and share their thinking with the teacher. The student is also willing to be vulnerable enough to reconsider their current thinking when they know that the teacher cares about them. When a student is willing to share their prior knowledge and is willing to reconsider that prior knowledge, a teacher can use adaptive teaching to help the student learn. Therefore building a relationship with students becomes a prerequisite for the LAs' views of formative assessment.

The LAs talk about the importance of all teachers being seen as approachable by their students, but they feel LAs are at a particular advantage in this aspect of teaching compared to faculty or TAs. LAs consider their approachability as the main advantage for having LAs in the physics tutorials. They see two main advantages to their position. First, because they took the same course very recently, LAs are more familiar with the logistics of the course and the specific way the material is presented. The LAs have also experienced the tutorials from a students'

perspective. On the other hand, TAs are graduate students who have taken the course they are now teaching several years ago and who may have seen the material presented in a very different manner. The shared experience of the students and the LA means that the LA can provide more useful feedback, can give advice about logistics, and can sympathize with the students' experiences. Second, the LAs consider themselves to be less intimidating than TAs or professors. The LAs feel that students worry about looking "stupid" to faculty or TAs if they ask a question or admit to not knowing a concept. Because LAs are peers, it is okay for students to ask "dumb" questions or to admit to not knowing material. Because students are less intimidated by LAs than TAs or faculty, the students are willing to be vulnerable with LAs. The LAs can then help students learn by building on the information about their understanding that the students are willing to share with them.

Authority

A second element of student/teacher relationships that is common in LAs' writings and interviews is a focus on being seen as an authority figure by students. LAs want to be seen as an authority figure by students in two areas –

1. Their authoritative understanding of the material and
2. Their authority to enforce the classroom rules and expectations.

When LAs talk about the first area of authority they are referring to being seen as having content authority. This means they want students to see them as being a resource for their learning. The LAs worry that students may not recognize their authoritative understanding of the content because of their age or because they have not taken more advanced courses in physics. This concern is ultimately tied back to the LAs concern with student learning. LAs believe that if students do not see them as a resource or a content authority, the students will not ask them

questions or seek them out for help. Therefore this aspect of authority is tied directly back into the LAs' previous views of learning. The LAs believe that students will not be comfortable being vulnerable with a teacher who they do not feel has the content knowledge to help them and the LAs do not feel they will be able to help the students if the students are unwilling to ask and answer questions of the LAs.

The second area of LAs' focus on authority is concerned with being able to enforce classroom rules and expectations. This concern is mostly centered on being able to keep students on task so that they complete and learn from the tutorials. The LAs want students to recognize them as an authority figure so that students will listen and follow their instructions to stay on task, to curb off topic discussions, and to work diligently to complete the tutorials. Ultimately LAs' concern with this area of authority is tied to their concern with student learning. Because the LAs recognize the tutorials as beneficial for student learning, they want students to have the benefits of working through the tutorials during class.

Both of these areas of authority refer to how LAs believe students see them not in how LAs see themselves. In other words the LAs do not question their own understanding of the material. They believe that they know the material well enough to teach it or that with a little bit of review prior to the tutorials, they will be able to teach it. The LAs' concern is with whether students view them as having a sufficient understanding of the material. With the classroom management area, LAs are aware that they lack the official authority to enforce classroom rules because they do not have any control over grades. The LAs concern is with whether students will follow their directions despite this lack of official authority.

The LAs' views on authority can be in tension with the LAs' views on approachability. At times, the authoritative persona that LAs want to project may be similar to the persona that

they describe as making instructors and TAs too intimidating to be approachable. Therefore LAs' desire to be seen as an authority can conflict with their desire to be approachable.

LAs' views on authority do not change over the course of the semester, though there are variations across LAs. Overall, LAs' views on authority tend to be fairly traditional in the sense that they focus on the instructor needing to prod students into working. These views can be contrasted with more reformed teaching philosophies that focus on student engagement.

Motivation

The final element of LAs' relationship with their students is being able to motivate or inspire their students. LAs want to motivate their students to enjoy physics and to want to study physics. Besides having the authority to keep students on task, the LAs also talk about motivating students as a way to address the problem of off-task students. The LAs believe that if they can find ways to help their students come to love physics, then the students will want to work on the tutorials. The LAs talk about motivating their students by inspiring them. They believe that by demonstrating a love of physics, their enthusiasm for the subject can be contagious for students. Finally, one of the reasons that LAs apply to the program is to have the opportunity to motivate and to inspire students. As with the authority element, LAs tend to describe motivation in fairly traditional ways. Their emphasis is on giving students a love of physics and an appreciation of entertaining experiments rather than helping their students develop scientific dispositions through exploration. In other words, the LAs talk about helping their students develop their conceptual ideas through construction, but they do not apply similar views to helping their students develop their affective ideas about science.

Ultimately we would like LAs to demonstrate views of motivation that are more consistent with the literature that ties motivation to identity. In particular, Ryan (1995) outlines

the process by which individuals move from external to internal motivation through the process of identification with the task. In this model, through the process of "identification" (valuing of a goal, accepting of the value of the task), individuals integrate aspects of the task into their own definitions of themselves. As the individual becomes increasingly identified with the task, the locus of causality and autonomy shift toward taking responsibility and ownership for causes and outcomes. As this occurs, the individual moves from being motivated extrinsically to being motivated intrinsically. Specific to classroom situations, Ames (1992) describes classroom structures that motivate or fail to motivate students by developing orientations toward performance among students. According to Ames, "mastery orientations" are engendered in students in learning contexts that focus on student autonomy, intrinsic value of learning, and student orientations toward developing skills and competence. "Performance orientations" on the other hand, are engendered in circumstances that are evaluative, comparative, and where success is normatively determined rather than self-determined. These two examples of motivation literature demonstrate the types of views and practices regarding orientation we would like for LAs to develop. However, results from this study revealed that the program is not addressing the issue of motivation in ways that have led to these outcomes.

Analysis

As stated previously, the above model of LAs' views of student/teacher relationships was developed through an analysis of LAs writings and interviews. This section will consider excerpts from these sources to demonstrate the three aspects of these views. The excerpts presented here will come from all four of the LAs. The individual case studies, presented later, will discuss the views of individual LAs and how they align or diverge from the generalized views.

Approachable

The importance of teachers being approachable is the most frequently articulated aspect of student/teacher relationships. Jamie describes the basic idea behind the generalized approachability model of student/teacher relationships while talking about what she learned during the semester,

> I think I learned much more about learning itself so, I think I developed a much better way of going about a problem and I think I developed a much better way of relating to people. Like, being a teacher kind of forces you to be good at interper- er intrapersonal relationships. So, I mean if you're going to be a teacher you have to be good at getting to know people . . . (Jamie, post, 53 – 58).

In the above excerpt, Jamie describes the basic premise of the model – a good teacher needs to be good at creating relationships with people. Jamie describes this idea in two phrases – "relating to people" and "getting to know people". These statements refer to helping students become comfortable. While "getting to know people" can also be an aspect of the views of formative assessment and specifically a focus on understanding students' prior knowledge, in this excerpt Jamie is focused on building relationships with her students as indicated by her focus on the word "interpersonal". On a side note, Jamie settles on the word intrapersonal, but she is actually talking about interpersonal relationships – relationships between people. These two terms are used in the LA seminar to describe two of the eight multiple intelligences (Armstrong, 2000) discussed in class. It was common for LAs to mix up these two similar words during class discussions, so it is not unexpected that she struggles with the terms during the interview.

According to the generalized model, the reason that it is important for teachers to be seen as approachable by their students is because ultimately this helps them learn. Jamie references this idea during her mid-semester reflection,

> I want to improve on helping all the students. Sometimes I worry that I just help the ones that ask more questions or the ones who I'm more familiar with, but often times I realize it's the ones that don't talk that are having the most trouble. I want them to be comfortable with asking for help and make sure they understand the material (Jamie, wk08, 1).

Jamie explains that she is working on being able to help all students learn instead of only those who approach her. To solve this problem Jamie's focus is on "wanting them to be comfortable" so that they will talk to her and so that she will be able to help them. For Jamie, the first step in students being able to learn is for them to be comfortable. Jamie explains that when students are comfortable they will be willing to ask for help.

Andy also emphasizes the importance of teachers caring about students,

> You need to show that you care that the students understand. And be friendly. You need to show that you're willing to help, not just that you're there to help just because it's your job. Just because, you know, it's Thursday morning and I don't want to be here to help but I'm here. You show that, you have a desire to help them. And want them to do well and then you're interested in how they're doing (Andy, post, 301 – 306).

In this excerpt, Andy uses the words "friendly", "willing to help", and "a desire to help" to describe teachers being approachable. He also emphasizes the importance of teachers showing that they care to students. It is not enough for a teacher to care for students if the students are unaware of how the teacher feels about them. For Andy, a teacher needs to go beyond being in

class because it is a job to being in class because they have a genuine desire to see students understand the material.

While previous excerpts have demonstrated the basic premise of the generalized model of approachability and have touched on various aspects, the LAs also talk very specifically about the entire generalized model and its mechanisms for how approachability leads to student learning,

> I mean I got to know lots of students, lots of great kids and, yeah became good friends with them as well as helping them. And I think that's really important - getting to know them and not just being. . . not just lecturing them or thinking about they're just some person sitting there, just trying to learn. I mean you need to try to get to know them and try to help them the best you can and make them comfortable, so if they're not really comfortable with you they're not going to admit, you know, if they're having trouble or anything or they're not going to ask for your help (Jamie, post, 3 – 10).

Jamie begins this excerpt by describing her students as her good friends. Her description makes it clear that she cares about them, that she knows what was going on with them, and that she feels invested in their situations. It also indicates that she feels the caring was at least somewhat mutual. Jamie emphasizes the generalized model's focus on "getting to know students' when she states that it is important to not just think of students as "some person sitting there, just trying to learn". Jamie is referring to the idea that teachers should not just see the people in their class as disembodied or disconnected students who exist only in their class and are outside of any other influence. Instead teachers need to recognize their students as whole people who have lives outside of the classroom and who bring these lives into the classroom. Rather than viewing these lives as impinging on the classrooms, teachers should also consider how students' lives can be

leveraged in their learning. Jamie's description of students as not "just some person" and her emphasis on "getting to know them" refers back to the generalized views of formative assessment's construct of the individuality of students. Jamie is emphasizing that students are unique and should not be considered what Leah earlier referred to as "identical learning units". In this excerpt Jamie goes on to explain, as she has done before, that it is the teacher's responsibility to make students comfortable and that if students are not comfortable then they won't ask questions or admit if they are struggling. Based on Jamie's description here, she expects the teacher to take the initiative to create a classroom climate that make students comfortable but she expects the students to recognize when they have questions or don't understand a concept. This somewhat contradicts the generalized views on formative assessment that expects the teacher to elicit students' ideas so that she can diagnose and then address students' understanding.

Andy describes a slightly different mechanism,

> The aspect of caring that encompasses listening, understanding, and knowing students, are all important attributes of a good teacher. When a teacher listens to students, a bond of understanding is formed. This leads to mutual trust which in turn leads to improved communication that is not limited to the subject at hand. In this way the teacher knows what different students are feeling and are going through. (Andy, AR2, 22 – 27).

For Andy, when a teacher listens to his students, the student and the teacher come to understand each other and to trust each other. When students and teachers trust each other they are able to talk about both the content and things beyond the content. Several weeks earlier Andy explained why it is important for him to know his students beyond their content knowledge,

My goal for this week was to incorporate other topics of discussion to facilitate learning physics. For example

me: " what are you doing for spring break?"

student: " I am going skiing"

me: " have you thought of the forces and actions pairs that occur when u are skiing?"

Some random topic can arouse interest in the topic of study for the day (Andy, wk11, 1). By knowing his students' interests or spring break plans, Andy hopes to incorporate this information into his interactions with students, thereby making physics more interesting and relevant to his students.

As mentioned previously the views of formative assessment and the views of student/teacher relationships are closely tied together in the LAs' writings. An excerpt from Jamie's final paper demonstrates this,

> In my previous tutoring experience, I did not put much consideration into the student's priorities. I didn't pay attention to the types of problems that they were having trouble with. I had only focused on getting them to the right answer. Previously, I mostly helped students with mathematics. In most cases I would just give the students a shortcut to the right answer and not allow them to think through the process themselves.
>
> After my experience in this classroom I have learned how to actually care about the students and focus on what is causing the difficulty they seem to be having. I pay attention to the mental models they have developed about a subject and help them to adjust these preconceptions to bridge to what I want them to learn. (Jamie, final, 9 – 17).

In this excerpt Jamie compares her previous experience as a tutor in high school to her semester as an LA. According to Jamie as a tutor her focus was on "getting [students] to the right answer"

and “just giv[ing] them shortcuts”. When Jamie was tutoring she was not focused on the “types of problems they were having trouble with,” by which she means she was not looking for patterns that would demonstrate students’ underlying mental models. As an LA Jamie now notices patterns in students answers and looks for evidence of their mental models. Jamie uses the information about students’ mental models to help them adjust and bridge their ideas. She also encourages them to “think through the process”, by which she means having students work on developing their problem solving and metacognitive skills. What Jamie is describing as her focus when tutoring is a focus on answer-making. While, this view of learning is often contrasted with sense-making and is often described in the literature as treating school as a game instead of a learning opportunity, that is not necessarily what Jamie is doing here. Later, Jamie’s case study will describe her original view of learning, which saw learning as collecting a pile of previously worked problems to be recalled as examples when facing new problems. Therefore, it is not that Jamie’s view toward school has changed, but her understanding of how people learn has changed. The LA experience has changed Jamie’s understanding of how people learn to align with the generalized views of formative assessment. This has changed her understanding of how she should teach. Therefore while she has always valued student/teacher relationships her understanding of the purpose of those relationships has changed. Jamie now recognizes, as described in the generalized views of relationships, that the reason students need to be comfortable with their teachers is so that not only are they willing to admit when they have questions, but they are also willing to share their prior knowledge with their teacher so the teacher can build on and leverage this knowledge. Jamie describes this process as “learning how to actually care about the students”. She is not suggesting that her students were not important to

her when she was tutoring. She is instead explaining that she now knows how to demonstrate and act on her caring in an effective manner.

While Jamie's above explanation of the generalized views of student/teacher relationships focuses only on the approachability construct, Leah's explanation demonstrates how the approachability construct can be intertwined with the authority construct of student/teacher relationships,

> I think a good teacher is a teacher who is able to relate to students and understand sort of what their needs are and at the same time be able to control the class and be the teacher and the authority figure but also somebody who the students aren't afraid to ask questions to. Because I know I've had teachers like that who are just really dry and really strict and you really don't want to ask them questions because you're afraid to look stupid and I think that that's kind of sad because how else are people gonna learn if they don't ask questions on what they don't understand. So I think that the best teachers are the ones who are approachable and yet still very knowledgeable and authorities but are able to relate to the students. (Leah, pre, 193 -213).

Here, Leah is describing a good teacher as having two jobs that she views as somewhat at odds with each other. First, a good teacher needs to relate to and understand students. She is implying the ability to help students open up and share their ideas and difficulties. Second, a good teacher needs to be able to control the class and be an authority. In this excerpt, Leah does not explain why it is important for teachers to maintain control over the class, though she goes on to link being an authority with having content knowledge. Leah's description of "dry" and "strict" teachers indicates that approachability, which she describes as the opposite of bad teachers who are dry and strict, is created by being interesting to and understanding of students. What Leah is

describing here is for a good teacher to be seen as a friend by students, which would explain why she pits this against the idea of being an authority figure. Leah goes on to explain that not being approachable makes students feel afraid and specifically a fear of looking stupid. It is, to use Leah's word, particularly sad that according to Leah, students' greatest fear is to be seen as not knowing something by the person whose job it is to teach them that something. The student feels the need to hide and protect a part of their identity from a person who is intended to help them. In other words, the student must be a knower instead of a learner. Leah goes on to recognize the need for students to not have this fear and to instead be willing to be vulnerable. She states that students need to be able to ask questions and admit what they do not know in order to be able to learn. Earlier Leah explains that to help struggling students, she needs to find out what they don't know. Here, Leah is explaining that only a good teacher, who relates to students, would be able to find out this information from students.

A final part of the generalized model of approachability in student/teacher relationships is the view that LAs are uniquely able to relate to students. Jamie explained this when asked what her previous LAs had done that she found helpful,

> . . . they arranged time to meet with us, if you needed it and they were also very approachable. I find that sometimes the TAs are threatening a little bit because they're all grad students, but the LAs, the cool thing about them is that they're undergraduates, just like you and they're right there and they can help you out. So, it's just more of a community I guess, like a learning community feels like with them. They kind of have a link to you that the TAs don't have (Jamie, pre, 25 -30).

To explain how LAs can better relate to students, Jamie creates a dichotomy in the above excerpt between TAs and LAs. She describes LAs as being "just like you" whereas TAs are described as

"threatening". Jamie uses phrases like "they're right there" and "they have a link to you" to describe the special circumstances that allow LAs to naturally relate more to students. Jamie describes students and LAs as being on equal footing while TAs are described as intimidating because of their higher academic status. For Jamie, this equal status and shared experience means that students see the LAs as more approachable.

Authority

The second construct of the generalized views of student/teacher relationships is the focus on authority. Jamie references this focus in her first interview when asked what concerns she has about being an LA,

> I think it's going to be weird when I'm teaching upperclassman . . . it just seems like it would be a little weird and I'm wondering if they'll still respect my ideas even though I'm so young, because I already went through this and I know (Jamie, pre, 214 – 219).

In the excerpt, Jamie is worried about a lack of respect from students because she lacks the authority that teachers usually have with respect to students that comes from their age or higher academic standing. Without the authority of a higher status Jamie is concerned students will not respect her ideas. It is important to note that Jamie's concern is with gaining respect for her ideas and not specifically for herself. This is because Jamie's focus is not on being able to manage the class, but on the content area of authority discussed in the generalized views. Jamie is concerned that her lack of authority will prevent her from being able to help students because the ideas that she presents will not carry any weight. Jamie chooses to frame this idea as something that she thinks is "going to be weird" and not as something that she is worried or concerned about. Not only does she not describe it as a concern but also she also further dismisses it as only "a little weird". Jamie is not all that concerned, or more likely, she doesn't think she should be all that

concerned about it. Finally, in line with the generalized views, Jamie is not concerned with whether she can actually help students but with whether she is perceived as knowledgeable by her students. Jamie knows that she has the experience and the content knowledge to be helpful.

Leah expresses similar concerns at the beginning of the semester as well, “I'm a little bit nervous about people listening to me and respecting me. Not making fun of me or anything. But, that will probably go away after the first day or two. I hope” (Leah, pre, 280 – 282). Just like Jamie, Leah is concerned that students will dismiss her because she is seen as lacking the authority to be helpful. She expresses this idea in the phrases “listening to me”, “respecting me”, and “not making fun of me”. Following her first week of teaching, Leah returns to this idea,

> My main goal was to try to get myself comfortable with being an "authority figure"; for a class of students. I felt that I met this goal, because I was able to maintain a reasonable presence throughout the tutorials that I taught. I felt that I was a person that the students respected enough to listen to and to ask questions (Leah, wk03, 2).

Here, Leah describes how she attempted to address her concern with authority. In order to convince students that she should be listened to and respected, Leah worked to maintain an authoritative presence in the classroom so that students saw her as knowledgeable. This solution also requires Leah to address the dichotomy between being approachable and being an authority – the same dichotomy she described good teachers as having to wrestle with. Leah’s solution to her concerns with respect is to create a presence or to put on a performance. This could be at odds with her focus on being approachable which involved being friends with students. Despite conflicts between Leah’s desire to be approachable and be an authority, her purpose for both desires is the same – to help students learn. As Leah explains she wants to be seen as an authority and respected by students so that they will ask her questions. This means that these views of

student/teacher relationships require teachers to walk the fine line between being seen as approachable so that students will be willing to ask them questions but also being seen as knowledgeable and respected because otherwise students won't bother to ask them questions.

Later in the semester Leah focuses on the second area of authority – managing the classroom,

> There were definitely some times where the students were very off track and just very unwilling to start the tutorial. And that was pretty frustrating. I'm not a very confrontational person so it's really hard for me to go up to somebody and say "hey, you need to start working now." So I would try and do it in a light hearted manner but that didn't always work so well, so I think in the future that is something I would definitely work on, was getting a better authoritative presence when students were not doing the tutorials at all and were completely off track, working on trying to help them get on track better. (Leah, post, 17 – 24).

Leah sets up the situation as a dichotomy between her and the students with her use of opposition words such as "unwilling", "frustrating", and "confrontational". Leah's concern here is that students are not doing their work. This concern is not about being seen as having the necessary knowledge, as with her previous concerns around authority, but about being seen as having the right or the status to tell students what to do. Once again though, Leah's solution is to perform so that she presents a stage presence to students that demands this status. Gen presents a similar concern when he describes how LAs can help students learn, "Like LAs could make sure that everyone's on the right track and make sure that everyone is doing it correctly and understanding it. Like just not sitting there for the sake of the grade" (Gen, pre, 210 – 212). Gen's focus is on LAs having the authority to manage the classroom. Gen isn't looking for this authority simply so

that he can have the power to tell students what to do. His focus is on making sure that students "understand" the material. His goal is for students to learn and he feels that authority in the classroom will be necessary for this goal. Gen returns to this idea later in the interview as he describes how he would address the problem of off-task students,

> Maybe motivating the kids who sat in the corner and just didn't do anything. I think that would be the only thing that would change. But I would try and incorporate everyone and makes sure that they're doing what they're supposed to be doing. Maybe, threatening them with a grade sanction would be a good thing too. Because they're showing up, they care about grades. If we threaten them they might think differently, like just change their thoughts. (Gen, pre, 268 – 274).

Gen uses the term motivation but he means it in a different sense than it is used in the generalized views of relationships. Gen is talking about using external motivation – grades – to manage his classroom. Yet, in his description Gen sets up an oppositional environment by talking in terms of "threatening" students. It is unlikely that Gen consciously means to do this. Instead, Gen is simply looking for a way to help students focus. Unlike Leah who is looking for authority through a stage presence, Gen is looking for it from systemic power, the control of grades, which he actually doesn't have as an LA.

Motivation

The final aspect of the generalized views is motivation. While Gen used the term to talk about gaining authority, this view is focused on LAs creating internal motivation for students. Jamie describes what successfully creating this looks like when she talks about her favorite teacher,

> He was really fun. And he was a huge inspiration to go into any type of science because he was just so devoted to it himself, you know. Like, he loved it so much, and he was just having so much fun in the class even if the students were just staring at him blankly, he always had a smile on his face and he was just a really good teacher. I wouldn't mind being like him (Jamie, pre, 158 – 162).

Jamie is describing how a teacher can inspire students and create motivation within them by modeling a love of science. Jamie considers modeling this style in her own teaching. She talks about why this motivation is important to her earlier in the interview,

> I'd like to make sure that groups are focusing more. 'Cause as I said there were some distracting groups and if there's any way that I can make them focus more or make the students that don't want to get involved in this more excited about this I think that would be good. Becuase, I mean, I really love physics and I just want everyone else to too. And, I just, I don't know, I guess I can't stand it when I see kids not enjoying it. So I just want to see them and I want to see them have fun with this. Even if it's not the same way that I think about it. I want to find a way to make them enjoy learning, just like I do (Jamie, pre, 143 – 150).

For Jamie, motivating students is a way to address off-task students, the same problem Leah and Gen talked about addressing using authority. Also, for Jamie motivation is personal as she wants students to feel the same way about physics that she does. Jamie returned to this topic several times during the semester. She talked about helping students to become more motivated to work on tutorials (Jamie, wk05, 4; Jamie, wk11, 1) and more excited about physics (Jamie, wk06, 3). For Jamie, this was an important part of why she became an LA (Jamie, wk05, 4), what she considered to be good teaching, and one of the main reasons she would consider a career in

teaching (Jamie, post, 355 – 274). For Jamie, motivation is an important aspect of her relationship with students because she wants to teach students to not only know the physics content but also to love physics.

Ultimately, the LAs' greatest concern is for students to learn the material. They consider the relationships between students and teachers to be critical to this learning. Therefore their view of student/teacher relationships focuses on three constructs. First, they believe teachers should be approachable so that students are comfortable enough to ask questions. Second, they want students to recognize LAs as being authorities who have the content knowledge necessary to help them and who have the right to insist that they focus on their work. Finally, LAs are a source of motivation to students by inspiring them to enjoy physics and to want to learn the material.

Individual Case Studies

Leah's Case Study

Leah's views of teaching include a model of formative assessment and the importance of approachability in student/teacher relationships. Of the four LAs, Leah begins the semester with a model of teaching that most closely resembles the generalized model of formative assessment since she talks about both the importance of having students construct their own understanding and of building on students' prior experiences. Leah goes on to construct a complete model of formative assessment similar to the generalized model during the first half of the semester. Within her model, Leah is the only LA to talk about the important life skills that students develop by learning to construct their own understanding of physics concepts. In her writing Leah describes how tutorials help students learn to work in groups and to creatively problem solve.

Leah is the only LA to begin the semester with a view of student/teacher relationships that includes a mechanism for how being approachable helps student to learn. Leah's model is based on the idea that students cannot learn if they are not willing to ask questions of the teacher. Yet students are not willing to ask questions unless they feel the teacher is approachable. Leah mentions this idea several times during the beginning of the semester interview, she does not return to the importance of teachers being approachable during the rest of the semester. Though she doesn't mention approachability again, Leah does talk about student/teacher relationships several times throughout the semester by mentioning her concerns with authority. Leah's discussions of authority are unique, compared to the other LAs, because her discussions of authority are focused on presenting an "authoritative presence" to address the problem of off-

task students. While Leah does mention issues around authority several times during the semester, these are not a focus of her writing; instead she is focused on issues around her model of formative assessment such as adapting her teaching to fit her students. Leah's views on student/teacher relationships are summarized in Table 5. This table summarizes Leah's views on each of the three elements of student/teacher relationships at various times in the semester. Several cells are empty because Leah did not talk or write about the topic in that time frame.

Leah is the oldest of the four LAs. She is a post-baccalaureate student who has returned to college to complete her medical school prerequisites after receiving her bachelor's degree in political science from a university on the east coast. Leah's previous experiences appear to have made her the most articulate of the four LAs especially in her article reports and final reports. Leah did not intend to pursue teaching as a career when she started the semester, and her opinion did not change following the LA experience. She is planning to attend medical school, though she hopes that her future career would involve some aspect of teaching. She has previously worked as an EMT during college and enjoyed the opportunities to teach fellow EMTs and high school students.

Student/Teacher Relationships

Table 5. Summary of the Development of Leah's Views of Student/Teacher Relationships.

	Pre	Early	Mid	Late	Post
Approachability	Relatable & open to questions				
Authority	Being respected by students			Keep students on task	

Leah began the semester acknowledging the importance student/teacher relationships. Of the four LAs, she is the only one to describe the mechanisms of the approachability model at the

beginning of the semester. Leah explained this mechanism when she was asked what makes a good teacher,

> I think a good teacher is a teacher who is able to relate to students and understand sort of what they're needs are and at the same time be able to control the class and be the teacher and the authority figure but also somebody who the students aren't afraid to ask questions to. Because I know I've had teachers like that who are just really dry and really strict and you really don't want to ask them questions because you're afraid to look stupid and I think that that's kind of sad because how else are people gonna learn if they don't ask questions on what they don't understand. So I think that the best teachers are the ones who are approachable and yet still very knowledgable and authorities but are able to relate to the students.(Leah, pre, 204 – 213).

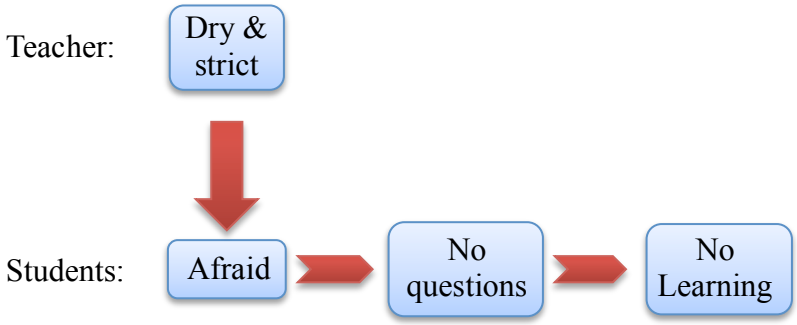

Figure 11. Leah's model of the role of approachability in learning.

Leah explains that approachability is important in student/teacher interactions so that students feel comfortable asking questions and do not feel the need to protect themselves from appearing stupid. Leah's model of learning is shown in Figure 11 and is shown in negative terms, how to prevent learning, since this is how Leah originally explained the idea.

Leah's above description of good teaching is focused on the teacher being approachable, but it also mentions the importance of teachers being an authority figure. Leah does not heavily

focus on issues of authority but she mentions the topic throughout the semester. In her description of good teaching Leah sets up a tension between being able to control the class and being seen as approachable by students. She considers both aspects of teaching to be important for creating an environment where students can learn. Leah returned to the issue of authority in the pre-semester interview, when asked what she was worried about, she responded that she was concerned that students would not listen and respect her – "I'm a little bit nervous about people listening to me, and respecting me. Not making fun of me or anything. But, that will probably go away after the first day or two. I hope" (Leah, pre, 280 -282). Leah again returned to the issue of authority in her weekly reflection following the first tutorial in which the LAs actually helped teach the class,

> My main goal was to try to get myself comfortable with being an "authority figure"; for a class of students. I felt that I met this goal, because I was able to maintain a reasonable presence throughout the tutorials that I taught. I felt that I was a person that the students respected enough to listen to and to ask questions (Leah, wk03, 2).

Leah was concerned that if students did not see her as an authority they would not be comfortable asking her questions. This is the first area of authority as explained in the generalized views of student/teacher relationships – being seen as a content authority. Leah did not mention the authority aspect of her relationship with students again until her week 12 reflection when she writes that her hope for the week was to encourage students to concentrate on and finish the tutorials since the semester was winding down (Leah, wk12, 3). Leah mentioned this issue again at the end of the semester when asked what didn't go well in her experience as an LA,

> There were definitely some times where the students were very off track and just very unwilling to start the tutorial. And that was pretty frustrating. I'm not a very confrontational person so it's really hard for me to go up to somebody and say "hey, you need to start working now." So I would try and do it in a light hearted manner but that didn't always work so well, so I think in the future that is something I would definitely work on, was getting a better authoritative presence when students were not doing the tutorials at all and were completely off track, working on trying to help them get on track better. (Leah, post, 17 – 24).

Toward the end of the semester Leah began to describe her concerns that students were not focusing on finishing their tutorials. She attempted to encourage them to get back on track but found that they didn't listen. She blamed this on her lack of an "authoritative presence". Now Leah is talking about the second area of authority. For Leah this authority came from the way she presented herself and was something that she could cultivate in the future.

Formative Assessment

Table 6. Summary of the Development of Leah's Views of Formative Assessment.

	Pre	Early	Mid	Late	Post
Construction	Don't give answers		Students learn important skills through the process of learning		
Prior Knowledge	Innate understanding		Intuition & learning preferences		
Individuality			Different methods work for different students		
Adaptability			Adaptability key to teaching		Flexibility important in teaching

The development of Leah's views of formative assessment is shown in Table 6. This table summarizes Leah's views on each of the four elements of formative assessment at various times in the semester. Several cells are empty because Leah did not talk or write about the topic

in that time frame. Leah's views developed in two stages. First she began the semester already recognizing the importance of having students develop their own ideas rather than simply giving them the answers. Leah also recognized that students had ideas from their prior experiences that could be relevant to their study of physics. Leah's ideas about these two constructs remain fairly constant throughout the semester. About half way through the semester, Leah began talking about a fully developed model of formative assessment that included recognizing that students responded to questions and other teaching strategies in different ways and therefore teachers needed to adapt their teaching to fit the needs of each particular student.

Construction

Leah entered the LA program recognizing the importance of students' creating their own understanding. When asked what the role of LAs is, she responded,

> . . .they're there to help you learn and so that I think to me sums it up. It's that the LAs weren't really teaching you but like sort of pushing you to understand the concepts better. It was really helpful that none of the LAs that I had have ever given me the answers or anything which a lot of people want. And I know a lot of times I've wanted them too. So, yeah, just sort of there as the guide to help you figure out what's the best way for you to learn and help you understand the concepts (Leah, pre, 109 – 115).

Prior to the beginning of the semester, Leah recognized that LAs were in the tutorials to help students figure out the physics concepts for themselves. This is the construction element of the formative assessment views. Based on her interactions with her previous LAs, she recognized the value in LAs not giving students the answers. Leah returns to the importance of having students construct their own understanding in her reflections from weeks five and six. She first explains that she wants "to work harder to get my students to understand and work through the ideas by

themselves, and to minimize any 'hints' that I gave towards the right answer" (Leah, wk05, 2). The next week she states that she wants "to work again on ways to coax students into understanding the concepts with questions and dialogue" (Leah, wk06, 3). It is important to Leah that her students work through these ideas on their own and that her job is to provide minimal help when necessary to coax students to the answer. She is working to use questions and dialogue instead of hints to help students reach an understanding. Leah, reiterated her view of the job of the LAs in final reflection of the semester ,

> My job as an LA is not to teach students new concepts, but to help them go through the process of understanding concepts that have already been introduced. I consider myself an aide to comprehension rather than a teacher, because it is my job to encourage students to understand material on their own. I can clarify concepts that may be fuzzy, but it is not my role to tell a student what an answer to a problem or question is. Rather, my role as an LA is to act as a guide so that students can get some help figuring out good ways to go about tackling a problem. (Leah, wk14, 5).

Leah's descriptions of the job of a successful LA are based on LAs offering minimal assistance to students so they can develop their own understanding. She considers her job as one of guiding, coaxing and clarifying instead of teaching. She defines teaching as giving information to students. In the end of semester interview, Leah explains why she feels it is important for students to develop their own understanding. When asked why she used questioning a lot when teaching, Leah explained,

> ". . . directed questions and carefully constructed questions can really help the students come to their own understanding of the concept which is going to be a lot more lasting

> and a lot more solid than just hearing an answer from somebody else" (Leah, post, 106 – 108).

Therefore, Leah views the type of teaching she uses as an LA to be helpful because the understanding that students develop is more robust and more lasting than if students were told answers.

Leah's responses in the beginning of the semester interview and in her final reflection hint at another reason Leah feels that it is important for students to develop their own understanding with the guidance of the LA. In both responses Leah explains that LAs can help students to figure out "the best way for [them] to learn" or to "figure out good ways to go about tackling a problem". Leah recognizes that LAs are helping students to learn more than just the physics concepts. Instead, LAs are also helping students to learn about themselves and their own learning preferences and to learn problem-solving skills. In the second part of the semester, these problem-solving skills become very important to Leah. During her mid-semester reflection she states,

> I have noticed that the more I teach and learn about teaching, the more I have realized the importance of allowing the student to reach his or her own answer. A student learns much better through thinking, and that process is much more important than the answer itself (Leah, wk08, 1).

Later, when asked why it isn't helpful to just give students the answer, Leah explains why the problem-solving process is so helpful for students,

> Lectures and answer-giving will not advance an understanding of the nature of science because students need to be able to produce their own creative ideas and thoughts regarding a specific problem. It is not simply scientific knowledge that students must

> learn, but scientific skills. These problem-solving skills can be applied to all subject areas but are particularly important in science. The scientific knowledge that students learn will be much more lasting and useful if students have a deep understanding of how someone arrived at those concepts, and how to understand specific topics in relation to other topics in science (Leah, wk13, 2).

Leah's final paper returns to the importance of problem-solving as Leah describes how her views on small-group discussions have changed.

> I no longer see discussion as an exchange of information between student and teacher. Instead, I increasingly believe that the value of discussion lies not in the information itself, but in the way that students learn to generate ideas and understanding within a small group. Creativity increases significantly when students combine and develop their individual ideas as a group. Not only does discussion enhance problem-solving skills and allow students to contribute their own strengths to a group, but it is a necessary skill that nearly all students will need to use in the future (Leah, final, 81 – 87).

As the semester goes on Leah begins to talk about the importance of what was happening in tutorials. She recognizes that students are not just learning about physics instead they are also learning how they best learn, how to problem solve, and how to work within groups. None of these other important lessons would be possible in an environment that did not stress the construction of learning. Leah is the only one of the LAs to talk about the life skills that students develop in tutorials beyond learning the content and problem solving skills.

Prior Knowledge

Throughout the semester Leah talks about eliciting students' prior knowledge, the second element in the generalized model of formative assessment. At the beginning of the semester Leah

explained that she would start helping a group of students by first finding out what they understood and where they were struggling,

> First, I would probably try to figure out exactly what they were having a problem with. Like if there were certain parts to the problem that they understood and certain parts that they didn't. Then maybe try to figure out why they didn't understand, what they weren't getting (Leah pre, 149 - 152).

At the end of the semester she described a similar process.

> Well, I think that at first I would ask them to sort of clarify to me what their understanding of the situation is, what their understanding of the problem is and how they would or have gone about solving it. Because I think sometimes when students verbalize what they mean to somebody else it kind of helps them clarify what they mean and maybe even see some contradictions or something they didn't see before. (Leah, post, 85 – 90).

While Leah's answer at the end of the semester shows her continued commitment to base her interactions with students on their current understanding, it also shows an evolution in her understanding of problem solving. At the beginning of the semester, Leah's questions are based entirely around finding out where students are stuck in the solution process. This suggests that she is assuming that there is a single linear path to solve the problem and the students are stuck somewhere along this known path. At the end of the semester, Leah is focused first, not on simply finding out where they are stuck along the path, but on finding out what path they are on. She begins the conversation by attempting to understand what students think the situation is in the problem and what they think the problem is asking. In other words she is attempting to understand the terrain from the students' perspective. Then she asks them how they have tried to

solve the problem. Leah also references eliciting students' current understanding in the reflections when asked why she uses questions, "I tried to ask questions in a dialogic manner, so that I could see what the students were thinking and see what they had trouble with" (Leah, wk04, 2). The reason Leah is beginning the interaction with questions is so that she can see how the students are thinking about the problem.

When Leah describes helping students with specific problems in her weekly reflections, she does not usually describe how she elicited students' current understanding. This is because she chooses to focus her response on her intervention and begins her narrative once she understands where students are struggling. This is supported by the fact that she begins these descriptions by stating the student difficulty - "Most of the students at first thought about the problem in terms of energy, which is how I also first looked at the problem, and arrived at an incorrect response" (Leah, wk12, 1). On the other hand, when describing in the interviews how she would assist a hypothetical group of students, this step is included. This suggests that Leah is aware of this step but is using her reflections to think about her own teaching strategies rather than reporting on what happened in the classroom or documenting student ideas.

Throughout the semester, Leah references a variety of types of prior knowledge that students can access in their physics classes. At the beginning of the semester Leah references students' everyday knowledge of physics, "Because especially in physics, everybody kind of has an innate understanding of physics, it's just its hard to get there from just dry lecture or reading the book and stuff" (Leah pre, 154 - 156). Here Leah describes the everyday resources or experience-based knowledge that students can use to learn physics. She also points out the difficulty that students can have connecting their experience-based knowledge with the academic knowledge of physics given the way it is presented in lectures and textbooks. Later in the

semester, when she is asked to explain her theoretical perspective on learning, Leah includes an expanded list of the types of resources that student have, "Students have a particular way of learning already in their heads, coupled with information that they may have already been told and their intuition" (Leah, wk06, 4). Besides students' intuition or experience-based knowledge, Leah also now includes students' prior academic knowledge – information they've already been told - and their learning styles – a particular way of learning.

While Leah talks about various resources that students have, she does not consistently talk in terms of a traditional resources model. When asked what she is struggling to understand about formative assessment, Leah responds,

> What I did not understand were some of the distinctions between good ideas that students have and ideas that need some "fixing". It is difficult to distinguish between a preconception that a teacher can build on and one that actually is wrong (Leah, wk05, 1).

Here, Leah distinguished between ideas that students have that are just wrong and those that can be useful to build on. Leah returns to this point several weeks later "It's very rewarding when a student reasons their way to a thorough understanding of a concept on their own, but sometimes students' intuitions are plan incorrect" (Leah, wk09, 2). By the middle of the semester, Leah struggles to reconcile her understanding of theories of learning that instruct teachers to find student's current understanding and then shape that understanding with her experiences of student ideas that she can't reconcile with her understanding of the topic.

Individuality

Leah began talking about the individuality of each student, the third element of the formative assessment views, partway through the semester following the introduction of learning theories in the LA seminar. For the rest of the semester Leah talked about the importance of

teachers' noticing the differences between students and paid special attention to the differences in students' learning styles or preferences. Leah also implicitly noted differences' in student ideas when she reflected on students' ideas and how she helped students.

Leah chose to focus both of her article reports and her final paper on students' individuality. Her first article report contrasted Redish's article on mental models (Redish, 1994) with Knuth and Peresini's article on discourse styles (Knuth & Peressini, 2001). She talks about how teachers can use different questioning styles to elicit each student's unique mental model. She goes on to describe individuality as one of the two main goals of teaching. In her second article report, Leah analyzes Lederman's (Lederman, 1998) call for science standards that include the nature of science in light of Armstrong's (Armstrong, 2000) call for teachers to recognize students' varying mental intelligences. Leah argues that Armstrong's argument can be expanded to a call for an increased focus on the individuality of student learning. In her final paper Leah comments,

> It is all too easy for a teacher to view students as identical "learning units" that must be filled with a particular subject. Analyzing these two articles at the beginning of the semester helped me to understand that students necessarily learn in distinct ways. A particular form of discussion may enhance one student's understanding of a concept, but could do absolutely nothing for another student (Leah, final, 29 – 33).

Leah first mentions differences in her students during her week six reflection. When asked to evaluate her teaching for the week, she begins by stating that "different teach methods worked much better for different students" (Leah, wk06, 2). Leah demonstrates in her response this week that she recognizes that students do not learn using the same methods and therefore respond to various teaching methods differently. Leah's references to differences between

students tend to focus not on conceptual differences but on learning styles. This could be because Leah finds working with different learning preferences to be challenging while building on different student ideas to be relatively easy. Therefore she focuses her writing on the aspect with which she struggles. Another possibility is that Leah tends to use a teaching strategy that does not build on students' ideas but has students start over from first principles. In this case she would not notice differences in students' prior ideas because she would always point them to the same starting point and therefore the only difference between students would be how they responded to her various prompts.

Leah continues talking about the individuality of students in the post semester interview, when she explains one of biggest things she feels she has learned about asking good questions is that "the same question is not going to have the same effect on every student so you have to get to know your students, maybe how your student learns and how your student thinks in order to ask good questions to them" (Leah, post, 113 – 116). Leah's papers show that she values the unique ideas and styles of each student and the influence this has on effective teaching.

Leah's awareness of differences between students is also evident from her descriptions of students' difficulties or her strategies for helping students with particular problems. Leah begins her descriptions by describing a problem *most* or *many* students had – "Most understand that force always acts at the center of mass" (Leah, wk12, 2) and "a particular group of students thought that the vectors pointed in the same direction" (Leah, wk14, 6). She then describes an intervention that *usually* worked – "Generally what worked for most students was when I went through each force . . ." (Leah, wk06, 2). In other words, Leah is recognizing that while there were common issues with which many students struggled and that there were common strategies that helped these students, these were not universal and other students had other ideas.

Throughout the latter part of the semester Leah demonstrates the value she places on recognizing the individuality of her students and the influence this has on her teaching.

Adaptability

Of all the LAs, Leah talks the most extensively about adapting her teaching to her students - the fourth element of the formative assessment views. Leah began talking about this during her first article report –

> While both articles present the learning experience in a different manner, they each emphasize the necessity of adaptability of teaching style. Certain students and situations will require the teacher to guide the learning process differently. I support the general argument of both articles—a successful teacher must be able to alter lessons or concept explanation based on the individual situation and student (Leah, AR1, 19 – 23).

Leah explains that in order for a teacher to be successful they must alter both the general lesson and the specific explanation to the situation and the student. Leah's description suggests that the teacher must make overall adjustments to the lesson as well as moment by moment adjustments to the explanation she is using. Leah's description also suggests that while teachers need to adjust their teaching to individual students, the same adjustment won't always work for the same student so the teacher has to also respond to the specific situation. At the end of the semester, Leah relates the concept of adaptive teaching directly to the job of an LA,

> I found that one of the most important roles of the learning assistant was to identify the ways in which these students struggled and to try to find alternative ways of understanding the material that did not rely so heavily on logical and mathematical intelligence (Leah, final, 60 – 63).

For Leah, the job of the LA is to understand where students are struggling and to then adapt her teaching strategies to these students' needs. Leah talks specifically in terms of multiple intelligences since this was how she often categorizes student differences. In the final interview Leah does not talk in terms of adaptability in teaching as she did in her article report, but she explains the same idea in terms of flexibility in teaching,

> I think flexibility is maybe the biggest thing that makes a good teacher. Because students are all so different. They're all coming from such different places and they all have such different experiences in the classroom, even with the same teacher and the same material. And so I think the best teachers are the ones that can recognize when what they're doing for a particular student or for a particular class is not working and be able to be open to changing that. I know that I have experiences with a lot of teachers who think that their way is the right way of doing it and that works for some people but it doesn't work for others. And so for the students who really are getting that method of teaching, they're just sort of left in the dust. So, I think that the best teachers are able to look at their individual students' needs and be able to change their teaching method accordingly (Leah, post, 201 – 211).

Leah pulls on her previous experience with teachers who only use one type of teaching strategy to reach all students to explain what she considers to be good teaching. For Leah, a good teacher is not wedded to a single teaching strategy or concept explanation. Instead a good teacher makes instructional decisions based on what the student needs.

Leah begins the semester already recognizing the importance of students constructing their own understanding and of the value of students' prior knowledge in learning. She talks about the first idea based on her experiences with her own LAs. Leah values student's prior

knowledge because she recognizes that everyone has intuitions that are valuable in learning physics. Leah begins talking about recognizing students' individuality and the importance of adaptive teaching in week six and especially in her first article report. Leah then continues talking about these ideas throughout the semester. Leah begins the semester talking about aspects of both views of learning – formative assessment and student/teacher relationships. But as the semester continues she focuses solely on the formative assessment views. As the semester develops, Leah's view of learning comes to very closely resemble the generalized views of formative assessment.

Andy's Case Study

Andy begins the semester with a commitment to students constructing their own understanding. At first he talks about this only in terms the importance of having students talk about their ideas so that they can think more clearly. As the semester progresses Andy begins to talk about using questions to help students construct their understandings and eventually using both questions and explanations to help students. As the semester progresses Andy's views of teaching and learning also expand to include the other elements found in the generalized model such as prior knowledge, individuality, and adaptive teaching. While Andy mentions prior knowledge and individuality, his focus remains throughout the semester on having students construct their own understanding. He only mentions adapting his teaching to help students process their understanding at the end of the semester.

Andy's views on student/teacher relationships evolve over the semester. At the beginning of the semester, he recognizes the role his relationship with his previous LAs and teachers played in his own learning. Yet he does not talk about trying to build similar relationships with his own students. As the semester progresses, Andy begins to talk about the impact of student/teacher relationships on his own students' learning and he begins to talk more explicitly about how to build these relationships. When talking about his own students, Andy's focus is on learning about their everyday life so that he can draw on their experiences in his teaching. Andy is unique in the practical way he talks about improving his relationship with students and his focus on strengthening these relationships. While the other LAs talk about wanting to build relationships with students, they do not mention practical steps about how they would build these relationships like Andy does. Andy's focus on relationships in the second half of the semester is somewhat

surprising since he never mentions wanting to build relationships with students in the pre-semester interview or the early weekly reflections.

Andy is a sophomore mechanical engineering major. While Andy had not made any career decisions by the end of the semester, he is the only one of the four LAs to eventually pursue a teaching certification. Andy's interviews are unique in the emphasis he places on his previous LA and TA. At the beginning of the semester Andy talks about his positive experience with his LA in PHYS 1110 the previous semester. Andy pulls on this experience to describe the job of an LA and how he thinks teachers can help students learn. Several times during the semester Andy also mentions his TA from PHYS 1110 who is now one of the TAs he works with as an LA. He had a good experience with her as a student and continues to like how she works with students throughout his semester as an LA. These two people had a very strong influence on Andy's understanding of how people learn and the role of an LA.

Formative Assessment

Table 7. Summary of the Development of Andy's Views of Formative Assessment.

	Pre	Early	Mid	Late	Post
Construction	Students need to talk about their ideas	Questions help students learn	Both Questions and Explanations can help students		
Prior Knowledge		Important to elicit student ideas		Important to understand the problem from the students' perspective	
Individuality			Every student is different		Different strategies help different students
Adaptive Teaching					It's a puzzle to figure out what methods will help which students.

The development of Andy's views of formative assessment is shown inTable 7. This table summarizes Andy's views on each of the four elements of formative assessment at various times in the semester. Several cells are empty because Andy did not talk or write about the topic in that time frame.

Construction

Andy's valuing of the construction of knowledge, the first construct of the general model of formative assessment, remains fairly constant throughout the semester. While his focus remains constant, Andy's understanding of how to help students construct knowledge changes over the semester. At the beginning of the semester Andy believes that the best way for students to construct their own understanding was for them to talk about their ideas aloud. As the semester progresses Andy begins talking about using questions to help students talk about their ideas and to construct their understanding. By the middle of the semester Andy recognizes that explanations could be equally effective for students in certain situations.

Andy's views on the construction of knowledge, are first apparent in how he describes the role of the LA. He begins the semester with a clear idea of what he thinks the job of an LA is, how he thinks they should help students, and why this method is effective –

> The job of an LA is someone, they have to facilitate learning and their job is not to teach their job is to help the student kind of teach himself or teaching themselves on their, by, you know the student's half way there you give them a little hint then they kind of understand it but they're more part, because when you work something out on your own you understand it a lot better than when the teacher works it out. So if the students are able to understand the material pretty much on their own then they really have learned it a

> lot better than otherwise. So an LA's job is to help them learn on their own (Andy, pre, 80 -87).

Andy explains this point again during the first reflection when he states that, “I think that my job will be to help students learn. I am not there to provide answers, but to facilitate the students understanding of the material” (Andy, wk02, 1). Andy’s beginning views of teaching place a very strong emphasis on the construction element of the formative assessment model. Andy’s use of the phrases “facilitate learning, “teach themselves”, and “help them learn on their own” refer to the views that it is important for students to create their own knowledge rather than passively absorbing information from the instructor. Under this view the instructor must step back and take a secondary role to the student in the learning process. The instructor is a facilitator or an assistant. As an LA, Andy wants to make sure that students do most of the work and teach themselves. Therefore the LA should only offers hints so that students can continue figuring out the problem on their own. Andy reiterates this technique of giving only hints so that students can develop their own understanding in his second article report,

> In the recitation sessions that we have, the environment is set up such that we are supposed to help but not always tell the answer. Even though some students are uncomfortable with this approach, I have found that it is a good method to help students understand physics. (Andy, AR2, 49 – 51).

By the end of the semester, Andy notices that students are not always comfortable with how he wants to help them. Instead, the students want him to give them the answer to the problems. Despite students’ discomfort with this technique, Andy remains committed to it because he views it as one of the best methods for helping students learn since people learn better when they work the material out on their own.

For Andy, a key way that students construct their own understanding is by talking aloud about their ideas. Andy places a uniquely strong emphasis on this idea compared to the other LAs. He explains this idea when he comments on why group work is important,

> They use groups because when you discuss topics with other people, you understand them a lot better. If you try to figure it out in your head, I know from experience that a lot of times it won't make sense or you think you had it but then when you talk to somebody it will make a lot more sense. So when you say, “this is what I think”, somebody else says 'this is what I think' and they explain. It, it's almost like, it's like you're teaching each other the material, which is very helpful (Andy, pre, 41 – 49).

Based on this excerpt, Andy is drawing heavily on his personal experience in tutorials the previous semester. His learning strategy is based on several elements. First, working problems out in one’s head can be misleading since logical jumps or inconsistencies can be glossed over. Second, his strategy is not simply about talking aloud. What he values is actually the dialogue that occurs between students as they share their ideas. Finally, Andy equates these dialogues to teaching. In this statement he is referencing a previous comment he made when he stated that a person learns the material best when they teach it. Andy demonstrates how he would use this strategy when he describes how he would help a group of struggling students,

> Well, from what I've seen, what I think, and what I've seen this semester. What I would do is just kind of go over it. Talk over what they already did. A lot of times when someone, when you talk over it, and say well do you think this is correct, students get an idea that oh maybe I did something wrong. So they start thinking. I don't know, for me a lot of times when the LA would speak what our answer was and just kind of point out what we had done, “so this what you're meaning, this, this, and this”, suddenly it would

> come to me that "oh of course I was wrong. It has to be that". And then if not, as the LA I would, if they still didn't get it I would prompt a little bit. Say, "well," or I would give a counter example if there was one. To show a counter example and say, "well then what would be right." Counter examples help a lot to show that for some case it may work. For all cases it may not, though, for all of things. (Andy, pre, 102 – 113).

In this excerpt Andy gives several teaching strategies that he would use as an LA. All of these strategies are intended to encourage students to use the learning strategy, talking aloud about their ideas, that he describes above. First, he would encourage students to continue thinking about their ideas further. Second, he would restate students' answers, putting them in slightly different words. This rephrasing is done to highlight the implications of the students' idea. Finally, if neither of the above strategies are effective then Andy offers a prompt such as a counter example to provide more information for the students to consider. The counter example is intended to work very similarly to the second strategy in that it encourages students to evaluate their answer based on its implications. Andy describes these strategies in order of increasing interference from the LA. This is in keeping with his previously discussed emphasis on having the student do most of the mental work while the LA only provides guidance when necessary.

Andy remains committed to having students talk about their ideas as a way for them to learn throughout the semester. Yet, his ideas on how to facilitate this talk evolve. At the beginning of the semester Andy's strategies for helping students only include restating the student's response and offering a counter example. By the week four reflection, Andy begins talking about using questions to guide students' thinking when they do not recognize holes in their own argument. He demonstrates this technique in a vignette he included in his reflection based on his many interactions with students that week over a difficult part of the tutorial. In this

problem students had been asked to draw the acceleration vector of a particle traveling at a constant velocity around an oval track.

I: "why do you think that the acceleration is way that you drew it?" (the angle between the velocity and acceleration was greater than 90)

Student: "well acceleration points towards the center of the oval".

I: "does it?" (Sometimes that was enough for them to see their mistake)

Student: " yes when an object moves in circular motion, the acceleration points towards the center of the circle"

I: "is the track a circle?"

Student: "no." (often they would get a puzzled look)

I: "how does radial acceleration work? how is it related to velocity?"

Student: "acceleration is change in velocity over time"

I : "is the velocity changing here?"

Student: " there is constant speed, but the direction changes"

I: " so the object is not speeding up or slowing down, right?"

Student: "yes"

I: "how do u think acceleration would have to act on the object to make it turn but remain at a constant speed?"

Student: " oh. it would have to be 90 degrees?"

I: "do you think it would?"

Student: "yes, because if it was not then the object would either speed up or slow down. this makes sense now. thank you"

This one kind of conversation I had with students. (Andy, wk04, 2).

In his final paper Andy explains his thinking about the types of questions he often uses when working with students.

> I try to use indirect questions when I am discussing concepts with students. Indirect questions give the students an opportunity to develop the concept by themselves and that makes the learning process exciting and also more effective. For example, "What do you think about this diagram?", "Why have you answered the question like that?" and so on (Andy, final, 49 – 53).

Throughout the semester Andy tends to use vague questions with students – "do you think this is correct", "does it", or "what do you think about this diagram" – or brief questions that encourage students to reconsider a specific part of their solution or the problem – "well then would that be right", "is the track a circle", "how is [radial acceleration] related to velocity". These two types of questions are intended to encourage the student to continue thinking about their understanding. This technique of asking brief questions is very closely tied to his preference for having the student do most of the work while the LA only provides hints to help students when they get stuck so that students are able to develop a deeper understanding of the material. Andy takes the most extreme view of construction among the four LAs.

While Andy prefers to use questions to help students develop their understanding, as the semester progresses he finds that brief explanations are sometimes necessary and very effective. In his final paper, Andy describes these two techniques,

> There are two ways that I normally help the students. I either ask a question or explain the concept. I try to find ways to ask questions, as a question gives more room for thought generation than an explanation and can lead to a discussion. However, a simple explanation can do wonders at times. (Andy, final, 25 – 28).

Andy also explains why he uses these two techniques in his week seven reflection,

> I found that the combination of questions and explanations did the trick. But when I only asked questions, some of the students did not seem to know where to start. When this happened I would give some hint or read the question again (Andy, wk07, 2).

While Andy prefers to use questions to help students develop their understanding because it requires students to take a create role in their learning, he recognizes the value of explanations. Andy's use of the word "simple" to describe his explanations indicates that he is not talking about describing for the students derivations, example problems, or mini-lectures. Instead in his later excerpt, he equates explanations with "giving a hint" or "rereading the question". Even when Andy is talking about explaining things to students, his focus is on providing only enough information to give students the push they need to continue thinking through the problem on their own. In the end of the semester interview, Andy goes into depth about these two techniques that he commonly uses to help students,

> Sometimes I'd ask them, "so what did you do here" and they'd think about it and talk about it. I'd say, "You sure that's right?" Kind of look at me like "well, maybe it isn't right" so they'd look at it and say, "Well, if this was right could this happen?" I'd ask a question, and then they'd say "Oh, maybe not," and then they'd say, "well is it wrong?" And I'd say, "I don't know what do you think?" They'd go, "Well, if that couldn't happen then, maybe it is wrong, so then this would have to be right. Is this right?" "Well, does that coincide with everything else you've talked about?" And they'd say, "Humm, yeah." I'd say, "well then." (Andy, post, 40 - 47).

He uses vague questions, "are you sure that's right" and "what do you think" and brief explanations that serve as counter examples, such as "if this was right could this happen," that

are intended to spur students' thinking. In this excerpt Andy is demonstrating several teaching strategies he has already discussed. First, he is encouraging the students to continue thinking or rethinking about their answer. If that is not effective, then he revoices their answer to emphasize the implications of their answer. Andy also references a new teaching strategy or value – he refuses to validate students' answers. Instead he asks them to place their trust in their own logic.

Andy feels it is incredibly important for students to develop their own understanding of the physics content, and for them to create their answers on their own. As a way to facilitate this, he feels it is important for students to talk about their ideas aloud; not just to help those in their group, but to mostly help themselves. In order to help students develop their ideas, Andy tends to use very vague questions to encourage students to develop their thinking. When necessary, he is willing to use brief explanations to help them continue their concept development. Throughout the semester Andy wants the LA to take a facilitation role in students learning rather than being the one who develops the answer for the students. His teaching techniques are all intended to facilitate student thinking as much as possible. While the way he talks about these techniques becomes more explicit as the semester continues, the way he wants to teach remains fairly constant during the semester.

Prior Knowledge

Andy does not begin talking about the second element of the generalized model of formative assessment – student's prior knowledge - until several weeks into the semester. Andy recognizes the need to use questions to elicit students ideas and tends to use a resources perspective when talking about the value of students ideas. Andy is unique among the LAs in the emphasis he places at the end of the semester on understanding students' ideas. Andy attempts to see both the problem and the students' explanation from their perspective. It is not enough for

him to simply be aware of the students' ideas, but he wants to fully understand how the student is thinking about the problem and how they are attempting to solve the problem.

The first time Andy mentions the importance of recognizing students' prior ideas is in his week five reflection when he states that, "my goals for next week are to build off of students' misconceptions. I plan to do this by asking broader questions or more open questions" (Andy, wk05, 3). While Andy uses the word "misconceptions" he is actually using a resources perspective, as described in the literature review. In a misconceptions perspective an LA would talk about identifying, confronting, and fixing students misconceptions. While in a resources perspective an LA would talk about identifying students' resources and helping students use them to build up the physics concepts. Using the language of one perspective to express the ideas of another perspective can be a sign of learning as an LA struggles to reconcile an old perspective based on experiences with a new perspective. In this situation, though, the confusion of vocabulary and perspectives does not indicate that Andy is struggling with the two perspectives. Instead, he is emulating a common language convention used in the LA seminar. The instructors both taught and used a resources perspective but tended to fall back on the older language of misconceptions. Also, Redish's (Redish, 1994) article used the misconceptions perspective and the instructors and LAs discussed the differences in the two perspectives acknowledging the usefulness of the word misconceptions while addressing the problems of the perspective. Therefore the vocabulary used cannot be considered indicative of Andy's views on students' ideas.

Andy continues talking about the importance of students' ideas in his course papers. He focuses his first article report on students' prior knowledge by comparing questioning strategies with Redish's representations of mental models (Redish, 1994). In this paper, Andy talks about

using questioning strategies to help students "develop, change and build off of previously existing or new mental models" (Andy, AR1, 19). He also talks about the difficulties students have when trying to learn a physics concept that is very different from their current mental model. Andy suggests that questioning strategies can make this learning easier. In his final paper, Andy explains how he uses questions to elicit students' prior ideas,

> I have found direct questions to be useful when I am trying to find out exactly what the students understand or don't understand. For example, "What does this do?", "What is the value of x?", "Where did this come from?" I have found this type of question very helpful in understanding what the student's perspective is and what they know. (Andy, Final, 40 – 43).

Andy is describing how he diagnoses students' understanding by asking them very specific questions about their answers. By this point Andy is not simply talking about the importance of recognizing students' ideas but goes beyond this to discuss the importance of recognizing students' understanding of the problem itself,

> When students don't understand a problem, I have to be able to see the problem from their perspective. I read the question with them and try to understand what they are thinking. Sometimes I am able to see where they went wrong. But lots of the time it is not so black and white. I have found that analyzing the question based on the student's answers is a very useful technique for understanding their thought processes (Andy, Final, 19 – 23).

By the end of the semester, Andy recognizes the importance of understanding both students understanding of the physics concepts and their understanding of the problem. Andy is seeking to understand students from their own perspective instead of just comparing students' responses

to the correct response and finding where they diverge. Andy recognizes that his job is not that easy. Often there is not a clear point where students made an error like an addition error. Instead Andy recognizes that he often has to go back to the beginning and understand what students think they were being asked to do before he can understand what they did.

Individuality

Andy does not spend much time writing about the individuality of his students, the third element of the formative assessment model. He only talks or writes explicitly about the differences in his students in his first article report and later during the end of semester interview. Andy implicitly mentions this idea in the previously discussed excerpt from his final paper. He recognizes that students may think about the problem differently than he does and that he needs to spend the time to understand their perspective. It can also be assumed from his comments that Andy recognizes that students are thinking about the problems differently from each other and that it is not enough to simply understand one student's view. Andy focuses his first article report on Redish's mental models perspective (Redish, 1994) and Trowbridge's description of questioning (L. W. Trowbridge et al., 2000). While he talks mostly about the importance the mental model perspective places on recognizing students' prior ideas, he also states that this perspective stresses the individuality of students. As he explains, "The most important point that both authors make is that every student is different and unique. It is vital to keep this important point in mind when asking students questions" (Andy, AR1, 42 – 44). While Andy is talking about the articles in this comment, he does state that recognizing the individuality of students is not just something that is important to these authors' points. He states that the individuality of students is something that all teachers need to remember when they are working with students and particularly when they are asking questions. In his end of the semester interview Andy twice

references students individuality and its effect on teaching as one of the main reasons he enjoys teaching. When asked what aspects of his LA experience went well, he responds,

> I mean I enjoyed working with students and it was always interesting to see the concept from their perspective, 'cause I tried to do that. So I would be able to explain it to them. And it was cool seeing what different kinds of questions could do. Like, in order for me to get information about what or how they're doing or in order for them to build on it, talk about it more. To discuss with them and some points, it was a challenge because I'd have to sit there and then everybody's different so some people would get the concept if I explained it one way, but other's wouldn't so I would have to think of a new way to explain it that I hadn't done before if I had tried the techniques. (Andy, post, 10 – 19).

In this excerpt Andy now explicitly states that students have their own unique understanding of the content and the problem and that he needs to understand each students' perspective. Andy also finds that students differ in how they respond to questions. He doesn't just mean that students give different answers to his questions but that the questions trigger them to think about different things and lead them down different paths. While Andy does not talk about student differences in his reflections, his comments in his end of the semester interview suggest that his model of formative assessment does include this third element of the generalized model. Andy recognizes that students have different understandings of the content and the problems and that these differences need to be understood.

Adaptive Teaching

While Andy talks extensively about wanting students to construct their own explanations and he describes the importance of recognizing students' prior experiences, he does not talk about how these ideas influence his teaching for much of the semester. It isn't until the end of the

semester that Andy talks explicitly about adapting his questions to specific students – the fourth element in the generalized model. Andy mentions this first in the excerpt described above when he mentions how he would have to find different explanations for different students based on their unique ways of understanding the problem. Andy mentions this idea again when he describes how he improved his questioning over the course of the semester,

> But what really helped was going to recitation and questioning because I'd see that kind of question helped 'em get the answer, that kind of question didn't help them get to the answer. What was interesting is, as the semester went on I kind of found which students, which recitation, which students, what kind of worked for each kind of students (Andy, post, 223 – 227).

Andy finds that the most effective way for him to learn to teach is to work with students and to notice what helps certain students and what isn't effective for certain students. As the semester continues, Andy comes to recognize which techniques are effective for which students and how he could more effectively help other students. At the end of the interview Andy indicates just how ingrained adaptive teaching is to his teaching style even though he does not talk explicitly about it frequently. When asked whether he was considering teaching as a career Andy explains how he saw teaching physics,

> . . . teaching something like physics is definitely challenging, because you have to, it's not just you understanding, you get other people to understand and a lot of times they don't see it the same way you see it. So, it's, sometimes it's like a puzzle, you're like ha after you get them to understand and how do I get them to understand. I tried that, I tried that it didn't work, so now I'll try this (Andy, post, 322 – 326).

For Andy, teaching is ultimately like solving a puzzle. He is constantly trying to figure out how to adjust his teaching to meet the needs of his students and checking in with his students to see if they understand the material yet.

Andy began the semester with a heavy emphasis on students' constructing their own understanding of physics. As the semester continued he began talking about the importance of understanding students' prior knowledge and of recognizing the individuality of each students' ideas and experiences. While it appeared to permeate his teaching for much of the semester, Andy did not talk explicitly about adapting his teaching to his students until the end of the semester.

Student/Teacher Relationships

At the beginning of the semester Andy only talks about the role of student/teacher relationships in teaching when he mentions his previous LA and when he describes what makes a bad teacher. He does not talk about student/teacher relationships when he describes the job of an LA or when he explains how he plans to help students. By the end of the semester, he does talk about the role relationships play in the job of an LA and how they can help his students learn. For Andy, having a relationship with his students helps to create a bond of trust that allows them to communicate. Not only does Andy talk about relationships in his interviews and writings, but he places an emphasis on these relationships in his weekly reflections. He is the only LA to provide specific examples of how he plans to strengthen his relationship with students. Andy does not talk about motivaton or authority as elements of student/teacher relationships. Andy's views on student/teacher relationships are summarized in Table 8. This table summarizes Andy's views on the elements of student/teacher relationships at various times in the semester. One cell is empty because Andy did not talk or write about the topic in that time frame.

Table 8. Summary of the Development of Andy's Views of Student/Teacher Relationships.

	Pre	Early	Mid	Late	Post
Approachable	Good teachers are friendly and willing to help		Makes a goal to get to know his students	Listening builds a bond of trust	• Good teachers are willing to help. •Drawing on student experiences makes physics fun.

At the beginning of the semester Andy mentions student/teacher relationships when talking about his own previous LA and good teachers in general. When talking about his own LA from the previous semester, Andy begins by describing him as friendly, "I thought my LA was good. He was friendly. He helped us with everything" (Andy, pre, 36 -37). While Andy does not explain why he thinks it was relevant to his learning that his LA was friendly, he does go into more detail when talking about what makes a bad teacher. Andy described a bad teacher as "giv[ing] off a cold feeling that you don't want to help anybody, that you don't want questions" (Andy, pre, 157 – 158). Here Andy is implying that good teachers are friendly which helps students to feel comfortable asking questions. This is a key aspect of the student/teacher relationship views. As the semester continues Andy constructs more explicit explanations for why student/teacher relationships are important for student learning. At the end of the semester, Andy describes a good teacher in very similar, if more detailed, terms to his explanation at the beginning of the semester,

> You need to show that you care that the students understand. And be friendly. You need to show that you're willing to help, not just that you're there to help just because it's your job. Just because, you know, it's Thursday morning and I don't want to be here to help but

> I'm here. You show that, you have a desire to help them. And want them to do well and then you're interested in how they're doing (Andy, post, 301 – 306).

During both interviews Andy explains that a good teacher needs to demonstrate to students that he is willing and eager to answer students and that he cares about his students. In his second article report Andy lays out how this caring leads students to be willing to ask questions –

> The aspect of caring that encompasses listening, understanding, and knowing students, are all important attributes of a good teacher. When a teacher listens to students, a bond of understanding is formed. This leads to mutual trust which in turn leads to improved communication that is not limited to the subject at hand. In this way the teacher knows what different students are feeling and are going through (Andy, AR2, 22 – 27).

In this excerpt Andy lays out a mechanistic model for the importance of student/teacher relationships. His model is similar to the generalized model of approachability, but differs in some key points. A diagram of Andy's model is shown in Figure 12. As with the generalized model, Andy begins with the teacher acting. For Andy, the key process is for the teacher to listen to students. He considers this to be the most relevant aspect of caring. His model then diverges from the generalized model to describe mutual states that are created by the student and the teacher. Where the generalized model has the teacher acting and the students responding, Andy's model has both the teacher and the students responding. When the teacher listens to the student they both come to trust each other and they create a bond based on understanding that comes from this shared trust. When the students and the teacher trust each other and understand each other they are able to communicate. Andy does not state it but it can be implied from his other statements, that the level of communication that is achieved allows students to learn.

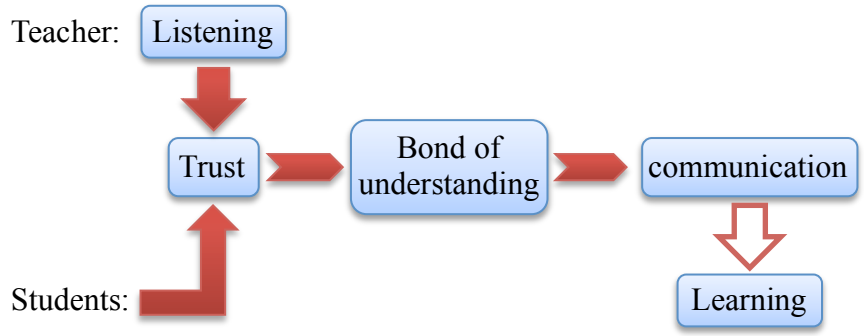

Figure 12. Andy's model of the role of approachability in learning.

Andy tends to talk about teacher/student relationships in two ways. When talking more generally about good teaching, as in the excerpts discussed above, Andy describes the importance of teachers caring for their students so that a bond of understanding is formed. When talking in specifics about his teaching, Andy focuses on engaging students so that he can tie their everyday lives into the physics content being studied. This type of engagement is separate from the generalized model, though it does not contradict the model. It is closely linked with the second element of the formative assessment model which values students' prior knowledge including their everyday experiences. Several weeks into the semester Andy begins focusing on building his relationships with his students. In his week five reflection he states,

> My goal for the week was trying to interact more with the students rather than just help them . . . I think that giving a random comment about anything helps break the ice. It seemed to me that the students were more comfortable asking me questions this week. So I think that I met these goals. (Andy, w05, 2).

Andy has a similar goal several weeks later,

> My goal for this week was to incorporate other topics of discussion to facilitate learning physics. For example
>
> Me: " what are you doing for spring break?"

Student: " I am going skiing"

Me: " have you thought of the forces and actions pairs that occur when u are skiing?"

Some random topic can arouse interest in the topic of study for the day. (Andy, wk11, 1). Andy works to get to know his students and their plans so that he can draw on their experiences when talking about physics. In his end of semester interview Andy explains that drawing on students' everyday experiences when he is explaining things makes physics more fun for students (Andy, post, 157 – 172). For Andy, relating to his students has a very specific purpose of being able to pull them into the physics topic. At the beginning of the semester, Andy does not talk about this aspect of student/teacher relationships, but as the semester goes on he begins to write of this as being an important part of his job. At the beginning of the semester, Andy is aware of the role that student/teacher relationships play in his general interactions with teachers, as indicated by his description of bad teachers as being cold and therefore apparently not open to student questions. Yet, Andy does not talk about the role relationships would play in his interactions with students or in his descriptions of the job of LAs. As the semester continues Andy still recognized the role that relationships play in general and is able to construct a detailed explanation of why they are important. He also begins to recognize the importance of relationships in his own interactions with students. Therefore building relationships with his students becomes a significant aspect of his teaching that he attempted to improve.

Jamie's Case Study

In many ways Jamie is the typical physics LA. She is the only physics major of the four LAs. She is a freshman and therefore the youngest of the LAs. Despite being young, she is already working in a plasma physics research lab. Her mother is a middle school science teacher and has often talked with her about the importance of having more qualified science teachers. Jamie is unsure whether she wants to pursue a career in physics research or in teaching. She really enjoys studying physics. She also wants to inspire people and sees teaching as a way to do this.

While there are many unique aspects to Jamie's views of teaching and learning, her ideas are also very similar to those of the other LAs and the generalized model which summarizes all of the LAs' ideas. By the end of the semester Jamie's views on teaching and learning tend to align with both generalized models. She places a strong emphasis on student teacher relationships in her views on teaching and learning. This is especially true for the approachability aspect of the generalized model. She is the only LA to emphasize the motivational aspect of relationships. While her final views on teaching and learning are closely aligned with the generalized model of formative assessment, her beginning view are very different. Finally, Jamie is the only LA to express frustration with her experience as an LA. Jamie's views on these issues are explained in the sections below.

Student/Teacher Relationships

Throughout the semester Jamie discusses all three aspects of student-teacher relationships – approachability, motivation, and authority. Jamie spends most of her time focusing on the aspect of approachability. At the beginning of the semester she emphasizes the importance of LAs being approachable to students. As the semester progresses she begins to add more detail to

this view by explaining why it is important to student learning that LAs are approachable. Jamie also talks throughout the semester about wanting to motivate students to enjoy physics and to want to learn physics. Jamie also talks about her concerns with off task students. While in the generalized model and the other case studies this concern is categorized as an aspect of LAs' authority, Jamie talks about addressing this problem as if it was an aspect of motivation. Jamie's views on these aspects and how her views change over the semester are shown in Table 9. This table summarizes Jamie's views on each of the three elements of student/teacher relationships at various times in the semester. Several cells are empty because Jamie did not talk or write about the topic in that time frame. These views are explained in detail in the following sections.

Table 9. Summary of the Development of Jamie's Views of Student/Teacher Relationships

	Pre	Early	Middle	Late	Post
Approachability	LAs are approachable & not intimidating		Students need to be comfortable to ask questions		
Motivation	·Wants students to enjoy physics ·Good teachers are inspirational	Wants to motivate & excite students			
Authority	·Worried about having student respect ·Worried about distracting groups			Worried about distracting groups	

Approachability

The element of student/teacher relationships that Jamie spends the most time talking and writing about is the importance of students seeing their teachers as approachable. Jamie talk extensively during the pre-semester interview about the importance of LAs being approachable to students. Jamie describes her previous LAs as being very approachable and willing to meet with students outside of class – "Well, they arranged time to meet with us, if you needed it and they were also very approachable" (Jamie, pre, 25 – 26). Jamie also compares LAs to TAs by saying that LAs are more approachable because TAs are somewhat threatening – "I find that sometimes the TAs are threatening a little bit because they're all grad students, but the LAs, the

cool thing about them is that they're undergraduates, just like you and they're right there and they can help you out" (Jamie, pre, 26 – 28). Jamie returns to the importance of approachability later in the interview:

> Interviewer: How do you think LAs help students learn?
>
> Jamie: As I said before they're much more approachable so I think that helps them learn because they feel more comfortable because one thing about them is they're not a professor, they're not a grad student/TA, they're kids just like you who just learned the material just like you so they feel more relatable and I think that helps us a lot more because I feel LAs have much more insight. Like, TAs, they went through it a long time ago, but LAs were just there and they can see how the students are doing and they can relate to that a whole lot more and I think that's why they're a lot better at teaching the students.
>
> Interviewer: What are the differences between an LA and a TA?
>
> Jamie: Approachability. I mean, sure a TA has more experience and they know more but with that they become less approachable, though they try and be friendly and everything. But LAs, though they only have experience in that class, they seem so much more approachable. I mean they're pretty much the same with all the teaching that they try to do in the tutorials and everything, but when you think about it, I think more students want to go to an LA or feel more comfortable going to an LA because there's more a sense of authority with TAs. You have to respect them more in the sense that it would almost be insulting if you asked the wrong thing. But with an LA I feel like you can ask them anything. You'll just be like, 'okay I know this is a stupid question but. . .' But with a TA

> it's kind of like asking a professor and you kind of feel a bit more uncomfortable with it (Jamie, pre, 95 – 115).

In the above excerpt Jamie explains the importance of LAs being approachable. She claims that if an LA is approachable then students will be comfortable and will therefore be able to learn. Part of the reason LAs are approachable is that they're able to relate to the students more since they are also undergraduates. The other part is that LAs are not intimidating unlike professors or TAs. Jamie feels that faculty and TAs are intimidating to students because students can't feel comfortable asking them any questions. She believes that students have to worry about what questions they ask faculty and TAs because it would be disrespectful to ask them a stupid question. On the other hand, since LAs are more like peers there is not such a concern with showing respect. The importance of approachability in student – teacher relationships is evident in Jamie's description of an LA as a "partner in the learning experience" (Jamie, wk02, 1). For Jamie, LAs are effective because they are more approachable than TAs or professors and can therefore be seen as partners instead of intimidating authority figures.

As the semester progresses Jamie becomes more explicit in her writings about the importance of students seeing teachers as being approachable. She brings this up several times in her writings and end of the year interview. She clarifies that it is important for teachers to be approachable so that students are comfortable and therefore willing to ask questions and get the help that they need to understand the material – "often times I realize it's the ones that don't talk that are having the most trouble. I want them to be comfortable with asking for help and make sure they understand the material" (Jamie, wk08, 1) and

> You need to try to get to know them and try to help them the best you can and make them comfortable, so if they're not really comfortable with you they're not going to admit if

they're having trouble or anything or they're not going to ask for your help (Jamie, post, 7 – 10).

The importance of making students comfortable is the theme of Jamie's second article report –

> Both of these articles are related because they include personable aspects to teaching. They emphasize the importance of getting to know the students rather than just lecturing them. By doing this you create a much more comfortable atmosphere for the students which allow them to be more likely to ask questions and benefit more from their learning experience (Jamie, AR2, 23 – 27).

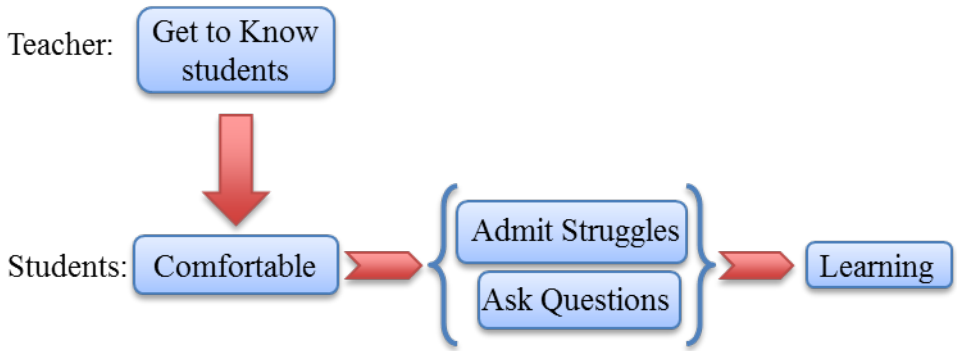

Figure 13. Jamie's model of the role of approachability in learning.

Figure 13 depicts Jamie's views on the importance of approachability in student-teacher relationships that she describes in the above excerpts. According to this view, teachers need to get to know their students so that students feel comfortable. Once a student is comfortable, they will be willing to admit when they are struggling and ask for help or ask questions. When a student is willing to ask for help, then they will be able to learn.

Jamie also explains how the LA experience has helped her redefine what it means to care for students in her final paper,

> After my experience in this classroom I have learned how to actually care about the students and focus on what is causing the difficulty they seem to be having. I pay

attention to the mental models they have developed about a subject and help them to adjust these preconceptions to bridge to what I want them to learn (Jamie, final, 14 -17).

Jamie is not claiming that she previously did not care about students. She is explaining that her new understanding of how people learn allows her to take steps that effectively help students therefore allowing her to act on her caring for students. These steps include focusing on where each student is struggling, eliciting student ideas, and using these ideas to help students learn. In her description of how to care for students, Jamie is referring to her view of formative assessment that will be described in the next section.

Motivation

The second element of student-teacher relationships that Jamie discusses throughout the semester is motivation. Jamie feels that an important part of her job as an LA is to motivate students to want to learn physics. When asked what she would do differently from the way things were done when she was a student, Jamie says that she wants to find a way to deal with groups who are distracted and off task during tutorials. Her main interpretation of these students' behavior is that these students are not enjoying physics and she hates to see people not enjoy a topic she loves so much (Jamie, pre, 143 – 150). She returns to this idea at the end of the interview when describing her favorite teacher, her high school chemistry teacher,

> He was really fun. And he was a huge inspiration to go into any type of science because he was just so devoted to it himself, you know. Like, he loved it so much, and he was just having so much fun in the class even if the students were just staring at him blankly, he was always have a smile on his face and he was just a really good teacher. I wouldn't mind being like him (Jamie, pre, 158 – 162).

Jamie is inspired by her teachers' devotion to and love of science, which she finds contagious. She therefore hopes to model a love of physics for her students in expectation that this will lead them to develop a love of physics too. Jamie is the only one of the four LAs to talk about inspiring her students or to describe good teachers as inspiring a love of the subject. Jamie returns to this topic several times during the semester. She talks about helping students to become more motivated to work on tutorials (Jamie, wk05, 4; Jamie, wk11, 1) and more excited about physics (Jamie, wk06, 3). For Jamie, this is an important part of why she became an LA (Jamie, wk05, 4), what she considers to be good teaching, and one of the main reasons she is considering a career in teaching (Jamie, post, 355 – 374).

Authority

Jamie also briefly mentioned issues of authority during her first semester. This element of of student/teacher relationships is the least emphasized of the three in Jamie's writings and interviews. At the beginning of the semester she is concerned that it will be awkward for her, as a freshman, to be teaching seniors. She worried that the upperclassmen would not listen to her (Jamie, pre, 214 – 219). She also mentions wanting to better control distracting groups compared to her section of tutorials the previous semester. The other LAs respond to this concern by using their authority to keep students on task. This is not Jamie's response. As mentioned earlier Jamie plans to address this problem by inspiring her students to love physics. She believes that if students love physics then they will stay focused in class. Jamie expresses concerns with the amount of distractions in the classroom again toward the end of the semester when asked what she is still working on (Jamie, wk11, 4). Yet in an earlier question that week, she states that one of her goals for her students is motivational and that she is trying to motivate her students by being energetic (Jamie, wk11, 1). Once again Jamie intends to address classroom distractions by

motivating students. Jamie is choosing to address the problem using a motivation-focused solution where other LAs are choosing an authority-focused solution.

Formative Assessment

Jamie's views of formative assessment are unique because she begins the semester with a model of student learning that is very different from the model she develops over the course of the semester. Unlike some of the other LAs, Jamie does not begin the semester talking about the importance of students' constructing their own understanding. She does start writing about this idea fairly early in the semester, though. She also quickly begins to talk about the importance of students' prior knowledge. While Jamie talks frequently about using students' prior knowledge as building blocks toward a correct understanding of physics concepts, she does not always use this type of language. Occasionally, she talks in terms of students' ideas as theories that tend to get in the way of students learning the correct concepts. Jamie occasionally talks about the variety in students' ideas in a way that demonstrates the value she places on the individuality of students' thinking. More often, though, she tends to talk about students ideas in terms of how they compare to her ideas. For instance, they either align with her ideas or they are unusual ideas that don't align with how she sees the problem. Finally, partway through the semester Jamie begins talking about the importance of building on students' ideas and adapting the teaching strategies she uses to do this based on the individual students. Her comments about this type of teaching closely align with the concept of formative assessment. Jamie's ideas are summarized in Table 10. This table summarizes Jamie's views on each of the four elements of formative assessment at various times in the semester. Several cells are empty because Jamie did not talk or write about the topic during that time frame. These ideas are also expanded upon in the sections below.

Table 10. Summary of the Development of Jamie's Views of Formative Assessment

	Pre	Early	Mid	Late	Post
Construction	Students learn by collecting tools	Help students discover concepts to apply later	Guide students to understanding the process and the content		
Prior Knowledge		Students apply P.K. to understand P.K. are building blocks P.K. are theories that can get in the way	Need to understand students' P.K.		
Individuality		Variety in students' ideas	Some students see things different than her		
Adaptability			Observe and build on students' ideas. Then adjust teaching to the student.		

Construction

Jamie's early statements related to how people learn do not align with the idea that students construct their knowledge. Yet it is unclear from these statements alone how Jamie thinks people learn. Later in the semester, after she appears to have adopted a view of student learning similar to construction, Jamie talks about how she used to think that people learned. Therefore the following explanation draws on statements Jamie made later in the semester to explain her original view of how people learn and to interpret her early statements about how people learn.

Jamie begins the semester with a view of student learning that is based on accumulating problem solutions. Jamie believes that a student understands a physics concept if they can solve a physics problem by remembering a similar situation from the past and then applying that solution to the new problem - "I've always thought that people learn by using applications to expand their understanding of a situation" (Jamie, wk06, 4). This means students need to accumulate enough things that they can always find a similar situation to apply to whatever new problem they are facing. These things could be information from lecture, example problems, previously solved

problems, etc. Students don't necessarily need to fully experience or comprehend these things; they just need to store the information so they can pull it out later. Therefore, as an LA, Jamie is focused on helping students get the correct answer to the problems, as she articulated later in the semester - "The first couple of weeks I focused on helping the students get the right answer rather than helping them understand their answer" (Jamie, wk08, 1). While Jamie does not explicitly talk about this view of learning at the beginning of the semester, her later descriptions of this view are helpful in interpreting her early references to how students learn. At the beginning of the semester, Jamie states that she would help struggling students by,

> I would first try and relate it to other topics before. . . because everything in physics relates. So you go through it and be like, 'hey, okay what do you guys know', and talk to them about all the stuff they've already learned and see if they can relate it and if they still have trouble with that I would help create another problem, a similar problem and help walk them through that, and with that I think that would help a whole lot (Jamie, pre, 119 -124).

To address this hypothetical situation, Jamie begins by asking students to review the previous content of the course to find information that will be useful to the problem. In light of her later descriptions of her early model Jamie is helping the students look for concepts or similar problems that they can apply to the current question. If the students are unable to find any applicable information, then Jamie creates a new problem for them. She then walks them through how to solve the new problem. According her model, this new problem would then be added to students' arsenal of solved problems that they could then apply to a new problem. The techniques that Jamie describes above involve the LA taking a very active and central role in the interaction. While the students in this situation are likely to be taking a more active role than they

would during a lecture, the LA is doing most of the mental work. This is different than the role of the LA envisioned by the other LAs. In most models the LA acts as a facilitator who elicits and organizes students' ideas, while the students are responsible for most of the mental work or concept creation.

Jamie's original understanding of how people learn can also be understood in terms of a tool box. Jamie views student learning as collecting a bunch of tools in their tool box. The tools represent all of the things they can use to solve a problem such as facts from lecture, worked examples from the book, and previously solved problems. When students are confronted with a new problem they rummage around in their tool box until they find a tool that will be useful and they match it to the current problem. The main difference between Jamie's original view and her eventual model of formative assessment is that Jamie appears to think that she can give students tools for their tool box. For instance, when the struggling students are unable to come up with an appropriate tool for solving the new problem, she gives them a new tool in the form of another problem that she walks them through. According to her final model, students cannot be given a new tool by the instructor, they need to build their own tools and if they do not have a useful tool already, then they can to find ways to modify their current tools.

As the semester continues Jamie's views of teaching evolve to incorporate concepts from the LA seminar into her understanding of how people learn. In the first weekly reflection she states,

> Being a learning assistant means you help the students explore a subject so that they may discover the concepts that surround science and mathematics. You help them form a basis of understanding so that they may successfully solve similar problems on their own, (Jamie, wk02, 1).

In this excerpt, Jamie is referring to the construct of the construction of knowledge when she talks about helping students "explore a subject", "discover the concepts", and "form a basis of understanding". All of these phrases refer to the importance of having students construct their own knowledge. While Jamie describes a theoretical perspective on learning that is moving toward her eventual model of formative assessment, she is still referencing the ideas of her original implicit model of learning. This is seen in her focus at the end of the excerpt on helping students "solve similar problems on their own". This statement refers back to her early theoretical perspective on learning that emphases helping students develop a large collection of solved problems which they will then apply to future problems.

As the semester continues Jamie's model continues to develop. During her mid-semester reflection, Jamie talks about this change in her thinking,

> My teaching and thinking has changed a lot due to this class. . . . The first couple of weeks I focused on helping the students get the right answer rather than helping them understand their answer. As the weeks went by I tried to become better in recognizing what the individuals were getting hung up on and helping walk them through it. I began to help them understand rather than meet the goal (Jamie, wk08, 1).

Now Jamie is focused not just on helping students to solve that problem or to solve similar problems but on helping them understand the broader concept. This change in her goals reflects a change in her understanding of how students learn. During the end of semester interview, Jamie expands on this idea to explain why it was important for LAs to help students learn concepts rather than just give them answers or even to focus on them finding the answer.

> The job of an LA is you know, of course, it's in the title, we assist them in learning, but I think it's a bit more than that. I mean it's being a teacher but it sounds simplistic at first

> but when you really go into it it's all of those aspects, getting to know them, helping them through, not step by step through a problem but giving them the right thought process, you know, so it doesn't matter if they get it done it just matters if they learn the process as long as they get some benefit out of it, because getting the right answer often doesn't benefit anyone. . . . that's what being an LA is, is kind of being that little step to helping them understand it because it doesn't seem like the teachers are willing to do that sometimes, and I think that's what our job is (Jamie, post, 114 – 132).

Jamie is now talking about the importance of having students develop their own understanding of the concepts. She feels it is important that this emphasis on the concepts is not eclipsed by a focus on getting the right answer. Jamie claims that courses tend to focus too much on the answers to problems instead of on the development of content.

Jamie repeats her idea for how LAs help students at the end of the semester, when she was asked again to explain the job of an LA now that she had a semester's worth of experience. She states that "My job as an LA is to help the students learn. I give them the tools and the opportunity to learn and guide them through" (Jamie, wk14, 5). As she stated at the beginning of the semester, the LA helps guide students through the material. Jamie explains several times throughout the semester that she feels LAs should help students discover physics concepts rather than just telling them answers because this type of learning allows them to benefit from the process not just the answer.

Jamie's views of how people learn can also be seen in the strategies she describes using to help students learn. Jamie's focus on questioning demonstrates her desire to have students construct their understanding. Starting early in the semester, Jamie talks explicitly about using questions to help students learn the material, "My main goal for this week was to try to give the

students multiple ways of thinking of the problems that they faced, by asking them questions that would prompt discussion" (Jamie, wk03, 2). During the end of semester interview Jamie also describes in more detail how she uses questions to help students develop their understanding. When asked why she uses questions, she states,

> Because it's important to get them thinking. I mean, you don't want to just answer their own questions and just say yes or no. You want to be like, "Okay, tell us what you think. Tell me why that is." And then be like, "okay, so if that's what happens, what's the consequence?" "If that were the case, what else would be true." Those are the type of questions I try to ask. And I try and get them thinking like that. (Jamie, post, 192 – 197).

Therefore Jamie uses questions to prompt students to discuss their thinking and to think about it more deeply.

Prior Knowledge

In the first half of the semester, Jamie talks extensively about the importance of recognizing students' ideas and building on these ideas. She first mentions students' prior knowledge in her week four reflections, "I noticed that they applied their previous knowledge in order to understand and explain the problems better. They applied previous knowledge of geometry and thought about the attribute of a circle" (Jamie wk04, 1). In this excerpt Jamie refers to students' understanding of a circle, which they developed in previous geometry courses, as a type of prior knowledge they are using in the tutorials. As Jamie explains, the students are using this prior knowledge to help them work through the physics problems. Jamie is the only LA to refer to knowledge from previous courses as a type of prior knowledge. The other LAs tend to refer to students' personal experiences when talking about types of prior knowledge. Jamie mentions prior knowledge again next week when asked to explain what she understands

about formative assessment, “What stuck is the understanding to not dismiss students ‘misconceptions’, but to actually use them as building blocks to refine their thinking” (Jamie, wk05, 1). Now Jamie is explicitly referring to the idea that students’ prior ideas are useful for helping students understand physics concepts. The next week Jamie explains her theoretical perspective on learning by saying,

> I’ve always thought that people learn by using applications to expand understanding of a situation. Now my theory has expanded to include the idea of each student having their own preconceptions about a subject. These preconceptions are to be observed and built upon (Jamie, wk06, 4).

In this excerpt Jamie reiterates her view that students’ prior knowledge should be used to help them learn new material and indicates that this is a new idea for her. In her first article report, Jamie explains how she has applied this new idea about the importance of students’ preconceptions to her teaching. She begins by describing a situation where she was struggling to help a student even though she felt he already understood the topic and was only struggling to put all of his ideas together,

> . . . then Redish’s idea of a “mental model” came floating into my head as I suddenly realized we were going about the problem my way. Everything was perfectly clear to me, but the student’s ideas on the matter were far different than mine. Realizing this, I then took the time to clarify what the student understood. I sat and listened to their explanation of what was going on, with no sudden interjections and finally realized the key point that we had been getting stuck up on. Since then, I’ve been sure to take more time to listen to the students and take each problem from their point of view. (Jamie, AR1, 46 – 52).

Jamie returns to this point again in her week seven reflection, "Asking the students for more of their view of a topic helped a lot. It helped give us something to go off of. I'm trying to learn more and more about the preconceptions the kids have in order to help them as much as I can" (Jamie, wk07, 2). In both of these statements Jamie indicates that she has begun to focus her teaching on first understanding a student's ideas before she works with the student to shape his understanding. Jamie works to understand students' ideas by asking them questions and by listening carefully to their explanations.

While Jamie tends to talk about building upon student ideas in her teaching, this is not always the case. Sometimes she refers to student ideas as things that can get in the way. For instance, in the excerpt below Jamie describes how students' previous knowledge about the acceleration vector for an object traveling in a circle prevents them from finding the acceleration vector of an object traveling along an oval path.

> The second problem the students were having trouble with was involving the direction of the acceleration along the curve. Due to previously being told that the acceleration always points to the center of a circle, most students just assumed that was true of the oval, not realizing that would affect the velocity . . . Most students understood that the acceleration can't have a component in the same direction as velocity, but some of the other students were baffled by the sudden challenge of their "acceleration is always towards the center" theory (Jamie, wk04, 2).

Jamie uses this language several weeks later when she once again refers to student ideas as getting in the way of their learning.

> The students struggled with the concept of a spool on a frictionless surface moving the same speed of a block being pulled with the same force. I tried to enforce the basic

> concepts F=ma, and help them to understand how it worked. It was really difficult with the students being so set on their ideas about the force being transferred into torque (Jamie, wk12, 2).

In this excerpt Jamie describes students as "being set on" an idea that was getting in the way of their learning. She then describes herself as needing to "enforce" a concept with the students. Jamie's language here is adversarial unlike her typical descriptions of helping people learn. Despite occasionally talking about student ideas as hindering their learning, Jamie tends to view student ideas positively and as resources for their learning.

In her final paper she compares her position as an LA to her previous work tutoring friends. She describes learning to listen to students' ideas as the main difference in these two experiences,

> In my previous tutoring experience, I did not put much consideration into the student's priorities. I didn't pay attention to the types of problems that they were having trouble with. I had only focused on getting them to the right answer. Previously, I mostly helped students with mathematics. In most cases I would just give the students a shortcut to the right answer and not allow them to think through the process themselves.
>
> After my experience in this classroom I have learned how to actually care about the students and focus on what is causing the difficulty they seem to be having. I pay attention to the mental models they have developed about a subject and help them to adjust these preconceptions to bridge to what I want them to learn.
>
> I also recognize ways they learn better and try to find their primary intelligence. This helps me to assist them in learning the concept. By figuring out their primary

> intelligences it is much easier to relate the concepts to the students and make the material feel much less intimidating (Jamie, final, 9 – 21).

Jamie claims that one of the things that made the LA experience very different from her tutoring experience is that she has learned to focus on and care about students' difficulties and their primary intelligence. She claims this focus has made her a better teacher. In her previous teaching experiences, Jamie focused on helping students get to the correct answer. She usually did this by showing them a short cut to the right answer. In her LA experience, Jamie learned to help students by helping them go through the thought process starting from their mental model. Jamie learned to focus her attention on understanding the students' mental model and figuring out where they were struggling. In this excerpt Jamie also mentions another type of prior knowledge. Jamie describes students' primary intelligence as an important part of each student that she needs to be aware of when she is teaching. Jamie states that taking students primary intelligence into account will allow her to approach the material in a way that is more relatable and less intimidating to students.

As the above excerpts demonstrate, as the semester progressed, Jamie began to talk about the importance of learning about students' ideas and building off of these ideas. She also learned to use questions not just as a way to instruct students, but as a way of eliciting students' ideas so that she could fully understand what a student was thinking. Jamie also came to talk about the importance of listening to students. She recognized that she could only be helpful if she first listened and understood the students' point of view.

Individuality

Jamie did not talk much about the individuality of students' responses. The only time she mentions this explicitly was in her week four reflection when she states that, "The students had

great variety in how each of them look and go through the problems" (Jamie, wk04, 1), before going on to explain some of the conceptual ideas she saw during the tutorial. Later in the semester, Jamie makes several less explicit comments about having to use different methods to help some students. When talking about recognizing students' prior ideas, Jamie mentions that certain students did not respond to her typical ways of explaining the problem, "Sometimes when I was trying to help a student with something, I went about it the typical way I'd seen myself or other students do, but this lost a student a tad. After realizing this I tried to help clarify the confusion" (Jamie, wk07, 2). During her first article report, Jamie describes a situation where she couldn't understand why a student couldn't figure out the answer to a problem. She eventually realized that she was having the student work the problem based on her understanding of the situation, "Everything was perfectly clear to *me*, but that student's ideas on the matter were far different from mine. Realizing this, I then took the time to clarify what the student understood" (Jamie, AR1, 48 - 49). Once she recognized this she was able to much more effectively help the student. In both her second article report and her end of the semester interview, Jamie mentions struggling with a student who she describes as having a linguistic primary intelligence. She describes the problem as, "He and I were having difficulty articulating our points on many topics due to his expertise in semantics, which caused him confusion if my speech was slightly off. He took all my words literally and didn't think about the topics" (Jamie, AR2, 38 – 41). She then describes how by recognizing this difference she was able to improve the way she worked with this student. Toward the beginning of the semester Jamie mentions the wide variety of ideas she sees among her students. This aligns with the idea that students have unique ideas that are valuable for their learning. Yet, her later implicit descriptions of student individuality diverge from this view. These later excerpts tend to create a dichotomy of ideas. Her ideas are on one

side of the dichotomy along with all the other students who understand the situation in the same way that she does and who are helped using the same instructional methods that relate to how she usually thinks about the problem. On the other side of the dichotomy is the usually lone student who doesn't think about the problem in the same way. While Jamie works to find ways to help these students, her descriptions suggest that she thinks of them as unusual cases and possibly not normal. So while she recognizes and is willing to work with students' unique ideas, she does not value or expect these differences. This differs from the other LAs' emphasis on the uniqueness and value of each students' understanding and the recognition that all students are different.

Adaptive Teaching

Jamie talks about adaptive teaching as a direct consequence of the other aspects of her understanding of how people learn. In her week six reflection Jamie explains how her view of learning has already changed to include the need to adapt her teaching to her students,

> I've always thought that people learn by using applications to expand understanding of a situation. Now my theory has expanded to include the idea of each student having their own preconceptions about a subject. These preconceptions are to be observed and built upon. Teachers cannot simply lecture, they must pay attention to their students and help them learn. They must be prepared if a student doesn't meet the goals and help them to develop the skills in order to reach the goal (Jamie, wk06, 4).

Originally Jamie thought it was enough to expose students to as many problems and applications as possible. This meant that teachers didn't need to necessarily pay a lot of attention to students since their focus could be mostly on the content. Now that Jamie recognizes that students enter the classroom with their own preconceptions about the content and that teachers can use these

conceptions to help students develop an understanding of the material, Jamie's understanding of teaching has changed. Now, teachers need to focus on the students and adjust their teaching to the specific pre-conceptions of each student. The teacher must adjust not only how they teach the material but also what they teach. If a student is missing skills that are necessary to reach the goal the instructor has set, then the teacher must work with the student to develop those skills. When Jamie describes how her experience as an LA was different from her experience as a high school tutor, she refers to this concept of adaptive teaching,

> After my experience in this classroom I have learned how to actually care about the students and focus on what is causing the difficulty they seem to be having. I pay attention to the mental models they have developed about a subject and help them to adjust these preconceptions to bridge to what I want them to learn.
>
> I also recognize ways they learn better and try to find their primary intelligence. This helps me to assist them in learning the concept. By figuring out their primary intelligences it is much easier to relate the concepts to the students and make the material feel much less intimidating (Jamie, final, 14 – 21).

In this excerpt, Jamie discusses how the LA experience has taught her to help students by adapting her teaching to the student. Jamie describes how she has learned to pay attention to students' ideas and then work with students to bridge from these ideas to the scientific concepts. She has also learned to work with students' primary intelligence, which is the aspect of a student that LAs most often refer to when discussing the individuality of students.

At the end of the semester, Jamie relates this type of teaching to her specific teaching experience. As mentioned previously, Jamie struggled at times with students who understood and talked about the content differently from her. At the beginning of the semester, this made both

Jamie and the students incredibly frustrated. As the semester continued, though, Jamie learned to notice the way students talked and to adapt her teaching to their understanding,

> I think eventually we got through it, it's just sometimes the kids would get frustrated, I would notice because they didn't understand the lingo and would try and you know hit their type, er fit their kind of discussion, and sometimes it worked and sometimes it didn't but it got much better by the end of the semester. Like, that, I had trouble with that the first month but after that I'd sit down with the kids and be like - okay, so tell me what you think about this and I would try and get a feel for like how they think about it and try and fit that in more with how I try and help them. (Jamie, post, 42 – 49).

Jamie learned to begin her interactions with students by stepping back and listening to them first. By listening to the students Jamie was able to recognize how they were speaking and how they understood the problem. This allowed Jamie to adapt her teaching to her students instead of basing her explanations on her own understanding.

Dissatisfaction

Jamie is also the only LA to express dissatisfaction with her semester and to express a disinclination to be an LA again. She becomes slightly emotional as she describes the frustration of watching students with whom she has worked closely do poorly on the exams. This leads her to question the efficacy of the LA model and the tutorial activities,

> To some extent the LAing portion I feel definitely helps the students, but to another extent, I don't feel it is that helpful. Because I feel more one-on-one time is beneficial with them, and I found out that's how I got to know the students and that's how they felt more comfortable and that's how I help them more. Like, some cases I'd set up time to meet with them outside of class and I'd help them out then because, you know the

> tutorials, just weren't doing it. So, I feel like, maybe if they were run differently, I would do it, but in the case of how their run right now I, I don't know, I can understand with the statistics that we have that we are helping the students, but I wonder if it's enough. Because I do see the correlation, but I feel like, when I see the students and when I see them failing every test, I don't think we're doing anything. Like, I've seen so many students that I've gotten to know and that I've helped through the tutorials -- they get it, they totally understand it, everything that I ask them, they got it, but when it comes to a test, they just don't get it. And that's why I think the tutorials or being an LA should be differently done, because we're not actually doing anything, for the students it seems, because I've just seen so many of them, come back and be so disappointed in themselves, regardless of how good they are. yeah. (Jamie, post, 329 – 344).

While Jamie recognizes that the tutorials may be helping students somewhat, she states that a tutoring method is more effective and needs to be adopted. Jamie's frustration and expressions of failure indicate one of the possible pitfalls of creating relationships with students, especially when the bonds become as tight as those Jamie formed. She is also overlooking the impracticality of one-on-one tutoring for all students and the many successes she has had over the semester.

Gen's Case Study

Of all the LAs, Gen has the most extensive teaching experience. He previously worked at a foreign language school as a teaching assistant to the upper elementary math teacher. Gen wanted to be an LA because he enjoyed helping people, he thought it would help him learn the material, and he thought it would make him a better student. Gen was a first year biochemical engineering major, but he was a junior according to college credits. After graduating, Gen intended to attend medical school and become a family physician.

Of all the LAs, Gen was the most vocal about his struggles with teaching and with his students. Gen approached the education seminar instructors several times about issues he was having with the specific students and frequently used the weekly reflections to ask the instructors questions.

Over the course of the semester Gen develops a model of formative assessment that is aligned with the generalized model of formative assessment. Throughout the semester he recognizes the importance of having students construct their own understanding. He states that students need to actively and thoughtfully work through things themselves in order to have a deep understanding. His views on students' prior knowledge change over the semester as he begins by talking about focusing on what students' don't know and then moves to talking about students' using their prior knowledge to solve problems. Gen begins focusing on students' individuality very early in the semester and recognizes quickly recognizes the implications of this for his teaching. Yet, toward the end of the semester he starts talking about wanting to find an explanation that will work for everyone – an idea that appears to contradict his view of students' individuality. Gen also talks about student/teacher relationships throughout the semester. Unlike the other LAs though, Gen's emphasis is on his authority as an LA. One reason

for this difference appears to be the difference in how Gen views his job as an LA compared to the way the other LAs perceive their role. Gen's views on teaching and learning are explained in more depth in the sections below.

Formative Assessment

Gen's views on formative assessment are summarized in Table 11. This table summarizes Gen's views on each of the four elements of formative assessment at various times in the semester. Several cells are empty because Gen did not talk or write about the topic in that time frame.

Table 11. Summary of the Development of Gen's Views of Formative Assessment.

	Pre	Early	Mid	Late	Post
Construction	Students must think actively to build their own deep understanding. Teachers facilitate learning				
Prior Knowledge	Focus on what students don't know	Prior Knowledge is not academic knowledge	Students can use prior knowledge to solve problems		
Individuality		Different explanations work for different students	Everyone has a different starting point	Looking for a single effective explanation	Everyone has a different starting point
Adaptive Teaching			Need to change teaching to fit the student.		Need to change teaching to fit the student.

Construction.

Gen does not talk extensively about helping students to construct their own understanding in his weekly reflections, but he does go into detail about it in his other written assignments and in his interviews. At the beginning of the semester he feels that guiding students is the purpose both of LAs and of the tutorials,

> The purpose of the tutorial is to kind of like explore the idea of physics. If we, like even if it's a small thing, like even if it's a small question, you actually have to find, like, signs that would lead you to the answer. So, if I just blatantly say hey this question is going to use this thing and that thing, then they're not thinking about what they know of that would lead them to the answer, it's going to be like, "hey do this, do this." It's going to be, like, guided. If it's guided, if it's something guided, then why don't we have another lecture. Because like I said, 'okay for this tutorial do this, this, and this. Okay, I'll give you 15 seconds to do it. Okay, are you done? Alright, let's go to the next question.' That would be the same thing. So, like, the point about the tutorial is we actually have to let them navigate and let them think of what they're doing. (Gen, pre, 238 – 248).

He reiterates his understanding of the job of an LA during the first reflection.

> To be an LA, it means to become someone who facilitates learning of the students by themselves. In order to facilitate learning of the students, my job as an LA is to guide the students enough that they understand the material by themselves. To fulfill my job, I hope to guide them enough that they understand the material and have fun along the way. Teaching is to guide the students in a direction that leads to the full understanding of the material. (Gen, wk02, 1).

Gen also feels that guiding students to develop their own understanding is an important characteristic of good teaching,

> A good teacher doesn't teach like they actually facilitate learning, so teaching is something like reading out of the book, asking them to take notes, that would be teaching as well, but facilitating knowledge is having the students understand why, . . . So like

> hands on basis, facilitating knowledge, I think that's the most important part about teaching. (Gen, pre, 291 – 300).

For Gen, LAs and good teachers guide students through the problems and encourage the students to actively think about the material. It is important for him that students are actively thinking about the problem instead of just blindly following steps provided by the teacher or just listening to the teacher describe the solution to the problem. During the beginning of the semester interview, Gen reiterates the importance of students actively thinking about how to work through the problem when he explains why he finds tutorials to be more helpful than lectures, which he did not attend,

> Like, if you're sitting in a big lecture hall it's just a one-way road, so you don't, you're not able to say, 'hey, wait, why don't, why is this going on' to the professor. You can't do that. You can actually ask questions for them to answer but you can't, divulge your thought to the teacher and say, 'why isn't this right.' So it's kind of like that, having someone to interact with is a big thing for me (Gen, pre, 146 -151).

For Gen, students need to be thinking actively about a problem and why the given solution works. It is therefore important for him to be able to bounce ideas off of students and LAs so that he understands the correct answer completely. Gen refers again to the importance he places on making sure that students have a complete understanding of the correct solution when he states, "I've been asking questions on each step so that they have a strong reasoning behind all of the answers that they have answered" (Gen, wk05, 3). For Gen, it is important that students' understanding is complete and well-reasoned. This is different from Leah and Andy's focus on making sure that students have developed their own understanding.

At the end of the semester Gen explains how his understanding of teaching has changed. He describes his original view of teaching as focused on making sure that students learned the canonical or textbook solution path. As the semester goes on Gen begins to recognize the value of the process that students use to construct their answers. In his final paper Gen describes his beginning,

> Since I assumed that the job of an LA is to take the students to the correct understanding using the path that the textbook usually follows, I thought I needed to use closed questioning to guide the students step by step to the conclusion that the tutorial session was intending to reach. The second misconception that I had was my thought that equations and description of the situation would sufficiently teach the students the materials that is being covered. (Gen, final, 13 -18).

In the end of semester interview, Gen expands on his misconceptions of teaching and how his ideas have changed,

> So I first thought that it's just going to be teaching, like another teaching session, just telling them the right answer, guiding them to the right answer. But it's more than that. You actually have to make, like, rather than giving them the answer, making sure that they go through this thought process to say, to achieve the end, maybe the end result or somewhere close to it, maybe that thought process is beneficial even . . . . Just having them explaining it will be a beneficial thing because they have to incorporate other things and that's the highest learning that you can do. So, it's like. I think it's just promoting different kinds of learning than I think the job of an LA is to promoting different way of learning rather than sitting through a lecture and making sure that the students enjoy it while they're at it. (Gen, post, 78 -101).

Gen expresses the same opinion on not giving students answers during his week 13 reflection, “It is important to not always just tell students the answers because the students will only memorize what I have said rather than understanding that thought process behind the question” (Gen, wk13, 2). By the end of the semester Gen has come to value the thought process that students follow to find their answers and having them construct their own process. At the end of the semester interview he explains how he uses questions to encourage this thought process,

> Well, there are pretty much two choices, right? Just telling them the answer, or three, telling them the answer, giving them hints, or questioning them to guide them in the right direction. Well, choice A is out of the question because, well, it's not completely, but I tried, I prefer not to using just telling them what they're doing because they'll be confused. And giving them hints I think that's somewhat a good way. But asking them questions is a different thing than just giving them hints because they have to think about so what kind of question, like, what is the answer, according to this that I learned from class, I bet this has to be the right answer but, there are different possibilities so there is that vagueness inherent to the question because you're not giving them the answer so they go through the thought process more rather than this is the right answer. (Gen, post, 147 – 157).

Gen recognizes that simply giving students the answer can leave them confused because they do not understand why that answer is correct and he has valued understanding why throughout the semester. Asking questions allows him to encourage students to go through the thought process themselves.

At the beginning of the semester Gen recognizes the importance of involving students in their learning process so that they have a complete understanding of the solution. At the end of

the semester though, he feels his original understanding assumed a style of teaching that was too prescriptive. He now wants students to take more ownership in thinking out how to solve the problem. Part of this change is based on his new understanding of the value of the process of learning and not just the final answer.

Prior Knowledge.

Gen begins talking about student ideas in the beginning of the semester interview. When asked how he would help a group of struggling students, Gen explains that his first step would be to figure out what the students have wrong,

> I'll ask them why they're stuck. So like, first I'm going to ask them why they're stuck. See kind of like, diagnostics. And then if I see that they're on like very close to the answer, then I would give them like that small hint that they were looking for like, just something like, use the second law of Newton, that's going to be the F=ma. So if they're lacking that part then I would just give them that small hint that would take them to the end. But if it's something like they're completely stuck stuck and they don't have a clue why, how to do it, then I would just like, try to make, let them go through that thought process of, 'okay, start from here, let's see what you have, then let's see what you know of that would use these numbers and like that would pertain to this actual situation.' (Gen, pre, 216 -225).

While Gen is talking about diagnosing students at the beginning the semester he is focused on what they don't know and assumes that they either need a small hint such as a formula they've forgotten or they need to start from the beginning. If the students are "completely stuck", as opposed to "very close to the answer", he will lead them through a plug and chug problem solving process by having them "see what you know of that would use these numbers", which means looking for formulas that fit the variable list. This is essentially the "get it or don't" view

explained in Otero and Nathan (2008) – either the students basically understand the concept being taught or they understand nothing and the instructor needs to begin from the beginning. This view sees no middle ground of understanding.

Gen first talks explicitly about prior knowledge in his week four reflection when he talks about questioning,

> The situation where I used the questioning technique was when they just thought about the question without visualizing nor using prior knowledge. During one of the tutorial section, the students were supposed to obtain the change in velocity vector of a ball between two points where one lays before it turns around and the another that has started to roll down. Rather than visualizing the situation, even with another example other than the one that is described, they just look at the vector and think of it numerically. (Gen, wk04, 2).

While this statement indicates that Gen recognizes that students can bring prior knowledge to physics situations to help them learn, he claims that students are not doing that in this situation. Gen is viewing the term prior knowledge as only applying to every day experiences and not to prior academic knowledge such as math. Therefore he is frustrated that students are thinking numerically instead of in terms of everyday experiences. Yet, earlier in the same reflection Gen describes a situation where students use numerical knowledge as prior knowledge,

> In this section, the students are supposed to understand that even though the change in velocity vector decreases as the two points on the ellipse gets closer, the direction of the change in velocity approaches 90 degrees and the magnitude of the acceleration does not approach zero. When they initially thought about the question, they thought that the magnitude will be zero because change in velocity is zero and the change in time is also

> zero; however, the students are forgetting the fact that they cannot divide by zero requiring a limit to obtain the magnitude. After I told them that it is mathematically impossible to divide another number by zero, everything connected and use their mathematical knowledge to understand the relationship between acceleration and magnitude of the change in velocity vector (Gen, wk04, 1).

Here Gen recognizes that students, after thinking about the problem, choose to apply a correct mathematical concept in an incorrect way. He therefore gives his students a hint, and they are able to correctly explain the concept. Therefore during his week four reflections, Gen does not *explicitly* recognize mathematical knowledge as prior knowledge that students can use to help them understand physics, yet earlier in the reflection he *implicitly* uses a prior knowledge perspective to describe students using math to understand their physics problem.

Several weeks later, Gen describes another situation from a prior knowledge perspective, this time using experience-based prior knowledge,

> Another situation where I have encountered students using their prior knowledge to formulate their own hypothesis is when the students assume that the force of the book exerting to the book that is lying below it has to be labeled as a weight force. Since the students knows that the force acting on the lower book is caused by the weight force of the top book, they assume that the force on the free body diagram of the lower book should be labeled as the weight force of the top book caused by the Earth. This situation illustrates how the students do not have empty vessels because rather than asking for the help from the TA or me, the students were able to create a hypothesis that satisfied all of the situational occurrences they have been observing in the real world. In situations where the students are taking a course that they have never taken before, the students can

> use their prior knowledge to formulate hypothesis that would fulfill their observations illustrating how the students do not start from an empty state (Gen, AR1, 38 – 50).

In this situation, Gen describes students creating, on the spot, an explanation based on their experiences.

Individuality.

While Gen does not talk a lot about students' prior knowledge he does talk extensively about their individuality. Gen is actually the first LA to begin talking about the differences he notices in how his students understand physics. While he talks frequently about differences in his students' thinking, toward the end of the semester he appears to contradict this view by wanting to find a universally effective explanation. At the beginning of the semester Gen talks about learning to notice the difference in how students' think. In his first reflection he notes,

> This week was a learning experience for me. I've learned that there are different ways of guiding someone to the right answer. Even though I know the answer and the concept behind a particular topic, the person asking the question does not understand why that holds true, and that person has a different way of understanding a certain topic. Therefore, Next time if someone asks me a question and they are about to leave with a puzzled look on their face I will try different ways to convey [to] them the message until that person can tell me what I was trying to tell them. (Gen, wk02, 5).

This statement appears to reveal a transmissionist view of learning – "to convey [to] them" and "can tell me what I was trying to tell them". Yet, it does demonstrate that Gen has become aware that his students will not understand physics in the same way that he understands it and that this disconnect may prevent him from being able to help his students. Several weeks later when asked what he learned from the lesson on Formative Assessment, Gen expands his view on

students' individuality, "Everyone comes from [a] different starting point; therefore we have to accept the different views and try to build upon it" (Gen, wk05, 1). The comment indicates that Gen realizes that his students not only differ in how they may understand the material, but are actually beginning the lesson with different views that can be leveraged in instruction. Gen expresses a similar idea in his first article report.

> The most important concept that I always have to keep in my mind is that everyone has a different starting point and has different ways of understanding the materials and growing upon their starting points. (Gen, AR1, 6 – 8).

Gen returns to this idea again in his mid-semester reflection, "I have learned that there are many teaching methods that exist. Since all students are starting at a different starting points, everyone has their own way of learning the same material" (Gen, wk08, 1). In both of these statements Gen is acknowledging that students all differ both in how the ideas they bring to a topic and in how they best learn the topic. Throughout the semester Gen also implicitly references the individuality of his students when he describes common student difficulties or ideas. In week four he mentions that "some of the people thinks that they are supposed to add the vectors . . ." (Gen, wk04, 2), in week six he mentions "the common ideas that I have seen among the students . . ." (Gen, wk06, 1) and in week seven he states that "some of the students noticed that there is a problem . . . (Gen, wk07, 1). These implicit references indicate that Gen is aware that while there may be common ideas among students, these do not represent every student's thinking.

Gen returns to the differences in students' ideas and the influence this has on how he teaches during his end of semester interview. When asked what he learned this semester Gen responds, "I learned that there's more to learning than getting the right answer and everyone starts from a different point" (Gen, post, 15 -17). This statement demonstrates a constructivist

perspective that acknowledges both the prior knowledge that students bring to their learning and the differences among students in this prior knowledge. Yet, earlier in this interview he expresses his ambivalence about helping students when they all came from different points. When asked how his semester went, Gen replies,

> Frustrating but fun. Like, I enjoyed it so much that I want to do it again. I say it's frustrating because it's hard to see, hard to make the students do one thing and because there are like 15, there are as many answers to one question as the students. You could ask someone a question and they'll give you a different answer from a person you asked a day before. So it was frustrating but fun. (Gen, post, 6 – 10).

Yet, by the end of the interview when he is asked if he is considering a career in teaching, he replies,

> I think I am. I enjoyed working with students. I had fun interacting with them as a whole. Just bouncing [ideas], seeing what they understand, seeing what their understanding is is fun. Because you could see, you could get ten responses from ten students, no matter what. So, it's like it's fun to see how many ways of describing a single concept [there are]. . . (Gen, post, 269 -273).

Gen's comments indicate that he remains focused on the variety of student ideas and the effect this had on his teaching. Yet he appears to be ambivalent about this effect, which he describes as both fun and frustrating. This ambivalence can be contrasted to Andy's more consistently positive description of teaching as "rewarding and challenging".

While Gen mentions the importance of acknowledging students' different ideas and ways of learning several throughout the semester, toward the send of the semester his reflections begin

to contradict this view. Instead he begins focusing on finding a single explanation that can help all students.

> I am still struggling on finding a single explanation that will work for the majority of the students. Some of the concepts that we are covering right now are challenging, and I have a way of understanding the material; however, that method is complex in the eyes of the students making them more confused with the material. I need to think of an explanation that might be better for the students during the LA/TA meeting for the week, and if the idea that I prepare does not work, I need to think of ways to explain the material on the fly and listen to the way the TA is explaining it and adapt it to my explanation. (Gen, wk12 makeup).

He states a similar opinion several weeks earlier, "something that seemed not to work is having different ways of explaining something to the students. Having or coming up with one simple explanation to use will be helpful in this situation" (Gen, wk10, 5). It is unclear how Gen reconciles this desire for a single explanation to help all students with his stated view that students start at different places and then learn differently. It is possible that this apparent contradiction is simply the result of Gen learning and he is therefore changing his ideas and attempting to reconcile his differing ideas. It is also possible that while Gen recognizes the different ideas that students bring to the learning situation his is unsure how to take advantage of these different ideas in his teaching and after struggling to implement the new teaching strategies that he is learning about, he is attempting to return to his old, seemingly more successful teaching strategies. Despite mentioning his search for a universal explanation in two of his late in the semester reflections, he does not mention this idea in any of his end of the semester writings (i.e. article report 2 or final).

Adaptive Teaching

As with Leah, Gen talks extensively about the need to adapt teaching strategies to specific students. He begins talking about this idea in his first article report,

> Regardless of the fact that the professor provides the same lecture to all of the students, not all students understand the materials in the same way creating a need of teachers changing their way of teaching depending on their students . . . Since there is can not be a single method that can be provided as a genuine form of teaching the material so that all of the students understand the material, I have to understand different way of explaining the material and accommodate different students differently (Gen, AR1, 51 – 71).

Because Gen recognizes that all students do not understand material in the same way, he sees the need for teachers to adapt to their students. Ultimately this expands the task Gen needs to do as an instructor. It is not enough for him to understand one way of explaining the material. He needs to understand multiple ways of explaining the material so that he can adapt to his students. Gen returns to this topic during his mid-semester reflection,

> I have learned that there are many teaching methods that exists. Since all students are starting at a different starting points, everyone has their own way of learning the same material; therefore, I need to change my way of teaching from student to student (Gen, wk08, 1).

Now, Gen not only recognizes differences in how his students understand the material but also in where they are coming from when they begin to learn the material. This means Gen must adjust his teaching to both what his students know, their prior ideas, and their ways of learning. Gen returns to this idea at the end of the semester when asked if he was considering teaching as a career,

> I enjoyed working with students. I had fun interacting with them as a whole. Just bouncing, seeing what they understand, seeing what their understanding is is fun. Because you could see, you could get ten responses from ten students, no matter what. So, it's like it's fun to see how many ways of describing a single concept is and seeing how they could be used to other, like how we could use that to explain it to another student is fun. And I enjoyed it so much that it made me think about it (Gen, post, 269 - 275).

As with Andy, Gen found the need to constantly adapt and adjust his teaching to his students to be what made teaching fun. For both of these LAs adaptive teaching made interacting with students intellectually fun and challenging and inspired them to consider careers in teaching.

Student/Teacher Relationships

Gen takes a very different view on student/teacher relationships than the other three LAs. At the beginning of the semester Gen talked about LAs being more approachable than professors. Yet, his concern throughout the semester was on maintaining or gaining authority with his students. Gen's views on student/teacher relationships are summarized in Table 12. This table summarizes Gen's views on each of the elements of student/teacher relationships as various times in the semester. Several cells are empty because Gen did not talk or write about the topic in that time frame.

Table 12. Summary of the Development of Gen's Views of Student/Teacher Relationships.

	Pre	Early	Mid	Late	Post
Approachability	LAs & TAs are not as intimidating as faculty.				
Authority	LAs keep students on task		• LAs keep students on task • Is working to gain students' respect.		LAs keep students on task

At the beginning of the semester, Gen describes LAs and TAs as helpful because they're not as intimidating as professors so he feels,

> If I needed help I could call out my TA/LA or TA's name and ask them a very small question from the tutorial or I could jsut ask them an absurd thing like, 'how could a fly stop a moving truck'. So there was this like whole spectrum of what I could ask because they were kind of like down to earth, like they were kind of like my, similar to a friend. Rather than some teacher that I'm afraid of asking this stupid question and making them think, 'is he okay mentally' or something like that. So, I thought that was a good thing. (Gen, pre, 35 – 41).

Because Gen considers LAs and TAs to be more approachable and less intimidating than professors he is comfortable asking them his questions. Gen is the only one of the LAs to group LAs and TAs together as being equally approachable when they talk about this during the beginning of the semester interviews. This is the only time that Gen talks about the importance of LAs being approachable for students. Because Gen never describes a mechanism for student/teacher relationships to lead to learning, there is no mechanistic model of his views as there is for the other LAs. While Gen described the importance of his LA and TA being approachable and like a friend, he never mentions working to create this bond with his students. Instead Gen focuses on how to gain the authority to make students do what he expects of them or his lack of authority to make students do what he expects.

Gen's focus on authority appears in the beginning of the semester interview. When asked how LAs help students learn he responds, "Like LA could make sure that everyone's on the right track and make sure that everyone is doing it correctly and understanding it. Like just not sitting

there for the sake of the grade" (Gen, pre, 210 – 212). Gen returns to this idea when asked what he would do differently from his tutorial section when he was a student,

> Maybe motivating the kids who sat in the corner and just didn't' do anything. I think that would be the only thing that would change. But I would try and incorporate everyone and makes sure that they're doing what they're supposed to be doing. Maybe, threatening them with a grade sanction would be a good thing too. Because they're showing up, they care about grades. If we threaten them they might think differently, like just change their thoughts. (Gen, pre, 268 – 274).

Gen's focus in both situations is on students who are not doing what they are supposed to do during recitations and how he can make students do what they are supposed to do. In the first quote he feels it is the job of the LA to make sure that students are doing the tutorial correctly and not just sitting in the room so that they get the points for their grade. In the second quote, he wants to threaten students to make them do their work. Gen returns to this idea at the end of the semester,

> . . . some of these groups are lagging behind and talking about the test they took the day before or about life in general. So, if that's the case, I try to get into their conversation a little bit and make sure that they get to the end and say, "okay, guys you've had your conversation time so. . . get". Maybe like get them motivated, and like get them talking a little bit, warm up their tongue and say, "okay, now let's do something about physics." (Gen, post, 21 – 26).

Gen is choosing to create an adversarial relationship through threats to solve the unmotivated students problem, while Jamie suggests addressing the same problem by modeling enthusiasm in

the hopes that it would be contagious. Gen's focus on keeping students on task is explained when he explains his big concern as he begins the semester,

> Rowdy students. Rebellious students. Well, the biggest fear that I have is not being able to teach them or giving them their due. This [is] a direct quote from justice, the definition of justice, but I think everyone has the right to get what they're due so if I'm not able to give them what they're due, then I fail (Gen, pre, 345 – 348).

Gen goes on to define giving students their due as providing them with the opportunity to learn and enjoy physics. This means that Gen thinks that if he is unable to give students the opportunity to learn physics because they are being rowdy or other rowdy students are disturbing them then he has failed and is being unjust. Several times during the semester Gen wonders how to get students on task,

> My biggest problem during the session was deciding how much I should impose the rules. I can't decide whether or not I should yell at all of the students who are not doing what they are supposed to be doing or letting them decide if they need help from other group members or not. I will try different methods that would benefit the students the most. (Gen, wk03, 4).

During his mid-semester review, Gen worries because he doesn't think he has the students' respect, "The thing that I want to improve upon is gaining student respect. Since some of the students are not enthusiastic about being in the recitation, they do not pay attention to what I'm saying" (Gen, wk08, 1). Several weeks later Gen refers to a "respect crisis" (Gen, wk10, 6) in his classes. Several times during the semester Gen laments his lack of authority in the classroom due to his lack of grading authority, for instance, "Since I don't have any grading power, I could only advise the students to not leave; therefore, what should I do in a situation

where the students start to leave" (Gen, wk11, 5). Gen's reflections often describe his relationship with students in adversarial terms, for instance he talks about yelling at them or threatening them. Gen does not mention his struggles with authority in any of his written assignments. Gen is the only LA who focuses on his authority with students throughout the semester and this authority focus appears to be at the expense of relating to students. While Gen talks about motivating students, he is referring to getting them back on task and not on creating internal motivation based on their love of the subject.

Conclusion

The LA program involves many different levels of enactments of formative assessment. These levels of enactment can be placed on a spectrum that summarizes the literature on formative assessment and student learning. The spectrum describes the level at which students are involved in the processes of goal setting and/or idea sanctioning. The different ways that formative assessment is enacted within the LA program and the levels at which these enactments occur are shown in Figure 14. The LAs involved in this study were all teaching within a Washington tutorials context. This means they were *expected to teach* in ways consistent with the conceptual change model of formative assessment—elicit-confront-resolve-replace, that is employed in the Washington tutorials (McDermott, 2001). Research has demonstrated that this method improves student conceptual learning; LA supported courses that use the Washington tutorials have shown learning gains that are twice those of traditional physics courses on similar assessments (Otero et al., 2010; Pollock & Finkelstein, 2012). LAs in departments other than physics, who use other types of activities, might be expected to participate in a different level of enactment of formative assessment. While the LAs were teaching within a conceptual change enactment of formative assessment, they were being *taught about* a resources enactment of formative assessment in the LA seminar. The LA seminar focuses on the idea of eliciting students' ideas and then using these ideas as building blocks to help students construct the scientific concept. While the LAs were learning about formative assessment as a resources enactment model, the LA program design is based on yet another enactment model of formative assessment, specifically a community of learners/community of practice, transformative enactment model of formative assessment. This enactment model as applied to the findings of

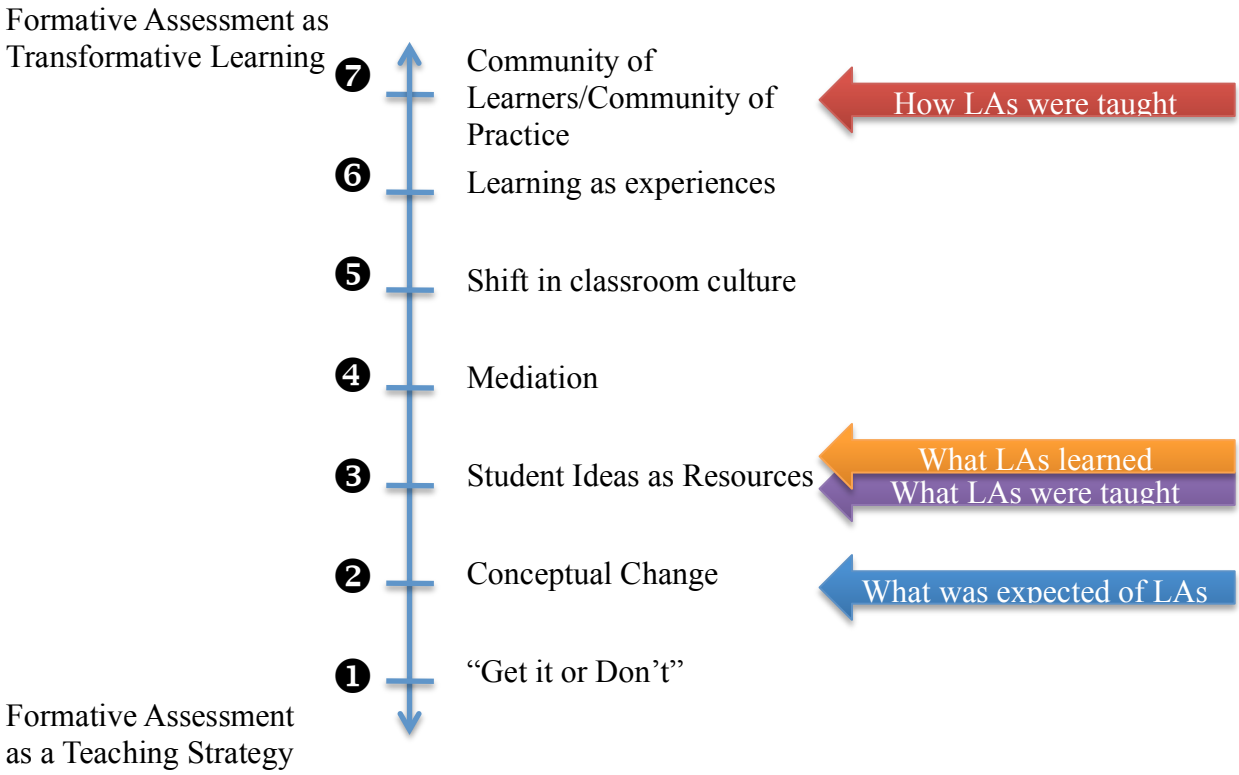

Figure 14. The multiple enactments of formative assessment involved in the LA experience.

this study is explained in more detail in below. Broadly, this means that the LA program works to initiate LAs into a community that values students' ideas and recognizes the need to always adapt instruction to each individual student. The decision to focus on the resources enactment model as the learning target for LAs using a community of learners/transformative enactment model was intentional in the design of the LA program. The decision about what model to have as a target for LAs' learning was made by the developers of the program based on their own formative assessment of where undergraduates were in their thinking as they entered the LA program. Additionally, the resources model was a revered entry-level model by the developers and was a logical next step for the LAs, given their assessment of LAs' views as they entered the program. The developers expected that the more sophisticated community of learners/transformative enactment model of formative assessment would continue to develop iteratively in LAs' experiences, for example, through a full teacher preparation program. Indeed,

part of formative assessment requires the teacher's understanding of the iterative nature of learning, and resulting selection of logical next steps rather than always aiming for targets that are beyond the reach of the students.

The findings of this study—specifically the views of teaching and learning developed by the LAs can also be placed on the spectrum of enactments. The generalized model of formative assessment, described in theme one, aligns with the literature that uses the resources enactment model of formative assessment. The LAs in this study recognized the importance of having students construct their own understanding of scientific concepts. The LAs wanted to elicit students' ideas about specific target physics concepts and to use these ideas to help students construct their understandings about physics content. The generalized model that represents the LAs in this study, along with the evidence of learning presented in the case studies suggest that the LA program is successful in reaching its learning target. The target model of the LA program is the resources enactment model and the data demonstrate that the LAs developed this model of formative assessment.

The LAs' views of student/teacher relationship are not an enactment model of formative assessment so it cannot be placed on Figure 14. Yet the LAs in this study tended to combine two views of learning in a more sophisticated enactment model as shown in Figure 15. This model *accounts for the context* necessary for formative assessment to take place. Specifically, in this model it is important for students to feel comfortable being vulnerable in class so that they are able to share their ideas with fellow students and the teacher. When students are willing to share their ideas, teachers can use these ideas to help students construct scientific understandings. In other words, the finding that the LAs' in this study expressed a model of student/teacher relationships demonstrates their thinking about a *prerequisite for learning* using their model of

formative assessment. This enactment of formative assessment demonstrates the importance of classroom culture in a way that is not emphasized in the traditional resources perspective described in the literature. I argue that this is a deeper enactment model of formative assessment than the resources perspective, which means that the LAs in this study learned a more sophisticated enactment model of formative assessment than the target model of the LA seminar. Namely, the LAs learned not just a model of formative assessment but also the conditions necessary for enactment of it, and the role of the teacher in creating and maintaining a context suitable for formative assessment to occur.

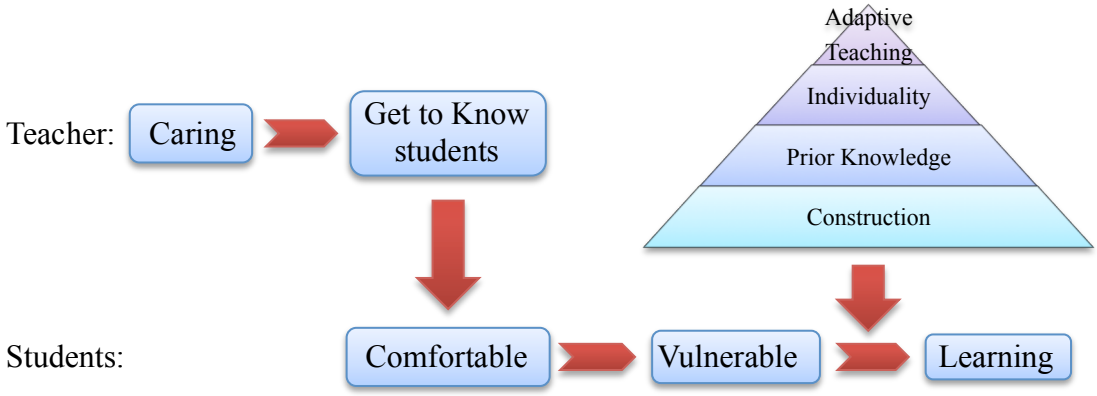

Figure 15. A model for combining the LAs' generalized models of teaching and learning.

The *LA experience* can be understood from a community of learners/transformative learning model of formative assessment. Under this perspective, LAs develop their models of formative assessment and student/teacher relationships through a process of induction into a community of practice. This process is visualized in Figure 4, which is reproduced below. The LAs construct their understanding of teaching by integrating the generalized pedagogical practices that are taught in the LA seminar with their practice during the tutorial sections. This

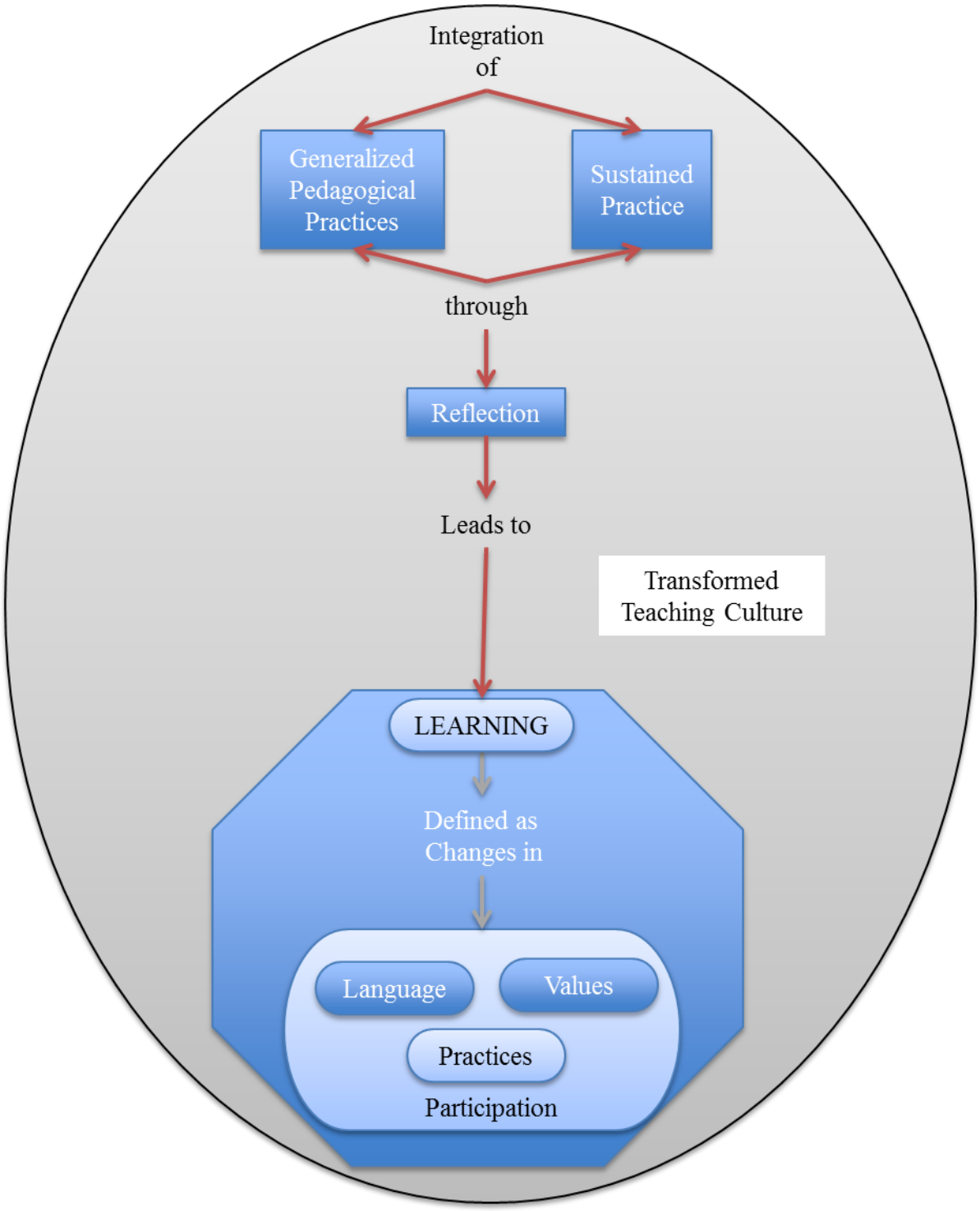

Figure 4. Conceptual Framework of LA Learning.

integration process is an example of Vygotsky's theory of concept formation through mediation (Otero & Nathan, 2008; Vygotsky, 1986; Wertsch, 2007b). The LAs use their teaching *experiences* as a forum for making sense of the abstracted pedagogical principles being introduced in the LA seminar. They try out these abstracted ideas in their teaching experiences as a mechanism for developing an understanding of the ideas. At the same time, the availability of these abstracted academic principles of learning provide a lens with which they are able to select salient events and interpret their teaching experiences. This in turn, allows them to abstract important principles from these experiences, which now represents their conceptual understandings—*their experience-enhanced views* of the resources enactment model of formative assessment. This study demonstrated, that LAs' experienced-enhanced views were even more desirable than the abstracted principles they were being officially taught in seminar. This difference between what was taught and what was learned also represents how abstract principles taught in formal learning environments are necessarily laced with student experiences, in this case in a very positive direction. For instance, Jamie uses the principle of mental models which was introduced in the LA seminar to make sense of a frustrating experience she had with a student,

> A couple weeks ago, in class I was having great difficulty helping a student. I could not understand why he was not getting the problem right. He had all the knowledge at his disposal and I knew he could figure it out, but he still seemed to be having trouble. I kept trying to walk him through it, ask him question after question, knowing that the answer was right there, but he just couldn't reach it. I had no idea why it was so hard, but then Redish's idea of a "mental model" came floating into my head as I suddenly realized we were going about the problem *my* way. Everything was perfectly clear to *me*, but the

> student's ideas on the matter were far different than mine. Realizing this, I then took the time to clarify what the student understood. I sat and listened to their explanation of what was going on, with no sudden interjections and finally realized the key point that we had been getting stuck up on (Jamie, AR1, 42-51).

In this interaction Jamie uses the notion of mental models, which she was currently in the process of trying to understand, to make sense of why she was struggling to help this student. This interaction between experience and deployment of academic terms/concepts in situ represents how learning requires the involvement of both experiences and formally introduced ideas and suggests that neither on its own is sufficient.

This study demonstrated that LAs also use the academic principles presented in seminar to push their teaching practices. For instance Leah's weekly teaching goal was "to work again on ways to coax students into understanding the concepts with questions and dialogue" (Leah, wk06, 3). In this goal she was working on two teaching strategies that were emphasized in the LA seminar: (1) eliciting students' ideas through (2) questioning and dialog. Later in the semester, Leah demonstrated her awareness of how both her teaching experiences and the discussions of formal principles about teaching and learning in the LA seminar shaped her thinking,

> I have noticed that the more I teach and learn about teaching, the more I have realized the importance of allowing the student to reach his or her own answer. A student learns much better through thinking, and that process is much more important than the answer itself (Leah, wk08, 1).

Leah's experiences, the availability of pedagogical principles, and her reflection on both lead to the learning she describes in the excerpt above. This integrated experience is indicated by her use

of the phrase "teach and learn" to reference both her teaching experiences and the material she learned through the LA seminar. It is also worth noting that the process of the experience that Leah wants for her students is the same experience she goes through herself to reach the view she describes - creating an understanding. Her use of the phrases "I have noticed" and "I have realized" point to this process of creation.

Another key aspect of learning from a transformative perspective is the environment within which the learning takes place. As mentioned above, the LA experience can be described as a process of increasing participation within a community of practice. The value of this community is visible throughout the LAs' writings and interviews. Before the semester started, LAs' views of what it means to be an LA were likely shaped by their experiences as students enrolled in LA supported courses. During the semester of serving as an LA, the LAs in this study mentioned that they learned from their fellow LAs who they had the opportunity to observe. The LAs also mentioned that they learned a lot from their own LAs the previous semester. The LAs often referred to their own LAs during the pre-semester interview to explain what they thought a good LA should do. These members of the community of learners appear to play a critical role in shaping LAs' views toward teaching and the role of the LA. LAs who work in departments that are starting LA programs may therefore begin their LA experience with views toward teaching and learning that do not agree with the generalized models described here, since they would not have had the opportunity to interact extensively with LAs as students. In addition, the context in which LAs were working with their peers as students *might* have allowed them to be more sensitive to the *process of learning* than they would have been if the students were younger and presumably less knowledgeable. The fact that LAs' students were peers, in some of the same classes that the LAs were taking as students, may have allowed them to view student ideas as

information, or in process rather than focusing only on whether they were right or wrong, a view which could curtail a productive enactment model of formative assessment.

Research has found that formative assessment is very difficult for prospective teachers to learn (Buck et al., 2010; Otero & Nathan, 2008). The LA program has found a way for future teachers to develop a deep understanding of formative assessment that is grounded in their teaching experiences. Observations of former LAs also suggest that this understanding of formative assessment actually transfers into teaching practices in K12 classrooms (Gray et al., 2012). Evidence shows that LAs do teach differently in the K12 classroom than their colleagues. In a former study (Gray, Webb, & Otero, 2012), 29 teachers who completed all or part of the teacher preparation program at CU-Boulder were observed. Half of the teachers had participated at least one semester in the LA program. The other teachers in the study had not participated in the LA program but were otherwise matched to the former LAs in terms of their years of teaching experience, degree area, teacher certification program, graduating GPA, and secondary school context such as ethnic diversity and school location (urban, rural, or suburban). These teachers were referred to as the Non-LAs. Over the course of five years the research group, consisting mostly of graduate students who did not know which teachers were former LAs conducted 178 observations of these teachers using the Reformed Teaching Observation Protocol (RTOP; Sawada et al., 2002). The RTOP is a structured observation protocol designed to quantify how much a teachers' practices align with National Science Education Standards (NSES) standards-based teaching practices (National Research Council, 1996). Statistically significant results (Figure 16, from Gray, Webb, & Otero, 2012) in both math and science ($p = 0.005$ and $p = 0001$, respectively) show that LAs outperform their colleagues. These differences

were seen in all categories of the RTOP except one – math teachers' Content Propositional Knowledge.

Through case studies, through generalized models of the way LAs are thinking substantively about teaching and learning, and through previous observation data of K12 classrooms, I have demonstrated that the LA program facilitates the development of useful formative assessment strategies. Other research has demonstrated that using formative assessment can improve student achievement for all students but it is particularly useful for those students who have previously struggled academically (Black & Wiliam, 1998; Shute, 2008). If

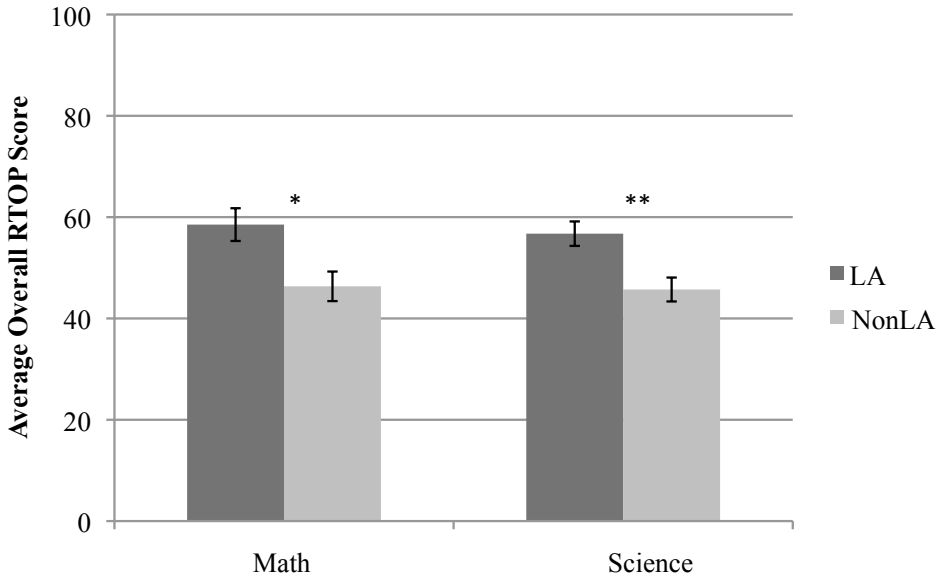

Figure 16. Overall RTOP Scores for LAs and NonLAs broken down by the subject observed. Error bars represent plus and minus one standard error on the mean.
* p = 0.005, ** p = 0.001

LA programs can both increase the number of science teachers and prepare them to enact formative assessment, then it follows that LA programs can increase the likelihood that science teaching in the U.S. utilizes strategies conducive to improving student achievement writ large. Given that the Colorado LA model has spread like wildfire throughout the nation, it may

therefore represent a key lever for addressing broader national issues associated with diversity, equity, and access.

The research presented here also provides several implications for the LA programs. The LA program appears to be effective in helping LAs learn about formative assessment using the resources model. The generalized models and case studies suggest that the LAs tend to talk about eliciting and building on students' ideas in a way that is consistent with the resources model. If future studies shows that many other LAs develop similar models of teaching and learning, then instructors of the LA seminar may want to consider raising the learning goals of the seminar. If LAs are in fact learning to view students' ideas through a resources model then it may be time for the instructors to push the LAs further toward a model of learning allows students even more involvement in the process of setting learning goals and sanctioning ideas. For instances, the LAs could discuss the application of a community of learners to their view of their classroom. The research presented here also demonstrated the importance LAs placed on being approachable for their students. This is a topic that is barely discussed in the LA pedagogy. Given LAs' interest in this topic and its relationship to their other teacher practices, the LA pedagogy seminar should discuss this topic so that the instructors can build off of LAs' current understanding. While the LAs views on approachability tend to be aligned with ideas on reformed teaching, their views on authority and motivation appear to align more with traditional views. These more traditional views tend to be in tension with their reformed views on approachability and formative assessment. Therefore the LA program needs to provide opportunities for LAs to interact with more reformed models of motivation and authority such as including readings by Ames (1992) and Ryan (1995). It is not enough for the LAs to read about reformed models of motivation. The STEM departments need to adopt curricula that have more of a mastery orientation that focuses

on student autonomy, the intrinsic value of knowledge, and the development of skills and competency. If the LA program emphasized motivation as it does formative assessment and student ideas, perhaps it could lead to outcomes that are more closely aligned with sophisticated practices for facilitating motivation among students.

The research discussed here suggests several directions for future research. The case studies demonstrate that these four LAs developed views of teaching and learning that were very similar despite several nuances. Therefore the first step for future research should be to investigate whether the generalized models developed here will hold up to the analysis of data from more LAs. Originally this work would need to focus on physics LAs, but later work needs to also consider whether these models can apply to LAs in different situations. For instance, do LAs from other departments and who therefore use different curricula, other than the Washington tutorials, develop similar models of learning. Also, do LAs who did not have an LA when they were a student in the class develop different views of teaching and learning than the views presented here. It is possible that without the extended interactions with LAs the previous semester the first-time LAs who are in a new LA program may not value approachability because they did not have the opportunity to experience that element when they were students.

Teachers who know how to create environments that are safe for formative assessment to occur are able to provide opportunities for students to just be smart and to become autonomous learners in the context of science. In learning how to make and support claims with data and to articulate and defend their ideas, students learn to stand up for themselves and gain empowerment through science. By helping students engage in the process of constructing their own ideas through scientific inquiry through sophisticated enactment models of formative assessment, teachers can provide their students the opportunity to make sense of the world

around them exerting greater autonomy over their learning in classrooms, their education more broadly, their lives, their community, and their nation (Proweller & Mitchener, 2004).

Science education is not just about forming a more scientifically literate workforce or better cities but it is also a civil rights issue. In previous decades civil rights has focused on students' access to physical spaces. Educators and civil rights leaders now recognize that equal opportunity should be focused on access to high-quality instruction. Therefore providing students with excellent science education, especially those who are typically denied such education, is not just good economic or political policy - it is a constitutional imperative. Students who are taught to construct their own scientific concepts and who recognize the value of their own ideas are prepared to not only help address the current scientific issues but to also learn about and work to solve the scientific issues of the future.

Research on formative assessment has tended to focus on the *teaching strategies* that teachers employ or on pre-service teachers' ability to define and apply formative assessment in limited ways in other teachers' classrooms. The research presented here uses a different approach of investigating the views LAs hold about learning and then considering how these views relate to the formal principles of formative assessment. This approach allows the analysis to show how the LAs' views on formative assessment develop over time and are related to their views on other education perspectives such as the importance of students constructing their own understanding. Looking at formative assessment as a teaching philosophy rather than a series of teaching strategies also makes clear the connection between formative assessment and the content being taught. If a teacher views science as a collection of scientific facts, then it is unlikely she will ever teach science using a deeper level of enactment than a "get it or don't" perspective. If, on the other hand, a teacher views science as a set of scientific practices and a

way of viewing the world, a view of science that subsumes the view of physical facts and topics as part of science, then she will have to teach science using an enactment more in line with a community of practice or community of learners perspective. Therefore the philosophy of teaching a teacher uses is inextricably linked to the science content and the nature of science perspective being taught. If students are to develop sophisticated understandings of science, then teachers must enact sophisticated philosophies of teaching.

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Appendix 1: Pre Interview Protocol

Purpose: Interview to be conducted with first time physics LAs at the beginning of the semester.

1. Icebreaker questions:
    a. How was your break?
    b. Are you going to have a busy semester?
    c. What classes are you taking?
    d. What's your major?
    e. How many more semesters do you have left?
2. Why did you decide to apply to the LA program?
3. What has been your experience with LAs?
    a. Can you describe how they helped you learn?
    b. What are some of the things they did that you liked?
    c. What are some of the things they did that you didn't liked?
4. Why do you think group work is used in the tutorials?
    a. How do you think group work is helpful to students?
    b. Do you think group work is helpful for all students? Why?
5. What has been your experience with tutorials?
    a. What did you like about tutorials?
    b. What did you not like?
    c. Can you describe what you found helpful?
    d. Can you describe what you found unhelpful?
    e. What do other people think about tutorials?

   f. I have heard that other people think that tutorials are repetitive. What do you think?

6. How would you describe the job of an LA?
   a. How do LAs help students learn?
   b. How does this compare to the job of the TA?
7. Let's say you have a group of students who are struggling with a particular problem—describe how you would assist these students.
8. How are you expecting the tutorials to be organized/run?
   a. What do you want to see happen?
   b. How much control do you expect to have over how tutorials are run?
9. Who was your favorite teacher (K-16)? Why? What did they do that helped you or that you liked?
   a. What makes a good teacher?
   b. What makes a bad teacher?
10. What is your interest in teaching?
   a. Are you considering teaching at the K-12 level?
   b. Are you considering teaching at a university/college level?
   c. Are you considering teaching as a second career or a fall back plan?
11. What do you think about this quote from Parker Palmer? "Good teaching does not come from technique. It comes from the identity and integrity of the teacher." [LA is given a hard copy of the quote.]
   a. Do you agree? Would you change anything about the quote to make it more accurate?

Appendix 2: Post Interview Protocol

Purpose: Interview to be conducted with all physics LAs at the end of their semester.

1. Icebreaker questions:
2. Tell me about your LA experience this semester?
    a. What went well?
    b. What didn't go well?
    c. What surprised you?
    d. What did you learn?
    e. How have you changed?
3. How do your sections usually begin?
    a. Walk me through a typical class.
4. Tell me about your experience with the LA seminar?
    a. What did you like?
    b. What did you dislike?
    c. What was helpful? What wasn't?
    d. What would you change?
    e. What did you learn?
5. How would you describe the job of an LA?
    a. How do LAs help students learn?
    b. How does this compare to the job of the TA?
    c. What makes a good LA? What about a bad LA?

6. Let's say you have a group of students who are struggling with a particular problem—describe how you would assist these students.
7. Why do you question students?
    a. Did you do this a lot?
    b. When did you find this helpful? When wasn't it?
    c. How did your students respond to your questions?
    d. How did your questions change over the semester?
    e. Do you think you're good at asking questions?
    f. What did you learn about asking questions?
    g. What about asking questions are you still working on?
    h. Do you think the LA seminar helped you improve your questioning
    i. What more could have been done in the LA seminar to help you with this?
8. What does the concept of Formative Assessment mean to you?
    a. (If not familiar) What about the bridge analogy?
    b. How would you define this idea?
    c. (If still confused) Do you remember the 3 questions, Where are you at, Where are you going, and How are you going to get there?
    d. Do you think this is a helpful idea?
    e. How did you apply this idea to your teaching?
    f. How did your ideas about Formative Assessment change over the semester?
9. What makes a good teacher? What makes a bad teacher?
10. Are you planning to return to the LA program next semester or in future semesters?
    a. What prompted this decision?

11. Would you recommend being an LA to a friend?
    a. Under what circumstances?
12. What is your interest in teaching?
    a. Are you considering teaching at the K-12 level?
    b. Are you considering teaching at a university/college level?
    c. Are you considering teaching as a second career or a fall back plan?
13. What do you think about this quote from Parker Palmer? “Good teaching does not come from technique. It comes from the identity and integrity of the teacher.” [LA is given a hard copy of the quote.]
    a. Do you agree? Would you change anything about the quote to make it more accurate?

Appendix 3: Weekly Reflection Questions

The actual wording of the reflection questions is listed below in alphabetical order of the question title.

Changes Based on Feedback	What changes (if any) have you made to your teaching in the past weeks due to the feedback you received from your student FCQs and the LA who observed you? Did the changes work as you expected/hoped? What changes do you still need to make?
Conceptual	What types of alternative ideas did you notice among the students you worked with? Regardless of what is right or wrong, what were they thinking, that is, what *do* they get rather than "do they get it or not."
Conceptual Topics	What types of alternative ideas or resources did you notice among the students you worked with? Regardless of what is right or wrong, what were they thinking, that is, what *do* they get rather than "do they get it or not."
Describe an LA	Given what you know so far, describe what it means to be an LA. What is your job? What do you hope to accomplish? What does it mean to teach?
Evaluation of Group Interactions	Did all the students appear to be participating? Any good discussion? Any problems with the group, and if so how do you plan on addressing that problem in the future?
Evaluation of Your Teaching	What seemed to work for you (or for the students)? What did not seem to work? Why do you think this is the case?
Goal	What was your main teaching goal(s) for this week? These can be conceptual, motivational, metacognitive, etc. Do you feel you met this goal(s)? Why or why not?
Job Descriptions	Given what you know now and your experiences so far, describe your job as an LA.
Just Tell Me the Answer	No doubt you have heard (and said), "won't you just tell me the answer!" In light of what you read this week, why do you think it is important to not always just tell students the answer. Do your best to explain what you mean.
LA Job Description	In what course are you working? What is your main responsibility (Do you help with clicker questions during lecture; run a co-seminar, help with tutorials, labs, or recitations; work in the helproom; etc?)? Are students required to participate in the part of the course in which you are working? Are you working with a TA or fellow LA? Do you have grading responsibilities?
Metacognition and Argumentation	Describe an example of metacognition or argumentation that you observed in your interactions with students. What did you do in your teaching this week to encourage metacognition or argumentation in your classroom?

Mid-semester Reflection	We are about halfway through the semester. Think back over your teaching so far and discuss how you have noticed your teaching and thinking changing. What have you learned? What do you do differently than you did the first several weeks? We also still have a lot of the semester left so discuss what you want to do with that remaining time. What do you want to work on? What areas are you trying to improve? What do you want to learn?
Multiple Intelligence	How were you able to draw on the strengths of different types of intelligences in your teaching this week? What examples of different types of intelligence did you notice? If you felt most of your lesson was focused on only one or two types of intelligence how would you have liked to change the activities to draw on other types of intelligence?
Nature of Science	The atom or magnetism activity (which you were given at the end of class on Wednesday) specifically addresses Nature of Science. What do you think this activity accomplishes? Why? In what ways and for what populations do you think this would be useful? Why?
Next Goals	Based on how things went this week, what are your goals for next week? Why is this what you want to focus on? How are you planning to meet this goal?
Notes About Observation	What were some of the good things that the LA you observed did? What were some of the things the LA you observed needs to work on? What are some of the suggestions you had for the LA observed?
Notes About the Observation Debriefing	What was some of the helpful feedback that you got from the LA who observed you? What was not helpful about the observation and observation debriefing session?
Observed	Who did you observe?
Observer	Who observed you for the classroom observation?
Other	What other things (if any) would you like to share?
Reflection	What do you think about this week. For example, I am really glad that I... Why didn't I... Next time I am going to... My biggest problem during session was... I wish I was more...

Appendix 4: Weekly Reflection Schedule

The following table lists the titles of the questions asked during each reflection. The wording of the questions can be found in the previous appendix. The numbers in the cells represent the order of the questions for that week's reflection.

	Weekly Reflection												
Question Title	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Describe an LA	1												
Goal	2	2		2	3	3				1			
Evaluation of Group Interactions	3	3				1				2			
What Actually Happened	4												6
Reflection	5	4				4					3		
Other	6	5	3	4	5	5	2	3	6	5	3	4	7
LA Job Description		1											
Conceptual			1								1		
Using questioning			2										
Stuck, Needed, Bounced				1									
Next Goals				3									
Conceptual Topics					1								
Evaluation of Your Teaching					2	2		2	5			3	
Theory of Learning					4								
Mid-semester reflection							1						
Metacognition and Argumentation								1					
Observer									1				2
Observed									2				1
Notes About Observation									3				3
Notes About the Observation Debriefing									4				4
Changes Based on Feedback									7				
Suggestions for the LA Program									8				
Multiple Intelligence										3			
What Are You Working On										4	2		
Nature of Science												1	
Just Tell Me the Answer												2	
Job Descriptions													5

Appendix 5: Weekly Schedule for Physics LAs Spring 2010

The following table shows the timing of seminar assignments and interviews. It also lists the topics covered in each tutorial and LA seminar by week.

		LA Seminar Assignments	Interviews	Tutorial Topics	LA Seminar Topics
Week 0	M				
	T				
	W				
	U				
	F		Pre Interview		LA Orientation
Week 1	M				
	T		Pre Interview		
	W				Discussion Techniques
	U			FMCE	
Week 2	M	TR2			
	T				
	W				Questioning
	U			Motion in 2D	
Week 3	M	TR3			
	T				
	W				Learning Theory
	U			Accel in 2D	
Week 4	M	TR4			
	T				
	W				Formative Assessment
	U			Forces	
Week 5	M	TR5			
	T				
	W				Student Conceptions
	U			N2 & 3	
Week 6	M	TR6			
	T				
	W	AR1			Cooperative Learning
	U			Tension	
Week 7	M	TR7			
	T				
	W				Info Session
	U			Work	
Week 8	M	TR8			
	T				
	W				Argumentation/Metacognition

		LA Seminar Assignments	Interviews	Tutorial Topics	LA Seminar Topics
	U			Conserv of E	
Week 9	M	TR9			
	T				
	W	FCQ/CR Obs1			LA FCQ
	U			Conserv of p	
Week 10	M	TR10			
	T				
	W				Multiple Intelligences
	U			Rigid Bodies	
Week 11	M	TR11			
	T				
	W				National Standards
	U			Equilibrium	
Week 12	M	TR12			
	T				
	W				Nature of Science/Math
	U			Conserv of Ang p	
Week 13	M	TR13			
	T				
	W	CR Obs2			Quals of Effective Teaching
	U			SHM	
Week 14	M	TR14			
	T				
	W	AR2			Future of Education
	U			Buoyancy	
Week 15	M				
	T				
	W	Final			Poster Session
	U		Post Interviews	FMCE	

Appendix 6: LA Seminar Syllabus for Spring 2010

University of Colorado
School of Education

EDUC 4610 Section 801, call#
Mathematics and Science Education, Theory, and Practice

Instructors: Valerie Otero, Steven Iona
Graduate Assistant: Kara Gray
Office: Otero: EDUC 320D; Iona: EDUC 320F, Gray 320F
Office hours: Otero: 4:00-5:00 Wednesday
Phone: Otero: (303) 492-7403, Gray: (303) 492-4331
Email: Valerie.Otero@Colorado.edu
Steve.Iona@earthlink.net
Kara.Gray@colorado.edu
Class time: Wednesday, 6:00 – 8:00 PM
Location: EDUC 231

COURSE DESCRIPTION

The course is designed for undergraduate students serving as Learning Assistants in science and mathematics courses. The course will help integrate educational theory, pedagogy, and practice. It will touch on theoretical issues such as conceptual development, conceptual change, collaborative learning, technology in education, and students' conceptions of various topics in mathematics and science, as well as practical issues encountered in facilitating learning, managing the classroom, formative and summative assessment, and differentiating instruction in a collaborative environment. This is a seminar course where students are responsible for weekly readings, in-class discussions, and project presentations all based on the Learning Assistant field placement.

Reasonable Accommodation: Any student eligible for and needing academic adjustments or accommodations because of a documented disability should consult with the course instructors. If you qualify for accommodations because of a disability, please submit a letter from Disability Services to the instructors in a timely manner so that your needs may be addressed. For additional information contact: 303-492-8671, http://www.colorado.edu/disabilityservices/

If you have a temporary medical condition or injury, see guidelines at
http://www.colorado.edu/disabilityservices/go.cgi?select=temporary.html

Religious Observance: If you have any conflicts regarding religious observances please talk to the instructors as soon as possible and we will accommodate scheduling conflicts.

Classroom Behavior: Students and faculty each have a responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be

subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with differences of race, culture, religion, politics, sexual orientation, gender, gender variance, and nationalities. The University of Colorado at Boulder policy on Discrimination and Harassment, the University of Colorado policy on Sexual Harassment and the University of Colorado policy on Amorous Relationships apply to all students, staff, and faculty. Any student, staff, or faculty member who believes s/he has been the subject of sexual harassment or discrimination or harassment based upon race, color, national origin, sex, age, disability, creed, religion, sexual orientation, or veteran status should contact the Office of Discrimination and Harassment (ODH) at 303-492-2127 or the Office of Judicial Affairs at 303-492-5550. Information about the ODH, the above-referenced policies and the campus resources available to assist individuals regarding discrimination or harassment can be obtained at http://www.colorado.edu/odh

Academic Integrity: All students of the University of Colorado at Boulder are responsible for knowing and adhering to the academic integrity policy. Violations of this policy may include: cheating, plagiarism, aid of academic dishonesty, fabrication, lying, bribery, and threatening behavior. All incidents of academic misconduct shall be reported to the Honor Code Council (honor@colorado.edu; 303-735-2273). Students who are found to be in violation of the academic integrity policy will be subject to both academic sanctions from the faculty member and non-academic sanctions (including but not limited to university probation, suspension, or expulsion). Other information on the Honor Code can be found at http://www.colorado.edu/policies/honor.html and at

http://www.colorado.edu/academics/honorcode/

Acceptance of late work or alternative assignments based on missed classes needs to be negotiated with the instructors. The assumption is that students attend each class session and complete assignments as assigned.

COURSE ORGANIZATION AND REQUIREMENTS

The Performance-Based Standards for Colorado Teachers are available on-line at http://www.cde.state.co.us/cdeprof/download/pdf/li_perfbasedstandards.pdf. These "serve as standards for the licensing of all teacher education candidates in Colorado and reflect the knowledge and skills required of beginning teachers." This syllabus is marked throughout with bracketed standards to give teacher education candidates clear indicators of their professional responsibilities. The brackets indicate when teacher education candidates are "developing and practicing" [DP] a standard. When a standard is met at the **Developing/Practicing** level **[DP]** that means that students will have opportunities to develop an understanding of the standard's knowledge base, to develop/practice with assistance the application of the standard in a field setting/university classroom, and to receive an evaluation of evaluate the success of the teaching performance.
Each of the assignments in the syllabus must be completed successfully in order to ensure that the student has achieved proficiency on the various Performance Standards for Colorado Teachers that are attached to each assignment.

This course is a seminar, and its success will depend on the **active** participation of all members in helping to shape its ultimate content and relevance. Our primary activity will be in-depth discussions of course topics and readings. Requirements include the following:

1. Class Discussion/Participation/Journals. *[2.1 (D); 3.1 (D), 3.2 (D), 3.4 (D,P), 4.1 (D,P), 4.2 (D), 4.3 (D,P), 5.1(D), 5.5 (D,P), 6.1 (D), 6.2 (D), 6.4 (D,P), 8.1(D,P), 8.2 (D), 8.5 (D,P)*. Class members are expected to contribute to class discussions. The purpose of these discussions is to help us as individuals, and as a group, develop meaningful interpretations of the ideas conveyed by the readings and to make connections to the Learning Assistant teaching experience. There will be weekly questions regarding the assigned article(s). Responses should be submitted electronically. Additionally, at the end of many class sessions you will be expected to write a short reflection on the discussions that took place that day. You will be given 5-10 minutes at the end of each class period to write the response. Turn them in before you leave class. The expectation is that students are attending every class session and participating in the discussions.

2. Article Reports *[5.5 (D,P)]*.
   Students are required to turn in two (three- to four-page, double-spaced, 12-pt font, reasonably margined) reflective paper on a selected pair of readings that includes the following:

   (1) A short summary of the central issue(s) or argument(s) contained in the readings.
   (2) Analyses of how these issues from the articles are connected to each other and to other readings.
   (3) A discussion of the relationship of the issues/topics to your teaching experiences as a Learning Assistant. You should use specific examples from your experiences.

The due dates for the Article Reports are listed on the calendar.
Although students are expected to *turn in* only two reflections, it may be beneficial to keep a journal of your article reflections each week.

3. Weekly Teaching Reflections *[2.1, 2.2 (D,); 4.1, 4.2, 4.3 (D,P); 5.1, 5.2, 5.3, 5.4, 5.7, 5.9 (D,P); 6.1, 6.2, 6.4 (D,P); 7.2, 7.3, 7.5 (D); 8.2, 8.3, 8.5 (D,P)]*. Each student is expected to spend approximately 5-10 hours per week working with undergraduate mathematics and science students in collaborative, learner-centered environments. Each class member is expected to fill out a weekly reflection on **CU Learn by Monday at midnight.** Students cannot pass the course if you do not complete your weekly online teaching reflections.

4. Weekly Article Reflections *[2.1, 2.2 (D,); 4.1, 4.2, 4.3 (D,P); 5.1, 5.2, 5.3, 5.4, 5.7, 5.9 (D,P); 6.1, 6.2, 6.4 (D,P); 7.2, 7.3, 7.5 (D); 8.2, 8.3, 8.5(D)]*. Each class member is expected to answer a collection of questions based on the weekly article reading. These should be answered on **CU Learn by Tuesday at midnight.**

5. Weekly Meetings with Lead Faculty in Mathematics and Science to Plan Instruction *[3.1, 3.2, 3.3, 3.4, 3.6 (D,P); 5.7, 5.9 (D,P); 6.2, 6.3, 6.5 (D,P)]***.** Each week, students are responsible for meeting with the science/mathematics course lead faculty members and the other Learning Assistants in the department (sometimes including the graduate TAs) to plan and reflect on instruction and to discuss student achievement. Students cannot pass the course if they fail to meet with the lead instructor each week (with allowances for necessary absences).

6. Peer and Self-Evaluations. *[3.2, 3.3, 3.4, 3.6, 5.1, 5.3, 5.5, (D,P)]*. Two times during the semester students will observe another LA as he or she works with his or her learning teams, and take field notes using the Observation Protocol. Each student will prepare a written summary of the observation to share with the LA observed and to turn in as a part of the grade. Students will also have a consultation session in class with the LA you observed. You will also be observed and participate in a consultation session. Once per semester, students will hand out an evaluation form to students and analyze the data. These data should be prepared in graphical/tabular form for presentation in class. *See calendar for due dates.*

7. Final Poster Project *[Designed to synthesize all CDE Performance-Based Standards for Teachers among the class]*. The purpose of this project is for students to apply and synthesize what has been learned related to teaching, learning, mathematics, technology, science, and students. You will develop a poster presentation that describes changes or development of your beliefs about student learning and the appropriate teaching that facilitates that learning. The aspects of teaching and learning identified should reference sources in the literature and experiences as a Learning Assistant. Since each presentation will address different CDE Performance-Based Standards for teachers, we anticipate that we will get a full review of the course content, your experiences, and connections as you

visit and discuss the posters of your peers. A written summary of the poster is due to the instructors one-week after the poster session.

Grading

ASSIGNMENT	**%**	**%**	**%**
Class Participation	**20**	**20**	**20**
Article Report 1	**10**	**10**	**10**
Article Report 2	**10**	**10**	**10**
On-line Article Questions	**20**	**10**	**10**
On-line Teaching Reflection	**20**	**20**	**10**
Classroom Observation/FCQ	**0**	**10**	**10**
Final Project/Poster	**20**	**20**	**20**
Poster Summary	**0**	**0**	**10**
CREDIT	**1 SH**	**2 SH**	**3 SH**

General Scoring Rubric for Article Report

Number of points possible	**Summary of central issues or arguments**	**Analysis of how issues are connected to each other and to other readings**	**Discussion of relationship of issue/topic to your own learning or your own teaching**
4-5	Provides a synthesis of two or more articles, discussing the broad issue that relates the two. Provides a brief summary that accurately addresses the central points relevant to the thesis.	Makes a general thesis statement and provides an argument to support it. Support may come from the readings or from experience. Discusses how issues in the article are related to aspects of teaching, learning, or students. Relates to other educational topics or readings.	Provides specific example from personal experience and clearly articulates how it is related to the thesis. The example should illustrate how your thinking about teaching and learning is developing.
1-3	Provides a summary, but summary is too long or doesn't focus on main points relevant to the thesis.	Provides a discussion about the issues in article with no clear connection to the broader general issue.	Provides specific example from experience.
0	No summary provided.	No discussion provided.	No example provided

Mathematics and Science Education Theory and Practice
Fall 2010 Class Schedule

Week	Topic	Reading (to have read by this day)
1.	Discussion Techniques: Dialogic versus Univocal; Classroom Discourse	Knuth, E., & Peressini, D. (2001). Unpacking the nature of discourse in mathematics classrooms. *Mathematics Teaching in the Middle School*, *6*(5), 320-325.
2.	Questions and Questioning: Bloom's Taxonomy.	Trowbridge, L. W., Bybee, R. W., & Powell, J. C. (2000). Questioning and discussion. In *Teaching secondary school science: Strategies for developing scientific literacy* (1st ed). Upper Saddle River, NJ: Merrill.
3.	Learning Theory and Mental Models	Redish, E. (1994). Implications of cognitive studies for teaching physics. *American Journal of Physics*, *62*(9).
4.	More than Misconceptions-Resource Perspective (Classroom observations protocol)	Otero, V. (2008). Preservice elementary teachers' views of their students' prior knowledge of science. *Journal of Research in Science Teaching,* 45 (4), 497-523.
5.	Student Conceptions and Conceptual Change	*Various Articles relevant to topic area*
6. **(First Article Report Due)**	Cooperative Learning and Expert Sharing (hand out FCQ evaluation forms)	Johnson, D. W., & Johnson, R. T. (1999). Making cooperative learning work. *Theory Into Practice, (38)*2. Johnson, D. W., Johnson, R. T., & Smith, K. A. (1998). Cooperative learning returns to college. *Change, 98*(4).
7.	INFO SESSION RECRUITING	UMC 235
8.	Argumentation/ Metacognition	Jimenez-Aleixandre, M., Rodrigues, A., & Duschl, R. (2000). "Doing the lesson" or "doing science": Argument in high school genetics. *Science Education, 84,* 757-792. Schoenfeld, A. (1987). What's all the fuss about metacognition? In A. Schoenfeld (Ed.) *Cognitive Science and Mathematics Education* (pp. 189-215). Hillsdale, NJ: Lawrence Erlbaum Associates.

9.	LA FCQ Classroom Observation 1	Analyze FCQ data collected from your students. Prepare CR Obs #1 ~Professional Learning Communities
10.	TBA	TBA
	Spring Break	
11.	Multiple Intelligences and Differentiated Instruction	Armstrong, T. (2000). MI and cognitive skills. In *Multiple Intelligences in the Classroom* (2nd ed.). Washington, DC: ASCD. Tomlinson, C. A. (1999). *The differentiated classroom*. Washington. DC: ASCD.
12.	The Nature of Science/The Nature of Mathematics	Lederman, N. G. (1998). The state of science education: Subject matter without context. *Electronic Journal of Science*, *3*(2).
13.	Qualities of Effective Teaching; Second Classroom Observation Consultation Classroom Observation #2	Stronge, J. H. (2002). *Qualities of effective teachers*. Washington, DC: ASCD. Palmer, P. (1997). Teaching in the face of fear. *National Teaching and Learning Forum, 6*(5).
14. **(Second Article Report due)**	Future in Education	Article TBA
15.	Poster Session	**Final Poster Projects Due**