Beliefs, Intentions, Actions, & Reflections (BIAR)

A New Way to Look at the Interactions of Teachers and Students

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Abstract

An accurate, nuanced capturing and characterization of student/teacher behavior inside and outside the classroom is a necessity in today's education reform. In this paper, a new framework, called the BIAR (Beliefs, Intentions, Actions, and Reflections) Student-Teacher Interaction Model, is introduced. This tool incorporates the use of TDOP (Teaching Dimensions Observation Protocol) in classroom observations alongside student/faculty interviews, stimulated recall sessions, and electronic surveys. Once gathered, the data can be compared and rated for their degree of correlation. While the work in this project wasn't aimed at making any specific claims about the practices of teachers or students, the introduction of the BIAR Model provides a structure for future work in this area.

1

Introduction

2015 – There is a palpable resentment toward most things Education in American society. The higher education system forces Americans to pay upfront for higher education with "astronomical tuition bills" or finish school with "enormous debt that demands fixed, sky-high monthly payments the moment [students] graduate and enter the work force" (Spitzer, 2009). Students in America are consistently placing low on global tests – the US ranked 30th in mathematics and 23rd in science on the 2012 PISA (Program for International Student Assessment) report[1] – compared to students in many other countries such as China, Japan, Ireland, and the Netherlands (Chappell, 2013). Indeed, there seem to be plenty of reasons for the desire among Americans for systematic change in this country's tackling of education. Even American's politicians and policymakers emphasize education reform. Michelle Obama called education the "single most important" civil rights issue facing the country (Superville, 2015). Education is an especially hot sociopolitical topic.

It may seem like an entire cultural revolution may be necessary in American schooling and as such, there is – now more than ever before in history – a societal need for increased focus on education research. The advances made in pedagogical theory and institutional reframing will pave the future of education in America and provide the solutions to today's problems.

One such problem facing American education is the shortcoming of education in Sci-

[1] PISA reports are issued every three years and rank the test performance of 15-year-olds from 65 countries from across the world. The next assessment will be conducted this year (2015) and will assess mathematics, reading, and science literacy in more than 70 countries and educational jurisdictions (National Center for Education Statistics, https://nces.ed.gov).

ence, Technology, Engineering, and Mathematics (STEM) fields. Indeed, since Thomas Friedman told us about the leveling-out of the global economic landscape in his book, *The World is Flat* (2005), many Americans have latched onto the idea that India and China will bypass the American economy by "outSTEMming" the United States (Sanders, 2009). This popular anxiety was given political acknowledgement when President Obama introduced the Committee on Science, Technology, Engineering, and Mathematics Education (CoSTEM) in 2010 as part of the America Competes Reauthorization Act. This team was tasked with creating a five-year plan to improve the field of STEM Education. In 2012, another committee, the President's Council of Advisors on Science and Technology (PCAST), released a report to the President titled *Engage to Excel*, which called for an increase in the number of STEM graduates in America by a margin of one million for the United States to remain economically competitive in the modern world.

While these programs are aimed at boosting numbers in university graduation statistics, digging deeper into the proposed methods of *Engage to Excel* shows that the creators of the report were focused on the retention of students upon entering college and the encouragement of underrepresented groups to participate in STEM fields. Indeed, undergraduate STEM programs are frequently labeled "leaky pipes" (e.g. Black, 2012) for their propensity to allow most of the students that enter into their programs to "trickle out" – drop out of college or switch to alternative majors – before reaching the end of process. *Engage to Excel* outlines three main goals in its solution to the leaky pipe problem: "(1) Improve the first two years of STEM education in college, (2) Provide all students with the tools to excel, and (3) Diversify pathways to STEM degrees." Each of these objectives – except the latter – focus largely on enhancing the students' experience in undergraduate education.

Education reform may put an emphasis on developing what students face in their first years of college, but how well do policy makers know the current "student experience?" What are the relevant factors in the quality of an undergraduate's education? Unfortunately, the majority of the knowledge on today's undergraduate classrooms comes in the form of sporadic peer observations, end-of-term student evaluations, and self-reported data from teachers (Hora, 2013). The former technique is too unstructured and infrequent to make large-scale claims while the latter two are too subjective and have the potential to be untrustworthy. As we will discuss in the next chapter, research in psychology has consistently pointed out that memory-based and self-reported data can be unreliable. Furthermore, even if the data collected by these measures is accurate, surely there are areas of the student experience where faculty have limited knowledge. What aspects of the student experience are being completely missed in current investigations? If programs such as PCAST are to allocate serious resources toward changing the student experience, strides need to be made toward better understanding what the student experience looks like already.

Additionally, what about the factors in education that are not student-focused? Our next task should be to replace "student experience" with a term that encapsulates the full picture of the educational experience – not just the student side. For this broader definition, this thesis will use the term "classroom milieu." Let's define what this means for our

purposes.

In characterizing the classroom milieu, we can go beyond the "student experience" to include the corresponding concept on the teachers' end, the "teacher experience." Surely we shouldn't expect these two experiences – of the student and of the teacher – to be identical but we must include both of these sides in our description. We might then think of adding the environments in which students and teachers interact. The most obvious of these environment might be the physical classroom but we extend our description to include aspects of a class that exist outside of the lecture hall: homework, exams, office hours, email correspondence, etc.[2] This means the classroom milieu is so far composed of the student experience, the teacher experience, and the many environments that these experiences exist.

Our description doesn't end there, however; while looking at the macro details such as teacher experiences and classroom layout will inform educators and policy makers of how the issues in education manifest themselves in observable actions, there is a fundamental part of the classroom milieu that lies hidden from sight: the underlying beliefs of students and teachers. While the concepts of beliefs will be more thoroughly defined later in this thesis, we can briefly say that beliefs are an individual's fundamental ideas that underpin their theory of education – for example, "students are hard working individuals" might be a possible teacher belief. Beliefs are the "behind-the-scenes" of the student-teacher interactions. Attempting to address issues in the milieu without regard for the beliefs of the participants is like a doctor trying to diagnose a patient without a knowledge of internal organs: the surface-level symptoms of the disease may be treatable but the sickness will likely persist due to some problem(s) deeper within the individual.

Now we have bifurcated the classroom milieu into two main components: (1) the observable practices of students and teachers and (2) their underlying beliefs that act as foundations for these observable phenomena. While this does well to highlight some of the unseen characteristics of the milieu, there is much more nuance to the interactions of students and teachers than this binary definition suggests. In this thesis, we will discuss some of the work already done in looking at these two categories as well as expand the framing of the classroom milieu to include more of what goes on. We have introduced a new framework that shows promise in formalizing the examination of the classroom milieu in a tractable, scalable, and ultimately meaningful manner.

The new framework is called the BIAR Model (pronounced, "buyer"). This model separates the classroom milieu into four layers: the (1) Beliefs, (2) Intentions, (3) Actions, and (4) Reflections of students and teachers (Fig. 1). The goal of this thesis was to not only

[2] Indeed, there are myriad outside-of-class factors that might dictate the meaningful environments in undergraduate school. The social dynamic of college life, traditionally made up of relatively inexperienced adults living away from home for the first time, has a vast impact on the way students view their college years. The friends that students make, the jobs that students hold, and the extracurricular activities in which students participate, all of these factors are crucially important to understanding what student life is like today. Nonetheless, while this thesis won't ignore these topics altogether (their importance will be brought up again in Chapter 5), the main focus of this work is on the factors of the student experience that are based in education.

develop a new framework but to also test the usefulness of the framework in studying the classroom milieu. One might ask "useful for whom?" or "useful how?" and these questions will be addressed later individually. As mentioned above, however, this framework was crafted in hopes of describing the reality of undergraduate classrooms, not in hopes of assessing the value of that reality. The data collected through the BIAR Model could be used in support of some specific agenda – such as making undergraduate instruction more interactive – but this thesis focused on the data collection itself rather than the separate task of judging the value of what is collected.

The following chapters will discuss the existing methods of data collection in the classroom before explaining how the BIAR Model was developed. Each of the four BIAR layers will be discussed individually, first delving into what each layer means and then elaborating on how data is collected in each layer. It should be mentioned that the scope of this project is large. The goal of my undergraduate research was never to finish all of the work surrounding the BIAR Model but to propose the new framework and take the first steps in investigating the framework's utility. There is much more work to be done in validating the BIAR Model beyond the progress we have made in the past year. Nonetheless, the prospective usefulness of this new framework is encouraging and hopefully future efforts will be devoted to fully exploring BIAR and its place in education research.

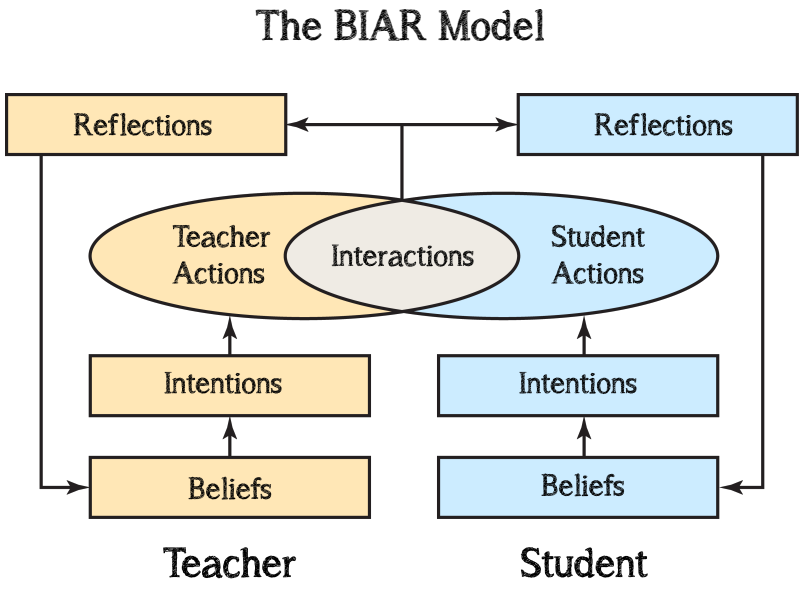

Figure 1 shows the BIAR Model, a new framework for characterizing the classroom milieu.

2

Background & the Model

While we mentioned that there is a necessity for a more refined manner in which to examine student-teacher interactions in the Introduction, the impetus for this thesis started largely from a desire to address a much more personal issue. I have felt for quite some time – as have many of my peers – that there is an unnecessary disconnect between students and teachers in classrooms. If only the teachers knew more of what students thought or if only students understood more of what teachers were trying to do, I thought, maybe some of the shortcomings of education (read: leaky pipes, PISA test scores, etc.) would naturally fix themselves. However, while this might be common student response to classroom difficulties, this simple description of education's problems is not a particularly informed one. The bulk of education issues are not things that can be resolved through counseling sessions between the students and teachers.

That being said, there is truth in saying that students don't know enough about the teacher side of the story and teachers don't know enough about the student side. Indeed, as we mentioned in the Introduction, even education research, a field devoted to studying the many facets of education, doesn't know enough about either side.

But what data are we collecting or have we collected on the classroom milieu? The next section will discuss some of the previous work done in examining classrooms as well as illuminate some of the things to consider when talking about the activity of students and teachers.

Existing Data on the Milieu

The majority of data collected on today's classrooms is in the form of intermittent peer evaluations, end-of-term student assessment, and self-reported teacher evaluations (Hora, 2013). Daniel L. Shacter singles out the problems of self-report data by citing the shortcomings human memory in "seven deadly sins": "transience, absentmindedness, blocking, misattribution, suggestibility, bias, and persistence (1999). Indeed, Shacter argues that these flaws in memory are actual "by-products of otherwise adaptive" parts of memory. Humans have evolved to have these unreliable tendencies in their memory. As such, data on the classroom milieu should not rely on self-reported data.

So what else can be done? Indeed, there have been considerable efforts devoted to characterizing the reality of classrooms, specifically the beliefs of teachers (see Pajares, 1992; Postareff, 2008; Sameulowicz, 2001; Spike, 2014; and others). This helps in the formation of theory for the procedures used in the BIAR Model that we explain later in Chapter 3. For instance, Benjamin Spike discusses the idea of stated beliefs vs. enacted beliefs (2001). This was a large motivator in the structure of the BIAR Model. There are ideas that individuals have and then there are the things that actually happen in the classroom. For this thesis, we kept the stated beliefs as simply "beliefs." These are the actual fundamental ideas that the individual holds. As for the enacted beliefs, we changed the label to practices – at first – as these are acted out buy the individuals.

In our early thoughts, we found the need to have a step between these two initial layers. Something must mediate the transition from an abstract concept to an observable action. For example, a teacher might believe that it is their job to "coach" students with a friendly, cooperative rapport. An observer might then observe this teacher kneeling next to students in class as he or she helps them work on a problem. These are the two layers as we've discussed thus far, but what was the thing that led this teacher to kneel? They must have *intended* to minimize intimidation between themselves and the students through their body language. This is motivated by their beliefs and is realized in their actions. Thus, we arrived at an initial concept of beliefs, intentions, and practices.

From this theoretical background, we developed our first draft of the framework for examining the classroom milieu. This chapter describes how the BIAR Model came about from the initial versions of the framework. It should be noted that this framework is a *grounded theory*. This means that the data collected is meant to inform the procedures used to collect future data (Strauss, 1990). In essence, as more data is uncovered through the process, the framework will be adjusted accordingly. Before arriving at the BIAR Model presented in the Introduction, many versions of the classroom milieu framework were generated – and modifications to this framework may still be impending. While earlier versions were never used in data collection, it is useful to discuss the steps that lead to the BIAR Model and the theory that motivated the decisions along the way. In discussing this progression, much of the background theory in which the BIAR is grounded arises naturally. The next section outlines each version of the model that we made and the faults in representation that drove us toward the BIAR.

Five Layers

The initial framework for describing the classroom was the "Five Layers" Model. We broke the classroom milieu into five categories stacked on top of one another like sedimentary rock layers in sandstone. The layers were (1) Teacher Beliefs, (2) Teacher Intentions, (3) Practices, (4) Student Intentions, and (5) Student Beliefs arranged from top to bottom in chronological order (Fig. 2). The Five Layers model was a natural first framework that showed how beliefs led to intentions, which then led to actions – moving from the outer layers of the diagram and stepping inward toward the middle. The layers also made it easy to visualize the comparisons between the different categories of the milieu. Diagrammatically speaking, it was easy to visualize comparing first and third layers – how do the teacher's beliefs correlate with what they do in the classroom? – or the second and fourth layers – are the intentions of teachers and students at odds with one another?

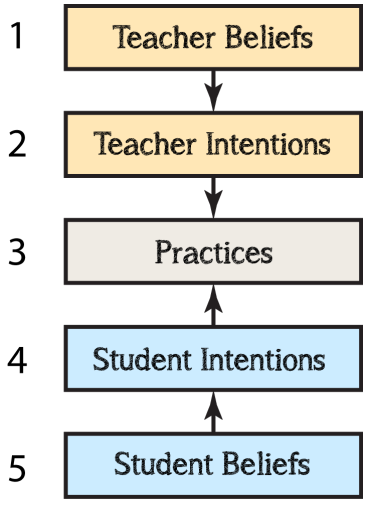

Figure 2 shows the initial framework for describing the classroom milieu, the Five Layers Model. The model incorporates the beliefs and intentions of students and teachers as well as the practices that both exhibit in the classroom.

While this arrangement was intuitive to work with at first, it became apparent that there were some unfortunate connotations that the Five Layers model suggested, connotations that other potential representations could avoid. For one, having an arrangement where the teacher side is placed vertically higher than the student side seemed to suggest some hierarchal relationship. While no value was ever explicitly assigned to the relative vertical positions of any of the layers, it's easy to imagine a subconscious – or even conscious – effect of arranging topics in this manner, a structure that is often used for ranking things as better or worse. Teachers sit on top of the classroom milieu in some privileged position while the students are in a categorically lesser position. Additionally, teachers'

practices in the classroom appear beneath them while the students must strive to measure up to the standards of educational practices. The Five Layers Model seemed to emphasize a pitting of teachers against students in some struggle for power.

The Power Problem

The power dynamic between teachers and students is a complicated topic with a history of research already committed to understanding its nuances. We make no effort to revisit this topic in its entirety but will include a brief discussion of the ideas that motivated changing the Five Layers Model.

Traditionally[3], education relied on a mode of interaction between students and teachers where most, if not all, the power in the classroom lies in the hands of the teacher. Within this dynamic, "learners must submit themselves to teachers" (Menges, 1977) as part of the educational process. This viewpoint asserts that without the "communication of power by the teacher over the student," learning simply doesn't occur. The paradigm of traditional education seemingly necessitates teacher-centered power.

Others have shown that while a "certain degree of teacher power is always present" in a classroom setting, the more that power is used by a teacher, the more likely that power will be required to control the students further (Hurt, Scott, & McCroskey, 1978). It seems that power begets the need for more power in order to have a functioning classroom in the traditional sense.

For a more in depth discussion of power's role in the classroom, consult such works as McCroskey & Richmond's *Power in the Classroom* series – published in many parts, starting with *Power in the Classroom I: Teacher and Student Perceptions* (1982) and continuing on to other topics such as *Teacher Communication Techniques as Alternatives to Discipline* (1983) and *Behavior Alteration Techniques, Communication Training, and Learning* (Kearney, 1985). The former of these explored the methods that teachers used demonstrate their power over students and how well the perceptions of these methods by students and teachers were aligned or not aligned. The study found that the students' perceptions of teacher methods were not isomorphic with the teachers' perceptions of their actions.

While the findings of this series are informative, the research started from the viewpoint that teachers are the holders of power. Whether or not this is valid for the majority of classrooms, we didn't want to make this part of the assumed structure of the classroom milieu for this thesis. In the style of true descriptivism, we argued that there is a theoretical classroom where the students hold the majority of the power and as such we should present power as a dynamic variable that is shared between students and teachers – without emphasis on either party as the main power holder. Prescribing that teachers hold all of the power could prevent the authentic observation of a classroom where students hold

[3] The term "traditional" here refers to the standard mode of "sage on a stage" instruction prevalent before efforts were devoted to making education more interactive for students. This traditional mode centers on a teacher standing at the front of the room dispersing the information to the students rather than engaging students in discussion and active inquiry.

the power.

In the Five Layers Model, the student side and of the classroom milieu was presented as the less-powerful one, even if this was never stated outright. The framework needed to describe the classroom milieu with as little preformed bias as possible if we hoped for it to capture a more nuanced picture than the current methods. To remedy this problem, the teacher and student sides needed to be equally weighted in their spatial relationship to one another.

Beyond Five Layers

The solution to the power problem was to place the teacher beliefs horizontally adjacent to the student beliefs with the intentions layer for each side directly above and the practices layer again above these in the middle – we can call this Model 2 since a it's an intermediate version (Fig. 3). In this way, neither students nor teachers were visually prioritized. Instead, Model 2 presented the beliefs layer for both students and teachers on the bottom and each following layer was above it. While the Five Layers Model flowed inward from the beliefs layers on the outside, Model 2 had an upward flow from the bottommost layer on both sides. The beliefs of students and teachers were presented as the foundation upon which each successive layer was built.

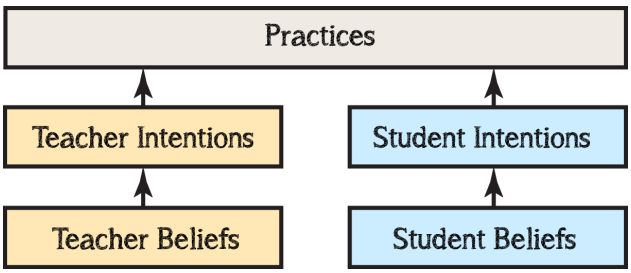

Figure 3 shows the Model 2 version of the framework for describing the classroom milieu. This version eliminates the negative hierarchical connotations of the Five Layers Model but still presents an oversimplified version of the practices layer.

Indeed, this adjusted model still left room for subconscious – or conscious – associations of meaning with relative placement of categories. However, the hierarchal connotations of the Five Layers Model were traded for the connotation that beliefs were the foundation of the classroom milieu. Some users of the model might still argue that the beliefs being on the bottom devalued them just as the students were devalued in the Five Layers Model. This interpretation of the model is possible but it is likely that just as many users will interpret the model as we've described above. Indeed, even if a user thinks that the diagram is rating beliefs below the other categories, this is a much better association than the negative connotations of the Five Layers Model.

The only way to avoid any vertical value connotations in the model would be to place all of the layers on the same horizontal line. For one, this is a less efficient use of space, as the model would stretch considerably wider than the Five Layers Model or Model 2. The model would be long and skinny rather than more equally sided – like a square. Any time that the diagram would be used, it would have to take up the whole width – or at least most of the width – of the page in order to maintain the legibility of the layers. Additionally, while a horizontal arrangement might avoid vertical value judgments, it would also lose the connotation that beliefs are the underpinnings of the following layers. Overall, we decided that the Model 2 was a definite improvement on the Five Layers Model.

Still, this version was still not an adequate framing of the classroom milieu. The Model 2 made it increasingly obvious that the top "practices" layer was an oversimplification of the activity of students and teachers. As the rest of the diagram was already divided into a teacher side and a student side, a first logical modification to the practices layer was to divide it into a corresponding teacher practices and a student practices side. Indeed, based on the theory of past beliefs vs. practices research, this may have been seen all the way back in the Five Layers Model. The teacher beliefs needed to be compared to *teacher* practices rather than just the overall practices of students and teachers combined.

Upon dividing the practices layer, however, it became evident that there were now two sides of the classroom milieu separate of one another. While many of the aspects of the classroom milieu can be considered in terms of separate student and teacher sides, surely the two sides must meet somewhere. So where do the students actually interact with the teachers? In an attempt to answer this question, we turned toward the philosophies of early activity theory.

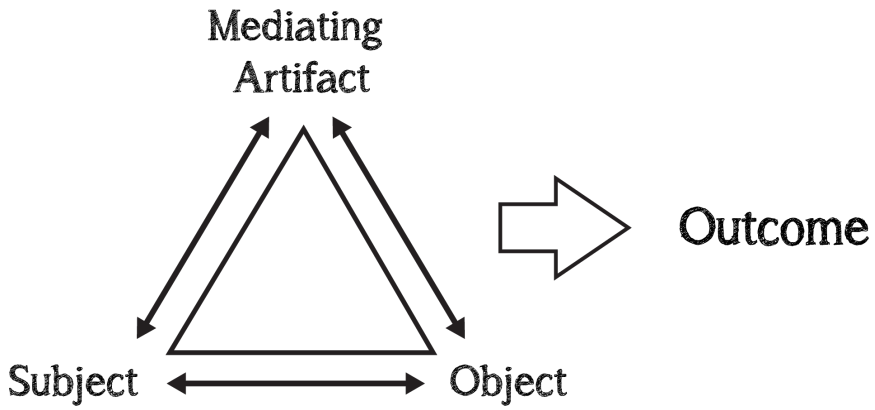

Figure 4 shows the simple activity triangle used to expand the practices layer of Model 2. Much of the details of activity theory will manifest themselves in the later discussion of how data is collected in each of the layers.

Stemming from classical German philosophy such as Kant, the writings of Marx, and later from the cultural-historical psychology of Vygotsky, Leont'ev, and Luria, activity

theory is socio-psychological approach to describing the actions of individuals that emphasizes the mediation of activity with artifacts (Engström, 1999). In its simplest form[4], activity theory incorporates four main components to any activity sphere: a subject, an object, a mediating entity, and the outcome (Fig. 4). The subject is the individual being studied and the object is the thing they are trying to achieve. The mediating object is some artifact that is part of the process that the subject uses to achieve the object. For example, if the subject is a basketball player, their object might be scoring a basket and mediating artifact could be the player's teammates, his/her fancy basketball shoes, or the players on the opposing team. Indeed, there are too many mediating artifacts in most situations to list them all at a time but the important thing to recognize is that, as a subject is moving toward their objective, activity theory puts emphasis on the mediating factors.

In our framework, we have two subjects – students and teachers – with their own objectives and mediating artifacts. When we frame the practices layer of the class milieu, we must consider the both the objects of students and teachers – what kinds of things are they trying to achieve? – and the mediating artifacts involved with those objects – what do they use to achieve these things? First of all, we need to use this combine the separated sides of our classroom milieu model. The key to this is that in student-teacher interactions, teachers are mediating artifacts for the student-based objects in a classroom and students are mediating artifacts for the teachers' objects. Surely, there are many practices that students engage in that are not mediated by the teacher and vice versa. However, the opposite party must mediate the *interaction* of students and teachers.

To represent this in the classroom milieu model, the practices layer of Model 2 can be replaced by an overlapping of student actions and teachers actions in the manner of a Venn Diagram (Fig. 5) – this can be Model 3. The region that is only student action or only teacher action is representative of the instances where the opposite party is not the mediating artifact. The region of overlap in the middle is representative of when teachers are one of the mediating artifacts for students and students are one of the mediating artifacts for teachers. While the diagram doesn't necessarily show the borrowed concepts of activity theory explicitly, the Venn-style actions layer showcases the combining of the two sides in Model 3. The details of activity theory will be more evident in the explicit investigation of each of the layers as discussed later in this chapter.

[4] Activity theory has been developed immensely over its lifespan, especially in the last few decades after the theory gained popularity outside of Russia. For the purposes of this thesis, the simple triangle of factors shown in Figure 4 are sufficient.

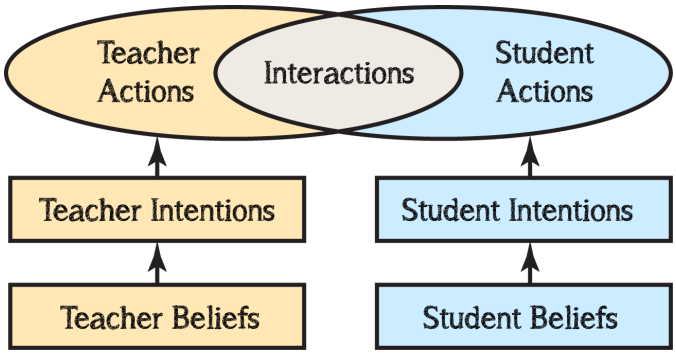

Figure 5 shows Model 3 which incorporated some of the concepts of activity theory to expand the practices layer of Model 2. While this is close to the final BIAR diagram, there was still a large part of the framework missing.

However, the influence of activity theory on the diagram was still not yet fully realized in Model 3. As explained above, activity theory emphasizes *four* key components of any activity. So far, Model 3 only incorporated the ideas of the first three, leaving out the concept of results. So in an effort to apply this concept to the classroom milieu, one might ask, what kinds of results are there from student-teacher interactions?

Indeed, there are a wide variety of these results in any given class, ranging from effective learning to a low grade on an assignment. In fact, these results – usually in the form of grades – might be some of the aspects that students and teachers focus on the most in the classroom milieu. This thesis was not so concerned with the performance of students on tests or homework, however. Instead, the purpose of the framework was to describe the educational milieu in a manner without prescribing any structures on the classes. Just as we mentioned in our discussion of power in the classroom, there might exist some class where convention is broken and grade-based results are not emphasized. A truly descriptive framework shouldn't impose this narrower framing of results. Still, to ignore this concept of results altogether would be to limit the framework drastically.

As a compromise, we introduced a final layer into the framework, reflection, that completed the BIAR Model (Fig. 6). The idea was to focus less on the results themselves and put more emphasis on how the results of the class were used by the students and teachers to inform future classes that the students took or the teacher taught. The results are still part of the framework but might simply be thought of as being the arrows that connect the interaction region to the reflection layer. The arrows that connect from the reflections layer back down to the beliefs layer on both sides emphasize the manner in which reflection can be used in the educational milieu as students and teachers adjust grow in their roles.[5]

[5] It may seem that the reflections made by students or teachers sometimes bypass the beliefs layer completely and affect the intentions or actions layer directly. We maintain that such reflections must have affected some belief indirectly before any intention or action is altered. Students or teachers may largely do this process unconsciously but it is still very much a part of the classroom milieu.

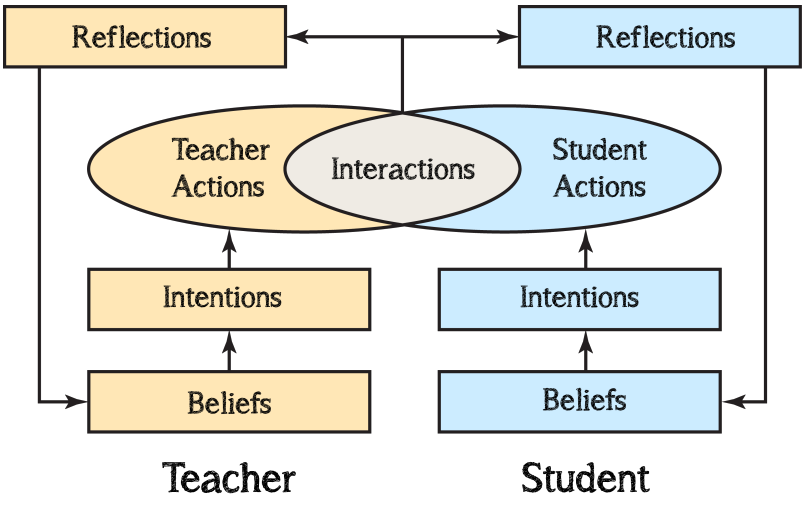

Figure 6 shows the final BIAR Model framework for the classroom milieu. This is the same diagram as is shown in Figure 1.

With the model completed and discussion already begun concerning the arrows surrounding the last layer of the diagram, it is fitting to discuss shortly what the arrows might represent in between the first three layers. As an arrow leads from one layer to the next, it should represent the aspects of the classroom milieu that mediate the gap between the layers within the individual. In the case of the Beliefs-Intentions arrow and the Intentions-Actions arrow, it seems the mediating aspects are the constraints and opportunities that the individuals face – either imposed by the institution, themselves, or even by the opposite party. For example, a student might hold the belief that they should devote themselves fully to a class they are taking. However, this student is taking 18 credit-hours during the semester in question and is busy enough that they only intend to spend 5 hours a week on each of their classes. The constraints of time management in a heavy course-load affect how the beliefs of that student form into intentions. Likewise, an observer might see that the student actually participates in actions that pertain to this class for 7 hours out of every week because they engage in meaningful discussions with their peers lose track of time in office hours. This time, an opportunity that was presented by the student's peers affected how the student actually acted beyond their intentions. The arrows that connect the first three layers represent these kinds of constraints and opportunities.

Before we move on beyond the discussion of the diagram, it is worthwhile to discuss the concept of reflection in more depth. The other layers of the BIAR diagram were already given a short introduction earlier in this chapter. We will devote a lengthy explanation to the reflection layer here as the theory for this layer is less established in the literature.

Reflection

The inclusion of the reflection layer was made rather quickly in the above description. In an effort to slow down and define the term, we start with some literature discussion of the topic. Reflection as a concept in education is used commonly and, as such, others have already taken time to discuss its role in the classroom milieu.[6] For example, in *Reflection: Turning Experience Into Learning*, David Boud, Rosemary Keogh, and David Walker discuss the importance of reflection and from where it stems. The authors start by emphasizing that "the activity of reflection is so familiar that […] teachers or trainers […] often overlook it in formal learning settings" (1985). Indeed, the act of reflection is common enough in our society that it blends into the background with the many other ordinary occurrence of everyday life. These authors claim the act of reflection is so commonplace that we regard it as a "natural event in our culture – as natural as breathing."

Perhaps society's familiarity-blindness with reflection has to do with the fact that the topic has been an integral piece of the discussion on learning for centuries. Indeed, it has been noted that Aristotle's writing on practical judgment and moral actions in *Ethics* references reflection in learning (Grundy, 1982). More recently, John Dewey reported on the importance of reflection with his discussion of "reflective activity" in learning (Dewey, 1933).

In his report, Dewey emphasized two types of experiential processes that led to learning: (1) trial and error and (2) reflective activity. The former was of limited value to the learner since the knowledge gained was specific to the certain problem at hand and restricted to the extent of the trial and error investigation. By contrast, reflective activity was where effective problem solving took place. For Dewey, reflective activity was the key to understanding the connections between the parts of an experience (Boud et. al, 1985). Much of Dewey's work in defining reflective activity paved the way for modern education theory (Grundy, 1982) and integrated the concept as a staple of vocabulary in education discussions.

Indeed, Dewey's discussion of reflective activity is the most applicable to how we use reflection in the BIAR Model. In particular, one aspect of Dewey's theory on reflection pertains to our purposes: he claimed that reflective activity is a feedback loop between the experiences of the learner and the connections that they make (Dewey, 1933). This is the exact role that reflection takes in the BIAR model. With the inclusion of this category in the diagram, a loop was created that flows from the beliefs, intentions, and actions of an individual and eventually feeds through reflection back to their beliefs. Reflection is the process by which students and teachers learn from the results of their interactions so that they can develop their beliefs into a more-informed version.

[6] Though such literature doesn't use the "classroom milieu" term that we've defined in this thesis.

This may be a good time to discuss *who is the BIAR useful to*?[7] In the case of reflection, it might be predicted that students and teachers don't reflect as much as is desired by the institution in which they are active. Administrators may see the classroom milieu as a stagnant structure that doesn't better itself through iterative reflection. The BIAR Model could provide a means for institutions to show students or teachers that there is a need for more reflection in the classroom milieu – perhaps by showing a student or teacher that the data collected from the beliefs, intentions, and actions layers don't agree with one another or by showing them that results from interactions were not of the desired form. The benefit of the BIAR Model in this instance is that it provides a based-on-data method to look at the classroom milieu and provide formative feedback to students and teachers. Especially for the teachers who might find the judgment of their work as too subjective and punitive, providing them with data that is less observer-biased could be a more convincing tactic in realizing institutional change.

This brings up the next point, however: how is data collected in the BIAR and what can be done to minimize observer bias? The next chapter will look at each of the four layers individually and show our proposed methods for collecting data within them. As the final part of this chapter, a summary of the progression of the framework is provided in Figure 7 The figure shows each of the versions of the model discussed above and provides a nice perspective on from where the final BIAR Model was derived.

[7] Be wary, while we discuss a potential application of the BIAR Model in institutional change here, we are not changing the purpose of the project: to develop a descriptive framework for the classroom milieu. Nonetheless, it is useful to mention some of the apparent uses for the BIAR Model as they arise in the mention of other topics.

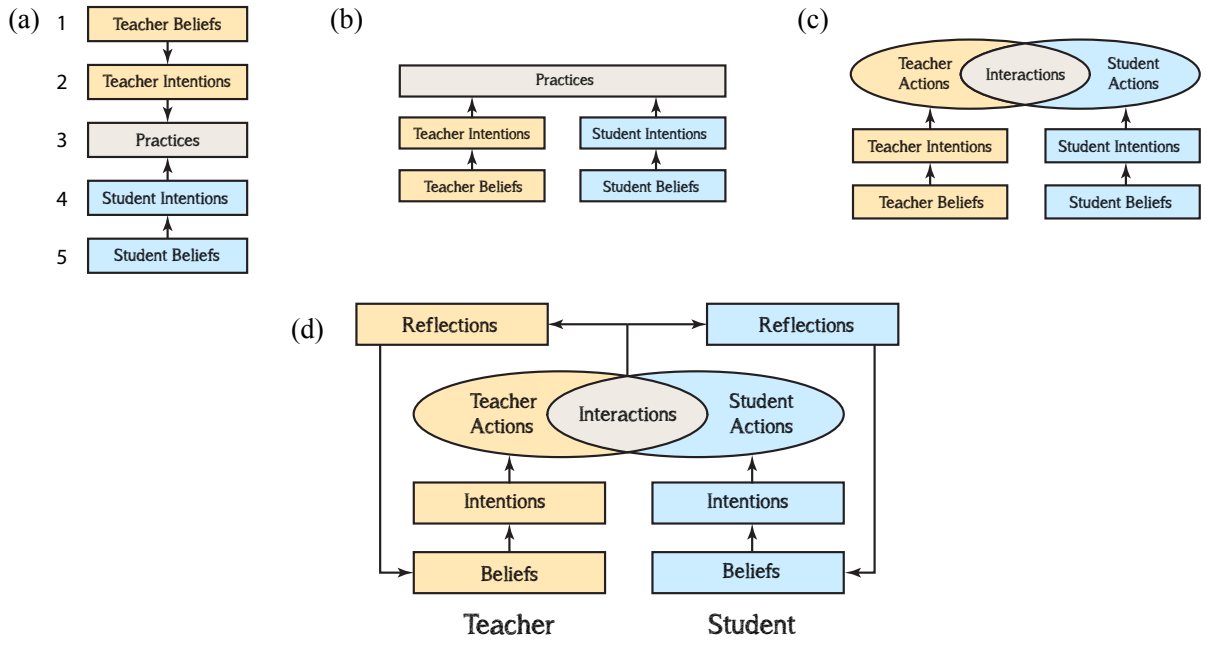

Figure 7 summarizes progression of the various versions of the framework from (a) the Five Layers model to (b) Model 2, (c) Model 3, and (d) the final BIAR Model. The formation of new visual arrangements was largely motivated by the desire to eliminate negative connotations such as hierarchal preference to teachers while promoting positive connotations such as the foundational nature of beliefs and the iterative suggestion of a feedback loop.

3

Data Methods

With the diagram complete and the theoretical BIAR Model finally constructed, we can now discuss how we would collect data in each of the four layers. In an attempt to collect meaningful data within each of the BIAR layers, we assigned different data collection methods that fit the nature of the layers themselves. While they might not capture the full breadth of the data in each layer, these data collection methods were a first step in characterizing the classroom milieu in the framework of the BIAR Model. In this next section, we look at the protocols individually. The International Review Board approved each of these protocols for use in a Human Subject Research Study and proper treatment of each individual studied was ensured throughout the data collection and analysis process.

Beliefs

As is typical in education research focused on the beliefs (see Chapter 2), the method of data collection used in the beliefs layer was individual interviews. The questions used in these interviews were largely borrowed from similar interviews being conducted by Melissa Dancy in the Physics Education Research Group at the University of Colorado Boulder. For the full versions of the interview protocols – both the teacher and student versions – please see Appendix A. The questions in these interviews were aimed at uncovering the fundamental ideas that teachers and students held about the classroom milieu.

For example, one of the questions we asked teachers was, "If you were to describe the students in this course to new faculty member, what would you tell them to expect?" This question is designed to uncover some of the general concepts that the interviewed teachers held about the students in their classroom. The goal of theses interviews was to pro-

duce a nuanced account of what the individual thought about the many facets of the classroom milieu. This descriptivist mentality meant that the interview process was approached more as a conversation between the interviewee and the interviewer than a interrogator prompting their subject with a set list of questions. Each topic to be discussed in the interview was listed in the protocol as a guide for the interviewer. In conducting the interviews, however, we focused more on steering the responses of the interviewees from topic to topic with more of a conversation-like dialogue. The interviews were originally designed to be about 1.5 hours in length but were later changed to less than an hour[8] for reasons discussed at the beginning of Chapter 5.

Intentions

In order to measure the intentions of students and teachers in the classroom milieu, we chose the technique of stimulated recall. This involves taping a lecture – or some other environment in the actions layer – and watching the recording with the students or teachers while asking them to elaborate on what they were intending to do with each action. This process is designed to get around the faults of human memory and allow the student or teacher to explain why they did what they did in a certain situation.

In his use of stimulated recall in 1953, Benjamin Bloom at the University of Chicago reported having as high as 95% accuracy in so called "checkable" events (1953). This work suggests that stimulated recall produces much more accurate representation of an individual's mindset from a past event than conventional memory alone. Since then, many other education researchers used stimulated recall in their studies of teacher cognition in the 1970s and 80s (see Calderhead, 1981; Clack & Peterson, 1981; Marland, 1984) with similar success. By using this in data collection method for the intentions layer of the BIAR Model, we can understand the intentions of an individual in a much more reliable way.

It might be noted that the stimulated recall is a technique that gathers data in a retrospective manner – the data collection is conduction after the event itself has taken place. This is because asking an individual about their intentions before they do anything is essentially just another form of asking them about their beliefs. Instead, if an individual has done an action, then the projection of his/her belief onto the real world – through all of the constraints and opportunities that the real world holds – has taken place and the intention can be examined. The process of acting forces the intention to become real, much like the collapsing of a quantum wave state through observation. Retrospective data collection is, therefore, the only means of really examining true intentions.

[8] The protocols presented in the Appendices are all the final versions after all revisions within the scope of this thesis had taken place.

Actions

The actions layer of the BIAR Model is the broad region of the classroom milieu where students and teachers display activity in a given course. As mentioned earlier, this layer incorporates lectures, homework, tests, office hours, email correspondence, and the many of other realms where students or teachers inhabit during their work or studying. Indeed, a whole series of research projects should be devoted to developing the protocols to collect meaningful data in this actions layer. Instead of tackling all of these realms in this thesis, however, we focused on only the lectures. This decision was largely made due to the fact that we had experience as a team running classroom observations.

In studying the actions of teachers and students in lecture, we used a recently developed protocol called the Teaching Dimensions Observational Protocol (TDOP). TDOP is an instrument designed by Matthew Hora and a team from the University of Wisconsin (http://www.wcer.wisc.edu) aimed at providing a nuanced description of teacher behavior during a lecture (Hora et. al, 2014). The protocol began development in 2009 as a tool for middle school science classrooms but has since then undergone extensive revisions with newer version of the protocol being released multiple times a year online. By the time we started using it, the tool had already been used in several universities across the country.

To use the TDOP, an observer logs into the TDOP website (tdop.wceruw.org). For the given class period, the user is then prompted to assign any number of codes[9] to every 2-minute interval of the lecture or presentation being observed as a way of describing student or teacher behavior. The codes are a simple "check-box" to confirm that a certain practice was observed at least once during that particular 2-minute interval. For example, the LVIS code – short for "Lecture with Visual" – would be selected if the lecturer was observed "talking to the students while referencing visual aides, such as slides, transparencies, posters, or models" (Hora et. al, 2014). The observer can check all or none of the boxes within each 2-minute interval and is also encouraged to jot down any notes in that time frame that describe events that the codes might not capture entirely. Through observing a class with the TDOP, students' and teachers' behavior can be characterized very specifically throughout the length of the lecture.

One of the tremendous powers of the TDOP is that a user can define their own codes. The protocol has a bank of built in codes already loaded but a user has the option to omit, redefine, or swap any of these codes within their study. This flexibility of the instrument allows every observation session to be tailored to the specific research question(s) that any team might have. This was one of the hallmarks of the TDOP that led us to use this it instead of others such as the Classroom Observation Protocol for Undergraduate STEM (COPUS) protocol or the Reformed Teaching Observation Protocol (RTOP), both of which are commonly used in classrooms to observe teacher and student behaviors. Other protocols don't offer the same flexibility that the TDOP does in what you focus on in the observation of a course.

[9] For a complete list of the published codes, refer to Appendix B.

For the use in the BIAR Model, we decided to use the preloaded codes on the TDOP website with the addition of only one code, LT, for lecture tutorials. This additional code was added due to the fact that there were many times when a tutorial was being used in the classes being observed but there was no existing code to uniquely describe the phenomena. Other than this single new code, we only used the preloaded codes in this thesis because we had no reason to believe that these codes wouldn't work from the outset. Hora and his team at Wisconsin have put in a good deal of work into defining these codes in a way that would capture the activity of teachers and students in a classroom. Without any motivation to alter the codes, we included the whole list (Fig. 8).[10]

Other major benefits of the TDOP are that it leads to objective observations and that the results are quickly and easily displayed for evaluation. Due to the check-box approach of observation, the TDOP allows raters to describe an instructor without passing judgment on the practices being used. This reduces an observer's bias about certain pedagogical techniques that might interfere with an honest evaluation of the teacher's behavior. Additionally, the data collected is output in an easily manipulated format so that it can be represented graphically in a variety of clear ways. This observation-to-graph step is all done for the observer in the website.

In running the TDOP for this study, we would observe around 5-10 class periods spread out over the course of a month. After getting permission from a teacher to run our study, we would conduct our observations without warning the professor of when we were coming. In this way, the teacher wouldn't plan their lesson differently than normal and the observation data collected would be a more accurate representation of the typical class period. By observing several classes, we could average the data on behavior and declare with even greater confidence the types of practices students or teacher tended to use.

Inter-rater reliability (IRR) of this tool wasn't checked directly with the data collected for this study but I was the only one to do observations. While this doesn't ensure that the data I gathered was particularly accurate, it means that we didn't have to worry about data not being comparable between two sessions. Also, I ran a short, informal pilot study of the TDOP the semester before I began my thesis data collection with a small team of undergraduate observers and we were able to confirm IRR with the same version of the TDOP. In practice, one can achieve desired IRR by having the raters observe the same class – or a video of a class – and comparing/discussing the data they collect to clarify any disagreements. This usually only takes a few iterations before raters agree on which codes to click when.

[10] As will be discussed in Chapter 5, these codes ended up capturing much of what the teachers were doing in lecture but did not capture as much of the students' activity. In future work, we may redefine some of the TDOP codes so that more of the student side is emphasized.

Teaching Methods

L	Lecturing
LW	Lecturing while writing
LVIS	Lecturing from pre-made visuals
LDEM	Lecturing with demonstration of phenomena
SOC-L	Socratic lecture
WP	Working out problem
IND	Individualized instruction
MM	Multimedia
A	Assessment
AT	Administrative task
SGW	Student group work
DW	Deskwork
SP	Student presentation

Student-Teacher Dialogue

IRQ	Instructor rhetorical question
IDQ	Instructor display question
ICQ	Instructor comprehension question
SQ	Student question
SR	Student response to teacher question
PI	Peer interactions

Instructional Technology

CB	Chalkboard
OP	Overhead projector/transparencies
PP	PowerPoint or other digital slides
CL	Clicker response system
D	Demonstration equipment
DT	Digital tablet
M	Movie, documentary, video clips, or Youtube video
WEB	Website

Potential Student Cognitive Engagement

CNL	Making connections to own lives/specific cases
PS	Problem solving
CR	Creating

Poedagogical Strategies

HUM	Humor
ANEX	Anectdote/example
ORG	Organization
EMP	Emphasis

Student Engagement

VHI	Very high
HI	High
MED	Medium
LO	Low

Figure 8 shows the list of TDOP codes used in this study. These are all of the preloaded codes on the TDOP automatically.

Reflections

To collect data on the reflections of students and teachers, we chose to use the method of online survey. The general premise was that the reflection portion of the BIAR diagram was similar to the beliefs layer but needed fewer questions. In-person individual interviews are often difficult to coordinate with busy students and teachers. However, if the individual has the opportunity to complete the survey at any point in the day - whenever is convenient – the logistical difficulties of scheduling time between an interviewer and interviewee is avoided altogether.

Questions on this survey would be centered on how students and teachers plan to use the results of a recent test, homework, or even the class overall to change their beliefs. It is likely that an individual won't think of this step in the classroom milieu. Nonetheless, asking students and teachers these questions should provide us with some insight into the reflection – or lack of reflection – that is taking place. For reasons discussed in the next chapter, a formal protocol was not developed for the reflections survey. The idea of using surveys was introduced but never acted upon for this thesis. This is yet again another area that future work should aim to explore.

4

Data

With established methods of data collection in place for each layer of the BIAR Model, the next step was to collect data and perform some analysis. For the purposes of this thesis, we were interested in showing that the data from BIAR (1) differentiated between individuals and (2) showed some consistency between the layers of the same individual. As the BIAR Model could be used as a tool for any number of purposes in a department, we will also show some of the possible ways to represent the data that might be meaningful for researchers.

Difficulties and Modifications

We set out to collect data in undergraduate classes at the University of Colorado Boulder in the fall of 2014. Professors were contacted about their availability to participate in the project via email. However, it became immediately evident that most professors were not interested in being a part of the study. Of the few professors that did reply, most respectfully declined participation on a couple grounds: they either didn't have time to contribute to the project on top of their many existing obligations or they were not comfortable with an undergraduate student analyzing their teaching. One of the professors that responded with the latter even stated that a lot of the professors that hadn't responded to our inquiry felt the same but just didn't want to care to reply.

This difficulty in recruiting teachers was not anticipated but it did suggest that changes needed to be made both in the structure of the BIAR study and in the manner that participation was requested. First, the time required of the subjects by the study needed to be minimized. To address this issue, two large adjustments were made to the procedures. As

most professors that we contacted were already decided that they weren't going to participate, we needed to trim the research project down significantly if any data was to be collected by the end of the semester. The solution was to focus on mostly the beliefs and actions categories of the BIAR framework[11], adjust the intentions portion of the data collection to be included with the beliefs, and then shorten the overall interview length to one hour total. With this adjustment, the professors would only need to find time for a single hour-long interview and then allow us to observe their classes with the TDOP. This interview would focus mainly on the beliefs of the professor but also included a short discussion on their intentions (see Appendix A).

In addition to this change to the protocols, we needed to change the manner in which we asked for participation. Instead of me, an undergraduate at the university, requesting permission from the faculty, we had my faculty advisor send the initial contact to the teachers explaining my study. In this way, the teachers were less likely to feel like an inexperienced undergraduate was judging their teaching. Also, we made sure to use language that emphasized that we were not trying to rate the quality of their teaching in our study.

While this adjustment to the data collection procedure was a drastic change, we knew that it would not prevent us from making some claims about the usefulness of the BIAR Model. The failure of the initial request for participation made it difficult to find teachers that would respond to a second request. Nonetheless, with some persistence, we were able to find teachers to volunteer their classes for the study.

The Study

The data collection was done in two stages. The first stage was completed in the late part of the fall semester in 2014 and focused on three physics courses. Luckily, even though our choice of course was limited, there was a good mixture of two upper division courses taught by very experienced teachers and a lower division course taught by a teacher who was new to the university. The data from this stage of the study was used to make slight alterations to the protocols. The second stage was then conducted in the spring of the 2015 semester after we reviewed the protocols from the fall. For this stage, we only observed one class to judge how well the adjustments worked.

In both stages we interviewed the teachers with the protocol as describe earlier. To obtain the student interviewees, we explained our study to the students at the beginning of a class period. The teachers then advertised our contact info on their website for students to use to volunteer for the project. In the case of one teacher, he actually referred individual students to me that he thought would be good to interview. This wasn't necessarily the desired method for acquiring student subjects as the selection process of the teacher might have some bias different than the self-motivated volunteer process. For ex-

[11] You will note that protocols are not included in the Appendices for the intentions or reflections layers. The issues with professor willingness caused us to focus on the beliefs and actions layers from a very early stage so while the general processes were decided upon for the intentions and reflections layers, the actual protocols were not generated into formal versions.

ample, it is very possible that all the students that the teachers sees as good interview candidates are the ones that make him/her feel good about their teaching. These students are more likely to respond to the questions in the favorable manner – toward their teacher – than a more representative sample of students.

Also, while we were looking for around 5 student volunteers from each course, it was difficult to obtain that number of students from some of the classes. The students were promised monetary compensation but, even then, many of those that agreed to meet with me didn't show up later to the interview. Because of this, the number of student interviews is much lower than desired for each class. In some cases, only one student came through to do an actual interview. In one class, no student volunteers were ever interviewed. This class – the course with Teacher 3 – was unique in the fact that it was a lab-based course with lecture component. The TDOP was run in the lecture portion but the bulk of the course was missed as the TDOP was determined to be ineffective in the lab periods.[12] Thus, the data collected for this course is less complete than the other courses. The breakdown of the data collected in this thesis by semester and by class is shown in Figure 9.

Fall 2014	
Teacher 1	Student 1
	Student 2
Teacher 2	Student 3
Teacher 3	-
Spring 2015	
Teacher 4	Student 4

Figure 9 shows the breakdown of the courses observed for this thesis. The first column lists the courses by teacher and the second column shows the corresponding student interviews that were conducted.

For an example of the interview data collected, refer to Appendix C, which includes a transcription of one of the teacher interviews. In any qualitative study involving interviews, the researchers must decide whether or not transcription will be beneficial for the data analysis process (Strauss & Corbin, 1990). For this thesis, the analysis of the interviews was done with the audio recordings themselves. Thus, transcriptions like the one in

[12] Running the TDOP in a lab section is possible but doing so would not be as informative as running the TDOP in a regular lecture. This is due to the fact that lab sections are very unvaried throughout their duration. With the code list used in this thesis, the codes that were checked in the first 2-minute interval would be the same as those checked in every subsequent interval. For this reason, some other protocol might be used in lab-type courses as they resemble non-lecture based environments more than lecture-based ones.

Appendix C were not made for every recording. An example of the TDOP data for the same professor is also included for comparison in Appendix D.

Once the data was collected, the next step was to do some analysis. Before we could analyze the data, however, we needed to establish some common criteria between the four layers. If comparisons were to be made throughout the many layers of the diagram – from beliefs of a teacher to their observed actions, for instance – then there needed to be some sort of way to relate the layers to one another. Comparing the data from the beliefs category to the actions category without underlying criteria would be like trying to compare two songs to one another without the vocabulary such as tempo, chord structure, melody, or lyric. These descriptors allow us to make informed comparisons of the two pieces. Similarly, the categories of BIAR needed some vocabulary of comparison if they were going to act as a meaningful framework for the educational milieu.

In the case of the BIAR categories, we generated five "categories" in which the data from each layer could be placed: (1) Role of Self, (2) Role of Others, (3) Expectations for Course, (4) Measures of Success, and (5) Structures and Technology. These categories were chosen with the hope that they would span the entire sample space generated by the data. In this way, any piece of data collected in the four BIAR layers would fit into at least one of the categories listed above. As discussed in Chapter 2, the BIAR framework was intended as a grounded theory. That is to say the data collected was to inform the analysis procedures. These five categories described here were not simply prescribed from our theory but were generated from careful consideration of the data collected. We initially brainstormed some of the possible categories to span the classroom milieu as a team and then reflected on the collected data to ensure that the five categories would work. If some part of the data didn't seem to fit with any category we had described, we shifted our definitions to generate a set of categories that left no data out. The results of that process are the five categories listed above. We offer a short description of the categories here:

Role of Self	The characteristics that the individual associates with their own role in the classroom milieu, either as teacher or student.
Role of Others	The characteristics that the individual associates with others in the educational milieu. For teachers, this category might contain the traits of students, other faculty, the institution, etc.
Expectations for Course	The characteristics of the course being investigated.
Measures of Success	The ways in which the individual or others assess how well things are going, either in the form of their actions or others' actions.

Structures and Technology — The influence of outside factors on the classroom as well as the tools used to accomplish the goals of the course.

Again, these categories were generated with the hope that they span the possible data collected within the BIAR framework. Nonetheless, as we will discuss in the in the next section of this chapter, the data collection for this thesis was fairly limited in scope. We were limited to testing the BIAR Model in only a few courses at our single university. Also, due to logistical barriers, we only collected data from two of the four layers within the BIAR. As such there is a large possibility that a future application of the BIAR would yield data that doesn't fit into any one of these categories. If this were to happen, these five categories would need to be adjusted. This adjustment to the theory through iteration is part of any grounded theory. With that being said, such a fault in these categories was not found during work on this thesis. This version of the five categories worked for our purposes.

You might note that the interview protocols included in the Appendix already have the questions divided into these five categories. This is because the protocols provided are the final versions generated after the fall data was collected. The original interview protocols had the same questions but they weren't grouped into these five categories. Also, Matt Hora and his team already The TDOP codes into subsections that are in the world of lectures (Fig. 8). However, the BIAR Model extends much further than the realm of lectures so the categories needed to be generated from a different motivation as we did above.

Analyzing Interviews

While the TDOP comes with a built in data analysis as part of the tool, we had to create our own method of analyzing the qualitative data from the interviews of students and teachers. To do this, we created a similar coding protocol that involves listening back to the recorded interviews in 2-minute intervals. The codes, listed by the category – role of self, role of others, etc. – in which they fit, are provided with short definitions in Figure 10. These were derived from the teacher interviews that we conducted and reflect the types of topics that were brought up by the teachers during their answers. The goal was to create a way to convert the hour-long recordings into a corresponding set of numbers just as the TDOP does for a 50-minute lecture. Instead of the simpler on-or-off coding method of the TDOP, however, the coding method for the interviews has the listener mark a +1 in the code if a statement was made that "agreed" with the concept represented by the code the and -1 if a statement was made that "disagreed" with the concept represented by the code. If the code is not observed at all during the 2-minute interval, it is left as a zero.

For example, one of the interview codes for teacher interviews is the "Homogeneous" code. This code exists under the Role of Others category and relates to the degree that the interviewed teacher believes that the students in his/her class are the same or different. If the teacher makes at least one comment like, "all my students are the same…"

then a +1 would be recorded next to Homogenous for that 2-minute interval. Alternatively, if the teacher makes at least one comment like, "the students are very different from each other in my class" then a -1 would be recorded for the same code. Indeed, if both of these comments were made within the same 2-minute interval then both a +1 and a -1 would be recorded. The +1/-1 scale is a representation of the interviewee's level of agreement with the concept represented by the code.

The idea behind this coding scheme is that it allows the rater to listen to interview in manageable chunks and record what was said about beliefs in a more objective manner. Indeed, there is still quite a bit of judgment required to run this type of protocol but the process is closer to a quantitative one than other methods such as a paragraph summary of an interview. The benefit of having the interviews converted into numerical data is that we can represent each interview with graphs and more readily compare the data to the corresponding data from the TDOP or other interviews. By counting the total number of +1's and -1's in any given code, the rater can see if the interviewee tended to agree or disagree with that concept. Also, the total number of times a specific code is given either a +1 or a -1 – in terms of the absolute value total – gives the rater a feeling for how important that certain concept was to the interviewee during the interview. A high total means that the subject mentioned this concept frequently while a low total means the subject mentioned the subject infrequently or not at all.

So what are the codes used? This is another area of this project that will be developed with future research. The codes presented here are the first attempt at generating quantitative data from the interviews. However, as more data is collected within the BIAR Model, these codes will likely be changed just like other components of the theory.

Role of Others (Student Characteristics)	Heterogeneous	The students of this class are the same as one another.
	Hard Working	The students of this class work hard.
	Proficient	The students of this class are proficient in the skills required to succeed.
	Interested	The students in this class are interested in the content that the class provides.
	Capable of Growth	The students in this class are capable of growing.
Expectations of Course	Content Goals	Content goals are emphasized in this class.
	Meta Goals	Meta goals are emphasized in this class.
	Student-centeredness	This focus of instruction in this class is shifted to the students.
Role of Self (Teacher Characteristics)	Powerful	The teacher sees himself or herself as a source of power in this class.
	Connected to students	The teacher sees himself or herself as connected to the students' thoughts and feelings about the class.
	Responsible for Information	The teacher sees himself or herself as a disseminator of information for the students to receive.
	Coach	The teacher sees himself or herself encouraging the students from a more even level rather than waiting for them to reach a certain standard on their own.
	Capable of Growth	The teacher sees himself or herself as capable of growth.
Measures of Success	Informal	In this class the teacher gauges how well they are teaching through informal methods.
	Formal	In this class the teacher gauges how well they are teaching through formal methods based on data.
	Value of outside measures	This teacher values the way that other people evaluate their teaching in this class.
Structures and Technology	Barriers for Students	The students in this class face outside barriers to their learning.
	Opportunities for Students	The students in this class are allowed outside opportunities to their learning.
	Barriers for Teachers	The teacher sees himself or herself as having to face outside barriers in teaching.
	Opportunities for Teachers	The teacher sees himself or herself as being allowed outside opportunities in teaching.
	Technology	Technology is used to achieve learning in this class.

Figure 10 shows the codes used to rate the interviews of teachers. A similar coding scheme was generated for students and is essentially the mirror image of this one.

This coding scheme in Figure 10 is for the teacher interviews. A similar scheme was created for the student side, which includes the same definitions but swaps the role of self and role of others codes. In this way, interview data from teachers can be more readily compared to the interview data for students.

As the goals of this data collection were to prove that we could differentiate between individuals and see some consistency in the data between layers, we now present some example data that focuses on these two goals. For this purpose, we compare the teacher interview data with the TDOP data – leaving the student side out. This is largely because the TDOP does a poor job of capturing student behaviors. Even creating some kind of connection between teacher codes from the interviews and teacher codes in the TDOP was difficult. Most of these codes simply don't overlap between the two coding schemes. Nonetheless, we found some areas that do cover the same concepts.

Within the "Expectations of Course" category, we have the Student-centeredness code – hereafter referred to as SC. This code should capture how much the teacher thinks the focus of his or her classroom is shifted to the students as active members. In the TDOP codes, there are four codes that especially seem to demonstrate how focused a class is on the students[13]: SGW (Small group work/discussion), SQ (Student question), PI (Peer interaction), and L (Lecturing). The first code represents when the observer sees students working in groups. The second code represents when the observer sees a student asking a question. The third code represents when the observer sees some kind of interaction between the students – usually including, but not limited to SGW. The fourth code represents when the observer sees the teacher lecturing at the students – specifically while they are not writing or using a visual such as a PowerPoint. This final code suggests the opposite student-centeredness. That is to say, if a class is more centered on the students as active members, then the L code should be lower. Conversely, if a class is focused more on the teacher as the active member, then the L code should be higher. By comparing all of these codes we should see some differentiation between the teachers. Also we should be able to make comparisons between the teachers' beliefs and their actions – between the interview data and the TDOP data.

Graphs of the abovementioned data are shown below in Figure 11. The top graph in each column shows the interview data for the SC code. The bar in the graph shows both the +1 and -1 totals – both of these are individually graphed and then a bar is drawn to fill the difference between them. In the case of Teacher 1, for example, there was a total of nine +1's and zero -1's for the SC code. Thus, there is a bar that stretches from zero to nine. As it turns out, all three of the teachers had no -1's in this code, meaning none of them mentioned that their classes were *not* student focused. This can be seen in the graphs as all the left ends of the bars are at zero. If a teacher had a total of three -1's and one +1 in the SC code then the bar would start at -3 and stretch to +1. This is a convenient way to graph the interview data as we can see the general lean of the teacher for each code from the overall placement of the bar either positive or negative. Also, we can see the im-

[13] Indeed some of the other TDOP codes might say some things about the centeredness of the classroom on the students. We chose to include these four codes as they were the more immediately evident of student-centeredness while I did the observations.

portance of the topic to the professor from the overall length of the bar.

The bottom graph in each column shows the four TDOP codes for the same three teachers averaged over the number of class periods observed. The bars are just the average number of times each particular code was clicked in the 50-minute class period. In this case, we might expect teachers that reported high student-centeredness in their interviews with larger averages for the first three bars – the SGW, SQ, and PI codes – and a smaller average for the last bar – the L code.

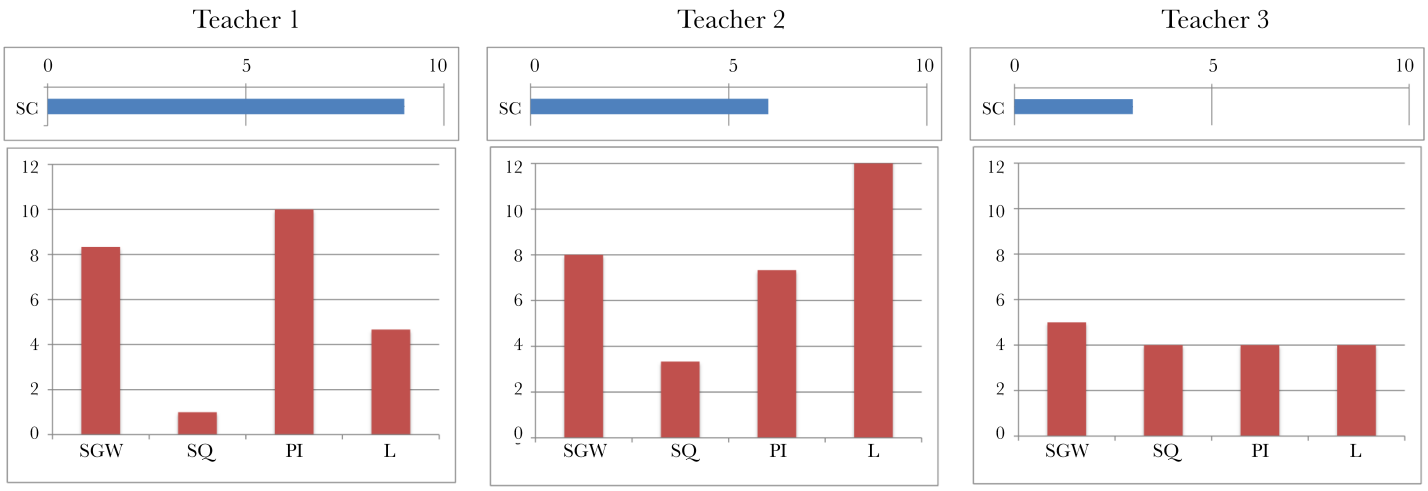

Figure 11 shows sample data from the three classes observed in the fall. The first row of graphs shows a selection from the interview data while the second row shows a selection from the TDOP data. Looking at these data next to one another allows us to check the usefulness of the data collection methods in the BIAR Model.

Comparing the six graphs to one another we see that there is decline in the belief of student-centeredness from Teacher 1 to Teacher 3. Teacher 1 believes his or her class is the student-centered more than Teacher 3 believes his or her class student-centered. In this way, it seems that the interview codes have reasonably differentiated between the teachers. Indeed, looking at the second row of graphs also seems to suggest that our protocol is providing different data for different individuals. This is good for the usefulness of the protocols we used. In this subset of codes, both the interviews and classroom observations describe the classroom milieu in a nuanced-enough way that different individuals are producing distinguishable data. While this doesn't guarantee that the data collected is *meaningful*, it does suggest that tools we are using are on the right scale within an order of magnitude.

Looking closer at the bottom row of graphs, we see that there isn't a consistent trend in the bars that matches the expectation from the interview data if the two were to be correlated. We might expect Teacher 1 to have larger SGW, SQ, and PI bars and a smaller L bar than Teacher 2 and 3 because he or she expressed a larger belief that their class-

room was student-centered. However, only the SGW and PI bars are the only ones that follow this trend. The SQ bar actually follows the opposite trend between the teachers, increasing as the SC bar from the interviews decreases. The L bar seems completely uncorrelated to the expressed student-centeredness of the teachers' classrooms. Teacher 2, who had the middle SC rating, has the largest L bar.

Nonetheless, while this data might not follow the trend suggested earlier, they do tell us some interesting things about the framework. At least, the codes that overlap between the interview protocol and the TDOP do not necessarily correlate to one another in simple ways. The concept of stated beliefs and enacted beliefs brought up in Chapter 1 suggests that what a teacher says about what they believe may be very different than what they prove they believe through their actions. In this case, the teacher may think that his or her classroom focuses on students as active members but they might do certain things in the classroom that limit how active the students really are. This is the heart of what many education research tools are trying to get at when they study the beliefs of individuals. However, the data we can collect on the beliefs and actions of students and teachers in the BIAR Model are related to one another in a complex manner: For example, the interview with Teacher 1 showed that this teacher believes that his or her classroom is student-centered but the TDOP data for this teacher showed very few students ask questions during class time. This doesn't necessarily mean that the professor was wrong in believing that students are active members of the class. There may be complex reason for why students don't ask questions in the class even though they are participating in many other ways. Indeed, Teacher 1's class had the highest amount of peer interaction and student group work out of the three classes shown. The relationship between interview codes and TDOP codes is a complicated one.

Still, despite this complication, the data collected is of the right nature. The interviews and TDOP sessions are capturing a snapshot of the classroom milieu that shows the differences between individuals. There is considerable work to be done in deriving a system of comparison between the layers but the foundational framework is viable in its function thus far. Comparisons *could* be made between the beliefs data and the actions data. Perhaps with a more informed agenda of what an individual is looking with the BIAR Model the methods for examining the coordination between the layers will be more attainable.

5

Conclusions

In this thesis, we have searched for a way to characterize the classroom milieu that will provide the kind of data to inform the future reforms in education. Though the scope of the project extended beyond the reach of an undergraduate thesis, considerable strides were made toward developing and validating the new BIAR Model as this new tool in which we were in search. Much work has been done to look at the beliefs of teachers and how they play a role in the activity in the classroom. Still, a framework like the BIAR Model is useful in that it provides a nuanced description of the full classroom milieu.

While there is confidence in the applicableness of the BIAR Model in the field of education reform, there is less assurance in the protocols used to study each of the layers within the model itself. We presented the methods that seemed to be the most logical in our effort to objectively capture the reality of the classroom milieu but did so while acknowledging that not enough data was collected to make strong claims about the accuracy of these protocols. The data collection in this thesis was a first and second pass in the process of a grounded theory – in reality a small fraction of the theory was tested due to some resistance we met from faculty – and further iterations are not only encouraged, but also entirely expected.

For example, the TDOP is an excellent judge of the practices that teachers use in the classroom but it does a poor job of representing the actions layer of the BIAR Model. The actions of students are hard to capture in this coding scheme and it leaves most of the observational data in this thesis biased toward the teacher side. A goal of this thesis was to provide a balanced framework that valued the student and teacher sides equally and the TDOP unfortunately does not achieve this goal on its own. That is not to say that the TDOP is useless in the framework. Instead, other methods must be added to the process that better capture the other aspects of the actions layer, ran in parallel with the TDOP –

which does an excellent job of representing the narrow window it does examine.

As these additional protocols are added, it should be kept in mind that the, if this framework is to be applied over a many other environments – as it was intended – then the consideration of students' and teachers' time needs to be paramount. The impact of the study on the daily, weekly, monthly, and semesterly routine of the subjects must be minimized if the framework is to be accepted by the institutions and the people that would potentially use it. We found in the first attempt of collecting data that teachers are especially resistive to the idea of an undergraduate judging their actions in teaching. Indeed, there is a feeling of a power reversal like the inmates interviewing the warden when an undergraduate takes a formal look at the activity of the teachers that teach him or her. Whether this is an opinion that is acceptable long term or not, the reality is that this is the way many teachers think and to treat them as if they were different would do nothing but shoot the data collection process in the foot.

With all of this said, the BIAR Model does stand as a potential candidate in describing the classroom milieu in a way that current methods do not. The limited data collected does distinguish between individuals and could be used to make claims about coordination among the layers of the BIAR Model. Future work must fill in the gaps left by this thesis but this work provides the first steps in a tool that has the capacity of informing the next generation of education reform in America and the world.

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Appendix A: The Interview Protocols used for both students and teachers. This version reflects the adjustments made after some of the teachers gave us feedback that the time commitment of the project was too high. As such, the last question of both protocols brings up the topic of intentions very briefly.

Student Interview Protocol – Interview (Beliefs/Intentions Focused)

The bulleted questions are general questions while the dashed questions are guides for follow-up as needed (i.e. if the subject doesn't bring them up on their own). Interview to be conducted as semi-structured (i.e. these questions are a guide, the interviewer is free to diverge as deemed worthwhile).
Talking points to introduce the project:

- Honors thesis focusing on student-teacher interactions and the beliefs and intentions that underpin these interactions
- We are interviewing you to understand more about your individual beliefs as you approach teaching in the undergraduate science setting

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BELIEFS

General/Overall

- Confirm who you are and what class we are focusing on this semester.

Role of others

- If you were to describe the professor of this course to a friend, what would you tell them to expect?
    - A lot of students complain about their professors. What do you think about that?
    - Can all the students succeed in this course?

- What types of teachers are the best in physics?
    - What makes some instructors better than others?

- What are your professor's goals?

- Are you happy with the overall quality of teaching in your department?
    - In an ideal world, what would you like to see different? The same?

Expectations for this course

- What are your learning goals/objectives of this course?
    - Encourage them to be explicit and to think in multiple areas: content, process (i.e. problem solving), student attitudes, epistemology, etc.
    - Are these encouraged/inspired by your professor?
    - How do you structure your time to meet these goals?

- Are these goals for this class specifically or all of the classes you are currently taking?
    - Encourage them to elaborate: why are these accessible/inaccessible to some students?

- Where do you learn/practice these objectives (inside of class, outside of class)?
    - Are you initiating these environments or do teachers set these environments up?
    - In what ways are you involved in each of these environments?

Role as a student

- What is your role as a student?

- How would your day-to-day life be different if you genuinely learned all the information in this course (not just got an "A" but really retained all the information from the course)?

- Is learning/being a student something you can improve at?
    - Do you saturate as a student? Is there some point where you can't keep getting better?
    - How do you go about improving?

- How would you describe your theory of learning?
    - What are the hallmarks of a good student to you?

Measures of success

- How will you know that you are doing a good job in this course?
    - What do you measure? How? Why?
    - Does the teacher have any good ways to assess the quality of your learning?
        i. What measures do they use?
        ii. Do you think these are good measures? What do you think these measures actually evaluate?
    - What does it mean to you personally to be a successful student?

Constraints and tools

- What are some of the barriers teachers face in education/learning?
    - Are these imposed by you? The university? Themselves? Society?
    - Are you doing anything to mediate these constraints?

- What are some of the barriers you face as a student and how do you navigate these barriers?
    - How does the university/department constrain you?
    - How do students constrain you?

- What are some of the opportunities given to you or your students in the teaching/learning environment (from the institution or from you/your students)?

- What are some of the tools that you use to achieve your goals in the class?
    - What technology do you incorporate (i.e. clickers, projectors, videos, textbooks, websites, etc)?
    - What technology are you using because it's there (i.e. lecture space, chalkboards, campus-wide websites, etc.)?
        i. What would you change about this provided technology if you could?

INTENTIONS

- Tell me about <*insert class title*>. What does a typical week look like? etc.
    - Why/how did you decide to <*insert behavior mentioned above*>?
    - What are you trying to achieve? How does this relate to what you decided to do?

- Are there any questions along these lines that I should have asked you but didn't?

Faculty Interview Protocol – Interview (Beliefs/Intentions Focused)

The bulleted questions are general questions while the dashed questions are guides for follow-up as needed (i.e. if the subject doesn't bring them up on their own). Interview to be conducted as semi-structured (i.e. these questions are a guide, the interviewer is free to diverge as deemed worthwhile).
Talking points to introduce the project:

- Honors thesis focusing on student-teacher interactions and the beliefs and intentions that underpin these interactions
- We are interviewing you to understand more about your individual beliefs as you approach teaching in the undergraduate science setting

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BELIEFS

General/Overall

- Confirm who you are and what class we are focusing on this semester.

Role of others

- If you were to describe the students in this course to new faculty member, what would you tell them to expect from the students in this course?
    - A lot of professors complain about their students. What do you think about that?
    - Can all the students succeed in this course?

- What types of students can succeed in physics and what type can't?
    - Why do successful students succeed and unsuccessful students fail?

- What are the students' goals?

- Are you happy with the overall quality of teaching in your department?
    - In an ideal world, what would you like to see different? The same?

Expectations for this course

- What are the learning goals/objectives of this course?
    - Encourage them to be explicit and to think in multiple areas: content, process (i.e. problem solving), student attitudes, epistemology, etc.
    - Do you share your goals with students explicitly?
    - How is your course structured to meet these goals?

- Are these goals for all students to achieve or just some?
    - Encourage them to elaborate: why are these accessible/inaccessible to some students?

- Where do students learn/practice these objectives (inside of class, outside of class)?
    - Are you initiating these environments/encouraging students to set these environments up?
    - In what ways are you involved in each of these environments?
    - What challenges are there in implementing these environments?

Role as a teacher

- What is your role as a teacher?

- Are you supposed to ensure that everyone learns or just provide the opportunity for the students on their own?

- How do you go about improving your teaching?
    - Do you saturate as a teacher? Is there some point where you can't keep getting better?

- Does the term 'coach' apply to what you are doing as a teacher?

- How would you describe your theory of teaching?
    - What are the hallmarks of good teaching to you?

Measures of success

- How will you know that you are doing a good job in this course?
    - What do you measure? How? Why?
    - Does the department have any good ways to assess the quality of teaching and learning?
        i. What measures do they use?
        ii. Do you think these are good measures? What do you think these measures actually evaluate?
    - What does it mean to you personally to be a successful teacher?

Barriers and Tools for Learning/Teaching

- What are some of the barriers students face in education/learning?
    - Are these imposed by you? The university? Themselves? Society?
    - Are you doing anything to mediate these constraints?

- What are some of the barriers you face as a teacher and how do you navigate these barriers?
    - How does the university/department constrain you?
    - How do students constrain you?

- What are some of the opportunities given to you or your students in the teaching/learning environment (from the institution or from you/your students)?

- What are some of the tools that you use to achieve your goals in the class?
    - What technology do you incorporate (i.e. clickers, projectors, videos, textbooks, websites, etc)?
    - What technology are you using because it's there (i.e. lecture space, chalkboards, campus-wide websites, etc.)?
        i. What would you change about this provided technology if you could?

INTENTIONS

- Tell me about <*insert class title*>. What does a typical day look like? etc.
    - Why/how did you decide to <*insert course structure mentioned above*>?
    - What are you trying to achieve? How does this relate to what you decided to do?

- Are there any questions along these lines that I should have asked you but didn't?

Appendix B: The full list of TDOP codes is included here, complete with their individual descriptions.

Code Bank (Basic Dimensions plus Optional Dimensions)

The following list of codes includes only code definitions. For a more extensive discussion of coding rules and different instructional scenarios that will likely be encountered, please consult the "TDOP Technical Manual" which is available on the TDOP website.

Teaching Methods

Teacher-focused instruction (teacher is the primary actor)

L **Lecturing**: The instructor is talking to the students and not using visuals, demonstration equipment, actively writing, or asking more than 2 questions in a row in a Socratic manner.

LW **Lecturing while writing**: The instructor is talking to the students while actively writing on a chalkboard, transparencies, digital tablet, or other material. The instructor must either be writing or referring to what they are writing (or have already written). This code also captures real-time drawing of graphics (e.g., molecular structure, physiological processes), and if the use of visual representations is of interest, this should be included in the notes section. (Note that this code also captures writing/drawing in front of students without speaking, as a separate code for silent writing was deemed superfluous).

LVIS **Lecturing from pre-made visuals**: The instructor is talking to the students while referencing visual aides, such as slides, transparencies, posters, or models (e.g., plastic model of molecular structure, examples of sedimentary rocks, multi-media). The instructor must be referring to the topic contained in the visual, but the visual serves only as a reference point for the material and not as a live demonstration of phenomenon.

LDEM **Lecturing with demonstration of phenomena**: The instructor actively uses equipment (e.g., lab equipment, computer simulation) to convey course content. The objects must be in active use in relation to the topic and must be used for more than a simple reference point (e.g., "here is an example of a sedimentary rock") to demonstrate a process or phenomenon in class (e.g., "here is how sedimentary rock erodes over time" while physically demonstrating this process).

SOC-L **Socratic lecture:** The instructor is talking to the students while asking multiple, successive questions to which the students are responding. Student responses are either guiding or being integrated within the discussion. A minimum of 2 relevant student responses is required to use this code. (Note that SOC-L can be co-coded with other types of lecturing, such as LW, if the instructor is doing both writing AND interspersing his/her talk with questions).

WP **Working out problems:** This code refers to the instructor working out computations or problems. These can include balancing a chemical equation, working out a mathematical proof, or designing equations or Punnett squares, etc. The intent of the code is to capture the working through of some sort of problems in front of students. (If the computations/problems are on a slide and the instructor is actively working through problems, then this will be co-coded with LVIS. If this process is being written out, then this code will be co-coded with LW, and if students are being asked to participate in the problem-solving process via questions, code SOC-L).

IND **Individualized instruction:** The instructor provides instruction to individuals or groups and not the entire class. This often occurs while the instructor is roaming the classroom, but students or small groups may also approach the instructor. This code is usually co-coded with SGW or DW (see below). It is important to recognize that this code should not be used to classify the types of student-teacher interactions that are occurring in a large class setting – instead, use this code only when students are engaged in SGW or DW and the instructor is directly interacting with one or more students.

MM **Multimedia**: The instructor plays a video or movie (e.g., Youtube or documentary) without speaking while the students watch. If the instructor is talking over a video, movie, or simulation, then co-code with LVIS.

A **Assessment**: The instructor is explicitly gathering student learning data in class (e.g., tests, quizzes, or clickers).

AT **Administrative task:** The instructor is discussing exams, homework, or other non-content related topics.

Student-focused instruction (students are the primary actor)

SGW **Small group work/discussion**: Students form into groups of 2+ for the purposes of discussion and/or to complete a task.

DW **Deskwork:** Students complete work alone at their desk/chair.

SP **Student presentation**: Groups or individual students are giving to the class or are otherwise acting as the primary speaker or instructor in the classroom. In this instance, only select this code and none others as long as the primary instructor is not actively taking the lead in teaching the class.

Student-Teacher Dialogue

Teacher-led dialogue

IRQ **Instructor rhetorical question**: The instructor asks a question without seeking an answer and without giving students an opportunity to answer the question.

IDQ **Instructor discussion question**: The instructor poses a question seeking information. These questions can: seek a specific fact, a solution to a closed-ended problem, or involve students generating their own ideas rather than finding a specific solution.

ICQ **Instructor comprehension question**: The instructor checks for understanding (e.g., "Does that make sense?") and pauses for at least five seconds, thereby indicating an opportunity for students to respond.

Student-led dialogue

SQ **Student question**: A student poses a question to the instructor that seeks new information (i.e. not asking to clarify a concept that was previously being discussed) **and/or** clarification of a concept that is part of the current or past class period.

SR **Student response to teacher question**: A student responds to a question posed by the instructor, whether posed verbally by the instructor or through digital means (e.g., clicker, website).

PI **Peer interactions**: Students speaking to one another (often during SGW, WCD, or SP).

Instructional Technology

CB **Chalkboard/whiteboard/Smart Board**

OP **Overhead projector/transparencies**

PP **PowerPoint or other digital slides**

CL **Clicker response systems**

D **Demonstration equipment**: These could include chemistry demonstrations of reactions, physics demonstrations of motion, or any other material being used for the demonstration of a process or phenomenon. The objects must be in active use in relation to the topic. This can also include objects such as rocks being passed around a classroom.

DT **Digital tablet:** This refers to any technology where the instructor can actively write on a document or graphic that is being projected onto a screen. This includes document cameras as well as software on a laptop that allows for writing on PDF files.

M **Movie, documentary, video clips, or Youtube video**

SI **Simulation:** Simulations can be digital applets or web-based applications.

WEB **Website:** Includes instructor interaction with course website or other online resource (besides Youtube videos). This can include using a website for student responses to questions (in lieu of clickers).

Optional Dimensions

Potential Student Cognitive Engagement

CNL **Making connections to own lives/specific cases**: Students are given examples (either verbally through illustrative stories or graphically through movies or pictures) that clearly and explicitly link course material to popular culture, the news, and other common student experiences. Students may also be given specific cases or incidents in order to link an abstract principle or topic (e.g., flooding) with a more readily identifiable instance (e.g., 2013 floods in Boulder, Colorado). For this code to be used, the observer will need to make a judgment that the specific case is something meaningful to students, such as a local historic item or location, or a widely recognized incident. In general, a high bar is required here that is based on specificity and salience to students, such that showing a picture of a sedimentary rock will not be sufficient for this code, but if the picture was of the Grant Canyon and named as such, it would be coded as CNL. This code will be particularly important in biology (e.g., Dolly the sheep) and geoscience courses.

PS **Problem solving:** Students are asked to actively solve a problem (e.g., balance a chemical equation, work out a mathematical equation/algorithm). This is evident through explicit verbal (e.g., "Please solve for X") or written requests (e.g., worksheets) to solve a problem. **This is coded in relation to closed-ended exercises or problems where the instructor has a specific solution or end-point clearly in mind.**

CR **Creating**: Students are provided with tasks or dilemmas where the outcome is open-ended rather than fixed

(e.g., students are asked to generate their own ideas and/or products rather than finding a specific solution). The task can be delivered verbally or in written form. **This is coded in relation to open-ended exercises or problems where the instructor does not have a specific solution or end-point clearly in mind.**

Pedagogical Strategies

HUM **Humor**: The instructor tells jokes or humorous anecdotes; this code requires laughter from at least a couple of students.

ANEX **Anecdote/example:** The instructor gives examples (either verbally through illustrative stories or graphically through movies or pictures) that clearly and explicitly link course material to (a) popular culture, the news, and other common student experiences, or (b) widely recognized cases or incidents that illustrate the abstract (both types are co-coded with CNL).

ORG **Organization:** The instructor writes or posts an outline of class (i.e., advance organizer) or clearly indicates a transition from one topic to the next verbally or through transitional slides. This transition from one topic to another can indicate a change in topics within a single class or from a previous class to the present class. These transitions must be verbally explicit statements to the class (e.g., "Now we're moving from meiosis to mitosis") as opposed to ambiguous statements such as "Now we'll pick up where we left off on Monday." This may also include statements concerning how concepts covered in different portions of the class (e.g., lecture, homework and lab) may overlap.

EMP **Emphasis:** The instructor clearly states that something is important for students to learn or remember either for a test, for their future careers, or to just learn the material well.

Student Engagement

VHI **Very High:** More than 75% of the students in the immediate area of the observer are either (a) actively taking notes, or (b) looking at the instructor/course materials

HI **High:** Between 50% and 75% of the students in the immediate area of the observer are either (a) actively taking notes, or (b) looking at the instructor

MED **Medium:** Between 25% and 50% of the students in the immediate area of the observer are either (a) actively taking notes, or (b) looking at the instructor

LO **Low:** Less than 25% of the students in the immediate area of the observer are either (a) actively taking notes, or (b) looking at the instructor

Appendix C: Example of interview presented in annotated form.

Teacher 1 Interview Transcription

Introduction to project

E: Alright so, could you just say [uh] your name and the class you're teaching this semester?

J: My full name is Jorge Simones de Sa Martins. It's a huge name like all Brazilian names. [uh] I go by Jorge Martins here. I'm teaching Physics 2010 which is algebra-based intro physics for non-majors and people that are not into any math-based career.

E: Mmkay

J: [uh] It's actually the first time I've taught such a… this kind of [stumbling] course. [uh] usually teach for engineer-engineering majors, physics majors, back in the old country. But, it has, it's been a great experience. It's a new stuff, so yeah [laughing].

E: Yeah, that's cool. Awesome. [um] So if you were to describe the students that are in your course now to like another professor or faculty member, [um] what would you tell them to expect from your students?

J: Well, [um] we have a large number of students that never took physics in high school. That are not proficient in algebra, even though the course is called algebra-based. [uh] So if you're thinking of relying on their algebraic skills, forget it. They don't know simple stuff like solving first-degree equation. [uh] I had one of those in my second exam: forty-five percent of students got it wrong. And it's a first-degree equation. [uh] So on the other hand you have a group [uh] that is very, very smart. Very smart students. You have a group that they call post baccalaureate. People that have already some major and get back to school to go to med school perhaps. I have about 10 of those and these are great students: they're more mature, [uh] they know what they want. [uh] Another large group, they don't understand why they have to take this kind of class, so they have a [uh] bad attitude towards-towards the subject. They-they really don't want to learn, they want to pass they class and that's all. So it's a very heterogeneous group of students. But again, I stress that half of them are very… I mean, it's very hard for us to make them both be interested in the class, participate actively in the discussions and the activities. So…

E: And that's because the algebra skills are maybe-

J: [Interupting] Well, it's hard, I would say they have troubles with basic reasoning, basic algebraic reasoning. So for instance, took me couple months to get most of the class understand that whenever I have a quadratic relation, say area and side of a square: if I double the side, the area will quadruple. This sounded like a big mystery. Even though I work out a number of examples in front of them. I had clicker questions for them o work on that. They still-they still do miss it. I mean, two months after we began the course I still have ten percent of the class that miss this kind of problem. But I mean, if it was just lack of skill but with an active attitude, I would say things would go better. Their attitude is not what I would expect. [uh]

E: So it's not just they haven't learned it yet, it's also how they're approaching the new stuff?

J: Yeah. Right. They are not excited. Yeah. Well, maybe it might be in part my fault. I mean, I think one of the important jobs of the lecturer is to make it exciting. I mean, to come up with interesting demonstrations, interesting examples, to powerful presentations, to questions that can be discussed in class and that they can feel that these questions have a bearing to their lives, to their profession. So in part, I would say that, I would love to teach it again, because I have learned a lot of this kind of student. As I said before, I'm not used to teaching this kind of student, so I've learned a lot about who they are. And I think I could do a much better job one more time.

E: So what do you think you would do differently, if you knew coming into this from the beginning?

J: For instance, I would try to work on basic algebraic skills since the beginning. I was supposing that this was a given! Try to work with examples of algebraic reasoning that were more connected to whatever they are studying. I

didn't think about that at first, because, again, I thought it was easy. [uh] I would chance a bit some of my presentations. I think I've chosen some examples that are exciting for me, for an engineering student, but so much for a student coming from the health community. So I would work more on trying to find the kind of examples that are more suited for the kind of student. Not to come up with simpler or easier examples, but examples that would excite them!

E: [Interrupting] That are more applicable to them.

J: So for 25% roughly, [uh] one fourth of these students I think that I could come up with better chosen examples for what they want to be in the future. Maybe I could have changed their attitude and this could have made a difference.

E: Okay. So you're saying that you might be able to motivate them to learn, say, these algebra skills, if you put them in some kind of problem that involved a health… or whatever?

J: Right. In a context where they could relate better.

E: Okay. Yeah that's very interesting.

J: When I talk about engines. So engines is something that excites me but it doesn't excite them at all. They think it's boring [laughs]. And of course, some of physics some good physics is learned when you think about blocks that slide down an incline. This sounds boring to that student.

E: [Interrupting] Very dry.

J: It's very dry yeah. So I should have had more time to… But again, to find the right examples to that kind of student, you have to spend time, 'cause, I'm not one of them. So I have to go into their background and it takes time. It's not something that do from one day to the next. And the problem is that I arrived here and next week I had to teach and I didn't know exactly what kind of student I had. [uh] So I would like to teach this course again.

E: Mhm. Interesting. So [uh] speaking on the different kinds of students and students in general, what types of students can succeed in physics? Is there one type that will always be successful and one type that will never be able to succeed?

J: It's a tough question. [uh] I… I think that there is one kind of student that will always succeed. And I have met many of those. I have some of them in this class. I have a woman, she didn't do too well on the first exam but she had the right attitude. So she came here, she discussed with me. I made some suggestions, she followed the suggestions to the letter: she got a hundred on the second. And not only that, but for the third, I'm sure that she will get another hundred because she came here. The questions that she has now are of a different level, you know. She is becoming an expert. And that's not her field. Students that can get motivated, that [um] understand that they have to, well working hard is important. You know, you cannot succeed if you don't work hard. And that's not just for physics but for physics in particular. And the way she taught me a couple of the things from her field just by looking at the textbook and examples. So she pointed out to me *these* examples are more interesting for me. And then [gestures like eureka] oh! So she was really interested in learning. She was not asking herself: am I going to need that in my future or not. She was already sure that she was never going to use Newton's laws. The kind of evidence based reasoning that is adamant to physics, she would use. And so this kind of student will always succeed.
I don't, but maybe I'm too optimistic, that there is a profile of student that will never succeed. But if you don't get a student motivated, if he or she does not have an intrinsically built logical reasoning, it is going to be harder for them to succeed. But even if they're algebraic skills are poor. Even if they never took science. If you can get them motivated, I think that they can succeed. So motivation for me is the key to success.

E: So, on that note, you mentioned this earlier as making the class exciting and motivation as part of your job as a teacher. What are some of the other things you have to do in your role as a teacher?

J: Well there are many things that I can think about. I need them to think of me as their coach. Like we are a team and I'm their coach. So I need, if we work together, our common goal is their success. I'm here so that they can succeed. I have to make them think about me in this way. Sometimes the students think, oh this guy, he wants me to fail. I'm kind of highlighting it, but I think you have to approach the students, get them as close to you as you can.

So, when I have clicker questions for instance, and when invite them to discuss, I go to the discussion. I share the discussion with them I need to hear what they are saying. I want to give them feedback, instantaneous feedback. Of course, I have big lecture halls: I cannot do that with every one but I try to do that with as many as I can. So this is another thing that I think is important to my job. And as I said before, I think the main thing is be able to motivate them and to be able to put together presentations that are both exciting, enlightening and that invite them to participate in the creation of learning. I need that from them.
Sometimes, you know, as I go around in the lecture hall, I can tell some of them, they never participate in the discussions. So we have this strategy of clicker questions and peer instruction and inviting them to discuss. I would say a large majority engage in this discussion, but we have some that never do. They don't want to. They want, what is the answer? And that's enough for me. I'll memorize that. Some of them are even good students in the sense that they are good memorizers. They can pattern match very easily. So I see them in my class, no they are not paying attention to me but they are doing something else. So here is a discussion, they won't participate, they are doing something else. They look at the final answer, they take note, and they get good grades. But they are not in the classroom. They are outsiders. They are outliers in many different senses. They are avoiding contact with other students and in doing so, the best ones of those are not engaging in something that would be good for them but even better for their neighbors. So I think they are [pauses, searching for word] egotistical? I would love them to share whatever knowledge they have. I know they have it because they get good grades at the end so they can time share, you know. They can do two things at the same time. Which is great for them! But they are not helping their peers. They lack solidarity. And again, this is a very important attitude for me. I think that we should work for them to create some values in them. One of the values I should cherish the most is solidarity. Being… getting… I want to help everybody that is around me. I think that we need that as a society and a good way to engage in things like that is the classroom.

E: So on that note, what are some of the goals of your course right now? You mentioned motivating them to engage in thought processes and that kind of thing. So what are some of the learning goals of the course, so like content…

J: So I would separate those. So I think of learning goals as very broad statements such as realizing science is about evidence based reasoning. Science is a living body of knowledge. Okay Newton lived two hundred years ago and science did not stop there. That we need to… that reasoning, convincing someone else of your view relies on evidence based reasoning. What is evidence? What is a given? What is a concept? What is a concept that I created, which are definitions? So I defined velocity such, this is a human based, human creation. Perhaps I could describe nature with different concepts. But the laws, those are different. So those are generalizations of experiements. So what are these things in the whole body of knowledge and what is role of mathematics in all that? So I make this distinction between man-made definitions, nature-given laws of nature, and theorems which are logically based both on the concepts and the physical laws to get some physical results. So I want them to understand this whole structure. to understand that this is a living structure. And that everybody has to participate in that. And I want them to, by studying physics, to get to get a point of what I call the cultural encyclopedia of this century. We live in a society that is the technologically based. I don't expect them to understand the technology of every gadget that they use. But I want them to understand that these gadgets are possible because of the science that created them. So even though, ah, would they after having your class, would they be a more scientifically based opinion to discuss, say, nuclear power of not, I don't believe that. But I do think that by at least having access to the encyclopedia of science that they can participate in the discussion. The end of that discussion, I would expect to be mostly driven by ideology at the end, but at least they are aware of what they are talking about. These would be the macro goals of the course. Now for the objectives, well, we cover a lot of material. And it's a lot of material for a semester, for a group of students that most of them never took physics before. I think it's too much. So anyway, I try to choose a set of learning objectives that is both comprehensive when you look at the whole of the material but on the other hand, not too big. So that it's possible for them to master everything that I intend them to master. So for instance, the relationship between velocity and acceleration: this is a learning objective. It's hard. It's not easy. It's hard een for physics majors. The connection between forces and motion, Newton's laws. What is the content of these laws, what are they saying? What are they telling us? The essence of conservation laws. Why do we need conservation laws? Why are they useful? And how do they appear? So these are some very objectives I can even write them down in a more specific way so that, given a certain situation, they can tell me if energy is conserved or not. And if it is conserved, I want them to be able to write down the equation to express this conservation. And I want them to be able to solve that equation for any number of quantities that appear in the equation. So these would be very specific learning objectives that I can state for each chapter. And I do that explicitly. So every chapter, they have a slide a text that tells them what I expect them to be able to at the end of the presentation. I think this helps them quite a lot. If they pay attention. I mean, I have a group, a fourth of the students that look at that as, you know, some… well… professor Martins has some

weird ideas [laughs]. They never look at that again, you see? And every class, I show them slides and I highlight what we have covered already as a follow up, you know? And, again, I think that most students like that and they give me feedback, positive feedback. Sometimes they say, oh, I hadn't realized that we had already covered that topic. So can you give me a hint on how to do that. So that's great! That's feedback from me to them, from them to me and we can work together.

E: Very good. So what about those big ideas about science and culture that you were talking about. Do you explicitly say those, list those on a slide kind of thing? Or are those just kind of things that come organically through the whole process?

J: Well, I expect them to be our backdrop. So in a sense I would say that I seldomly explicit them unless I have a good, a really good opportunity. Sometimes the history of science gives us those opportunities so I try to use those opportunities to show them explicitly. But most of the time, this is the background. Whenever I can, I mention that, but it's not at the forefront of the presentation most of the time.

E: Interesting. So how about this, we just talked about some of the goals and objectives of the class. Where do the students learn or practice these? Is it inside of your class? Is it on the homework? Is it in helproom study sessions? On the exam? What kind of environments do they really seem to…

J: Well, I expect them to happen in all of these environments, all of them. In the classroom, I have been following a strategy that most of the professors also follow which is a lecture of fifty minutes is actually divided into four mini-lectures of ten minutes. Just as a highlight of the important points of a topic and then I invite them to answer questions in the classroom. I want them to be active in the classroom. As opposed to what happened 15 or 20 years ago which we… a lecture was only the professor speaking and most of the students dozing, passively sitting in a classroom. But we try to make them active all the time. And I think this is very important because this is a once in a lifetime opportunity to interact with professor side by side with the other students. So they can hear the questions of the other students and participate in the whole discussion that is happening between the professors and the collective of the students. In the helproom, and I'm in the helproom three hours every week, we can have one on one discussions. Sometimes I like to try and put more than one together because I like to hear what they say to each other. It helps me to figure out what are their misconcepts and to attack them. And sometimes I invite them to have one on one meetings here in my office. Longer discussions. Mostly when I feel that they are not doing well at all, or in the other extreme when they are about to become expert students. So then of course the set of recitations for this course is pretty good. I'm using the latest version that was put together by Steve Pollock, I think, one or two semester ago and I think they are very interesting. Sometimes I feel that they are a bit too hard. If I could, I would soften them a little bit. Make them a little easier here and there. I think that sometimes they go beyond the objectives I have for each one of their topics. But overall, they are pretty good. So again, I would love to teach this class again [laughs]. You can tell.

E: Alright. [um] So you've kind of mentioned it a couple times and we talked about what you're supposed to do, what your role as a teacher is. IS teaching something that you are always improving at? Is there some point where you saturate?

J: I don't think so. No I think teaching is a career goal. You know, and I intend to be teaching until—well old age makes you dumb [laughs]—until that point I intend to be teaching. It's what excites me the most these days. Much more than what I used to do before which was doing research in hard sciences. Nowadays, I think my contribution is much more important to be a teacher than to be in the hard sciences themselves. I don't intend to come up with *any* bright new ideas in science but I think I will come up with bright new ideas in teaching [laughing]. So that's—by the way, that's why I'm here! The purpose of me being here is exactly to interact with what you are doing here, which I think is one of the best in the world right now. And to learn from them what novelties they have for teaching. So I'm both interacting with the people here from the department and the people from the education department, 'cause back in my country I was responsible for the training of pre-service high school teachers. So I was working with people from the communication department, the school of education, and putting together a new curriculum for high school physics and following that permutation of this curriculum. Recording the actual lectures, the lecture classes. Think about that…

E: So, on the same vein, what would you say are the hallmarks or the bullet points of good teaching? What is a good teacher? What is good instruction and all that?

J: I think that good instruction, first of all, understands what students we have. And that's one of our bad points in this class. I didn't know exactly who they were. So that's why I am sure I would be able to improve next time. So I want, I think that good instruction builds on what the student brings to you, previous knowledge, previous conceptions about all the world and science and the relation and between science and daily life. Good instruction invites the students to have an active participation in all the activities. Don't allow…well *allow* isn't the right word… but don't stimulate students to a passive role. Try to put them all the time in an active role. Try to get them more confident on their possibilities, so they call tell you what they are thinking without fear. This is important point because, you know a student is here, he sees a professor in front of him. So if I say something dumb the professor will think that I am stupid. So this cannot happen. The student has to be confident that the role of the professor is the one of the coach. I need to understand what you are thinking about that so that I can help you, not to criticize you. Not to make fun of you. Not to… you see? As clear as possible in your text! Think about the phrases in your presentation. The phrases you use are crucial. You have a very, very short time to tell them some story. So you have to think about each one of those phrases. Don't waste time. We have so little time with them.

E: So for you, how do you know you know when you are doing a good job teaching? So what types of things are good measures of successful teaching?

J: You know, I was very happy with today's lecture because I could tell almost all of the students were actively trying to master what I was talking about. I could tell the discussions, whenever we had a split vote for a clicker question, the discussions were active and really exciting. So I was really happy—and in the *end*, four of them come together, they were kind of sitting close together. They came to me and told me, "This was the best lecture of the semester!" So, you see? I had that feeling. They had that same feeling! So It's not something that is only subjective, objectively, you can tell when a lecture did work and when a lecture didn't. So before, one of my lectures didn't work at all because I chose the wrong questions to ask: they were to hard. So, you know, again this happens all the time so you have to be able to give yourself feedback. Get feedback from the students but you can give yourself feedback, a lot. Just by understanding what's happening in the classroom. So if you see that the discussion is not happening—why? Most of the time, the question is too hard. It was not leveled to where they were…

E: [Interrupting] So are there any ways that the physics department is measuring how good of a teacher you are?

J: Now this question I don't know how to answer. You have to remember I am a visiting professor here. I'm not a faculty—I'm not a member of the department so I don't know exactly how the teaching—how the quality of the teaching impacts the evaluation, overall career goals for the professors here. You know… Unfortunately, *my* institution I don't think their teaching skills are correctly evaluated. We do have evaluations, students have a few questionnaires but the administration doesn't take that into account as much as I would want to. I think that, in our constitution in Brazil, it is said that university professor has to engage in research, teaching, and outreach. And he has to be measured against these three measures in his personal life. But it's only… you know, it's not good. By listening to other professors discussing the matter here, I would venture that people here are not very happy as well. So they would like this department to be more engaged in the quality of teaching than it is. Form my perspective, oo I would love to be a professor here. You know, you are way ahead of my department.

E: So what are some of the constraints on students in your class? So maybe imposed by you or the university or themselves… what kind of limiting things are there?

J: Well I don't think there are too many of those. Well, they have a schedule to follow. So this is a constraint. They have to present homeworks by the due date. They have to be in the recitation and lab, if they miss the lab they can fail the course. So these are constraints. But I would say these are academic constraints that most of time I agree with. I think that most of the time you need some measure of involvement of the student in the activites of the course. So lab, for instance, there's no way to get knowledge from if you're not there [laughs]. I wouldn't mind students cutting class like in lecture as a whole. But again, since we try to make the lecture and instance of active engagement among themselves. As an instructor, I would see with good eyes some kind of constraint on how many lectures you can cut because this is part of the learning after all. If it was a traditional lecture which the professor—you know, we have a saying, some professors put the textbook on the blackboard. This kind of lecture I mean if

you're there or you're not, I mean it's the same thing. It's only the textbook again. But the kind of lecture that we're trying to put together here are very different so… So we have some constraints on the students but I would say…

E: [Interrupting] Small?

J: Well, I can't think of any one of these constraints that aren't based on some academic need. For instance, I know that some professors don't like to have their students' computer, or laptops, or tablets open—I don't mind. Because I know that some of them are doing some other thing, as I said before. But first of all, I don't think I have to be a police. If that's what they want to do, it's a pity for them and their colleagues but I don't want to … But many times, they are using their laptops to gather more information about what I am discussing. So I don't impose this kind of constraint on them if they want to check on Facebook, I don't care. And I even did use that in my favor. So one time I could tell a couple of them were checking some of the others work so I asked them to solve a simple problem on paper and then I asked them to take a picture and send it to me. Online. There. So I had my email open and they were sending to me picture of what their work. So I could send they feedback on their work instantaneously because they had their gadgets on. Right? So something that could be *against* instruction I tried to turn in favor of instruction.

E: So on the same coin but maybe on the other side, what are some of the constraints that are on you as a teacher or professor?

J: Well first of all, I have this material that I have to cover. Again, I think there's too much material for this course. I think you could be a bit more reasonable on this amount of material. It's too much.

E: And where does that come from? Is that something that you decided?

J: No this…

E: Were these content goals something that was passed from the professor before you? Or was it just like this class needs to be that?

J: It just needs to be that. It's written on the university catalogue. So I have to cover that material. I know there are some external constraints. For instance there are people who have to take the MCAT exam, and the MCAT exam has a list of topics that might be covered on the exam so this class might be a class that might prepare the students for the MCAT. There are external constraints as well. It's not just somebody who decided that those topics and… But again, I think it's too much. So if perhaps we could split this class in two, it would be more reasonable if it were in two semesters. But I know there are other constraints you know, more credits for the students, locations, fees, so that's a tough decision to make. And I'm happy to follow whatever has been decided. But this tells me that I won't have at the end, that my students won't have the proficiency that I would like them to have in those topics that I would think are more important because I would have to spend time on other stuff.

E: Okay. And you mentioned earlier, you were talking about laptops and phones and stuff. What are some of the tools that you use in your class? Technology? Or outside of class, for test or homework…what types of technology are you using or tools in general?

J: Well not much these days. All these lectures are presentations, so powerpoint based. I don't use too much the blackboard unless there is something unexpected that I didn't prepare. So I try to use their gadgets as I said before. This was one of the activities that I give … *in* the classroom. I also ask them, a couple of times, to write what I call two-minute papers. So get together with a couple of friends in the classroom and write me a couple of sentences about conservation of energy. This is what I call two-minute papers. After you've done that, you send them to me and I collect those and I present them back as questions. So these are the statements that students made. So which are correct and which are not? In the lab and recitation they use computer-based data collection but this was not put together by me, this was already given. So that's about it. Sometimes I show them simulations from the PhET. I didn't use too many of them but I did use some. I invite them to work on those simulations. Of course, every lecture needs to have at least one demonstration. One real demonstration, or else we are talking about what?
I always tell them the story that happened to me: so I was going to the lecture and I couldn't come up with a nice demonstration for that lecture. I was walking toward the lecture hall and there was a brick, so I grabbed the brick

and I took it with me and I put it on the table. And I gave my lecture as usual and the students were all looking at the brick. And so I said that's it. And the students—hey! and the brick? Well the brick is exactly for that. You know I always bring a demonstration to class and that is what makes you interested in what's going to happen. Something is gonna happen. So it keeps you tied up to what I'm saying. So that was the purpose of the brick. Unfortunately, there was no good demonstration for that. Sometimes you have to improvise. Again, to keep them interested in what you're doing. to keep them actively engaged in the discussion.

E: So you said you use clickers as well, right?

J: Oh yeah. Lots of those.

E: And a textbook?

J: Oh yeah we have one of those. I mean, it has been used here for the past 35 years I think. The point is that the students, at first, they don't like to read it. Second, they don't *know* how to read it. They read it as if it was a storytime. Even though the book is pretty good, it tries to highlight what is important what is not important. As I said before, one of the students that came here I taught her how to read the book and she benefitted a *lot* from it. So maybe we could send some time trying to teach them that as a new resource. Mike Dubson also put together some notes for this class and I also presented them as an excellent source, which is a condensed version of the textbook. Which they like, they don't like to read!

E: Alright, I think that's pretty much what I wanted to talk about. Is there anything along these lines that I should have asked you?

J: Well I don't think so, not off the top of my head.