CONGRUENCE OF STEM FACULTY CONCEPTIONS OF HOW STUDENTS LEARN AND INSTRUCTIONAL PRACTICES

by

ROBERT IDSARDI

(Under the Direction of Julie A. Luft)

ABSTRACT

Active-learning can be beneficial for undergraduate STEM students, but difficult for faculty to implement without support. This dissertation is composed of two manuscripts which aim to support reform movements promoting the use of active-learning. The first manuscript characterizes faculty members' conceptions of how students learn in relation to faculty members' instructional practices. Using interview and observation data through a qualitative study I describe five patterns of congruency between faculty members' conceptions and instruction. This manuscript also describes the diverse conceptions and instructional practices of faculty members engaged in four different PD programs. Implications of this manuscript include that PD programs should explicitly connect active-learning pedagogy to theories of student learning to support the development of conceptions of how students learn. PD programs also should account for and leverage the diversity and range of faculty members' prior knowledge, beliefs, and instructional practices. The second manuscript is an application paper of instruction that implements active-learning. This paper describes an active-learning oriented lesson designed using a 5E lesson format, and reflects the enactment of my own conceptions of how students learn. This manuscript promotes the use of active-learning by explicitly describing the process of planning and implementing an active-learning oriented lesson. This paper also provided curricular materials (e.g. 5E lesson plan template) STEM faculty members can use in their teaching. This dissertation suggests reconceptualizing the support we provide STEM instructors and suggests future directions for related research.

INDEX WORDS: Active-learning, STEM, professional development, student learning

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

In this chapter I describe the purpose of the studies within this dissertation, the theoretical framework used in this work, and give an overview of the remaining chapters.

Purpose of Studies

Reform movements in undergraduate STEM education call for the implementation of active-learning to improve student learning. In an active-learning environment the instructor stops lecturing for some to most of the class period to give students time to solve problems, contemplate their level of understanding, and interact with the presented material (Andrews & Lemons, 2015; Prince 2004). Studies show that undergraduates in STEM courses benefit from active-learning techniques, including increased conceptual understandings, increased focus on instruction, more developed critical thinking skills, and increased persistence in STEM fields (Freeman et al., 2014; Prince, 2004).

However, this kind of instruction is challenging for faculty to implement in undergraduate STEM courses. STEM faculty use less active-learning and more extensive lecturing than faculty in all other fields (Hurtado, Eagan, Pryor, Whang, & Tran, 2012). Hurtado et al. (2012) found 63% of STEM faculty self-reported using extensive lecturing, while only 47% reported having students work in small groups. These instructional practices are at odds with many of the reform movements in undergraduate STEM education. For instance, *Vision and Change* (American Association for the Advancement of Science [AAAS], 2011) calls for a focus on student-centered learning through active engagement in multiple modes of instruction.

Many factors influence instructional practice. These include contextual factors (e.g., subject area, the classroom, university, college, and department culture, etc.), personal factors (e.g. teaching experience, preparation, personality, etc.), and teacher knowledge and beliefs (e.g. knowledge and beliefs of teaching, knowledge and beliefs of learning, etc.) (Gess-Newsome, Southerland, Johnston, & Woodbury, 2003; Woodbury & Gess-Newsome, 2002). Of these, there is considerable literature on the central role teachers' knowledge and beliefs of teaching, learning, students, and content play on instructional practice, and efforts to change instructional practice (e.g. Brownlee, Boulton-Lewis, & Purdie, 2002; Gess-Newsome et al., 2003; Pajares, 1992).

Of particular interest in this dissertation is instructors' knowledge and beliefs of student learning. Despite advancements in our understandings and theories of how students learn in STEM, instructional practices in STEM courses are influenced largely by outdated theories (Brown, 1994; National Research Council (NRC), 2012; Olson & Riordan, 2012). Of the research on undergraduate faculty members' conceptions of teaching and learning, most is centered on conceptions of teaching, not learning. Few studies describe or characterize STEM faculty members' conceptions of student learning.

An early study on faculty members' conceptions of student learning described a hierarchy of beliefs from teacher-centered to student-centered (Prosser, Trigwell, & Taylor, 1994). Authors used conceptual change as a framework, a theory limited in that it does not account for recent literature that has shaped our understandings on student learning (e.g. socio-cultural perspectives). Through interviews, researchers characterized faculty members' conceptions of learning as information accumulation, concept acquisition, conceptual development, and conceptual change to satisfy either external or internal demands. In their hierarchical model, the authors claimed more sophisticated conceptions include less sophisticated conceptions.

There are two main critiques of this model. First, since each step in the model includes the previous steps, the model cannot describe faculty that might reject previous conceptions of learning. For example, the model cannot describe a faculty member that rejects a naïve preconception of learning they once held. Second, the model cannot account for any conceptions of learning that include behavioral, social, or contextual factors of learning because of the use of conceptual change as a framework.

A more recent study by Hora (2014) inductively describes faculty members' conceptions of how students learn, but like many studies only examines espoused conceptions without reporting observational data. Espoused conceptions are those expressed by faculty during conversation (Kane, Sandretto, & Heath, 2002). However, this approach risks not capturing the knowledge and beliefs that exist in an implicit form and are difficult to articulate (i.e. tacit), but are exhibited in faculty members' teaching (Kane et al., 2002).

Many of the beliefs about student learning described by Hora (2014) are not accounted for in the Prosser et al. (1994) model. It is an open question whether Hora's (2014) list of beliefs is exhaustive given the limited research in this area and reliance on espoused knowledge and beliefs. It is also unclear how different beliefs in this list compare to each other and to faculty members' instructional practices.

This dissertation expands on these findings by further characterizing faculty conceptions of student learning and describing the ways in which faculty conceptions are congruent or incongruent with their instructional practices. Specifically, I was interested in comparing the learning opportunities faculty members describe students learn through (e.g. listening, solving problems, group work) to the learning opportunities afforded to students during observed instruction. This dissertation also asked if faculty conceptions and instructional practices are similar or different among participants within STEM professional development (PD) programs.

This line of research is part of a reform movement to increase the use of active-learning in undergraduate STEM courses (e.g. *Vision and Change*, AAAS, 2011). The purpose of this work is to expand our understanding of faculty conceptions of how students learn, which is believed to influence instructional practice (Gess-Newsome et al., 2003). I hope this work informs those who facilitate faculty development by characterizing the range of conceptions their participants may hold. I hope this work also informs undergraduate STEM instructors by providing a rationale for the use of active-learning and an application of this kind of instruction.

Symbolic Interactionism as a Theoretical Framework

Interpretive traditions are based in the notion that human knowledge is developed from human interpretations (Prasad, 2005). This tradition places importance on "how we order, classify, structure, and interpret out world, and then act upon these interpretations" (p. 13). Prasad went on to explain interpretive theoretical frameworks emphasize meaning and intentionality over causal relationships. Prasad also emphasized the importance placed on social dimensions of knowledge construction within interpretive traditions.

There are several subsets of interpretivism; including ethnography, pragmatism, phenomenology, hermeneutics, dramaturgy, and symbolic interactionism (Prasad, 2005). Of these, the latter is most applicable to this dissertation. Symbolic interactionism is a framework which emphasizes the "creation of meaning in social situations" (Prasad, 2005, p. 19). This tradition is not just the study of symbols, but the study of human meaning. All social phenomena, including teaching and learning, are symbolic in that they hold different meanings to different individuals.

Symbolic interactionism is based in the philosophy that “objects and events have no intrinsic meaning apart from those assigned to them by individuals in the course of everyday social interaction” (Prasad, 2005, p. 21). As Jacob (1987) described, “Symbolic interactionists assume that individuals' experiences are mediated by their own interpretations of experience. These interpretations are created by individuals through interaction with others and used by individuals to achieve specific goals.” (p. 27). Three central assumptions underlie this perspective: 1) individuals act towards objects (including people) based on their meanings they have for those objects; 2) meanings are constructed through social interactions; and 3) meanings are not static, but can continuously change through interpretive processes of individuals interacting with the objects within their social worlds (Blumer, 1969; Prasad & Prasad, 2000).

However, it should be noted that the meaning of objects for individuals may become ‘taken-for granted and routinized’, with individuals acting a certain way towards objects without consciously thinking about the reasons why (Snow, 2001). Snow elaborated by describing how the important question to ask may not be how meaning of objects influences our actions towards those objects, but how contextual and societal factors can contribute to “the routinization of meaning” (p. 372). This would be an interesting perspective to apply to conceptions of teaching and learning, which may be routinized by STEM instructors.

Methodologically, in symbolic interactionism researchers try to understand the perspectives of participants on social situations. This tradition emphasizes the possibility for multiple interpretations from participants on the same situation and uncovering those differences. Methods usually include observations and interviews. Observations are done in the everyday lives of the participants, similar to ethnographies but more focused on the individual's interpretations than the culture at large (Prasad, 2005).

A critique of this perspective is the focus on an individual assigning meaning to objects or situations, while at times ignoring the possible irrational or imposed meanings someone may have for an object (Prasad, 2005). Critical theorists would argue that this perspective does not account for the role of power in society and meaning making. That individuals may not simply choose what an object or situation means to them, but have it essentially assigned or forced on to them by people in positions of power. While I do not consider myself a critical theorist, this would also be an interesting perspective to use to analyze STEM instruction, exploring the roles of power and promotion in faculty conceptions of teaching and learning.

Several studies in science education have used symbolic interactionism as a framework (e.g. Koballa, Gräber, Coleman, & Kemp, 1999; Moje, 1995). For example, Abell and Roth (1994) used symbolic interactionism as a framework to explore the perceived constraints of a preservice elementary science teacher using data from observational field notes, interviews, and instructional artifacts (e.g. lesson plans, handouts, and tests). Abell and Roth (1994) stated that, "This framework leads us to assert that our research is a process of interpreting meaning constructed by community members, rather than of reporting an objective reality. We discuss the constraints Marie perceived and actions she took based on her perceptions." (p. 79). Data were analyzed using an inductive analysis conducted collaboratively with the researcher and the student teacher.

In another example, Southerland and Gess-Newsome (1999) used symbolic interactionism and sociocultural theory as a combined theoretical framework to describe preservice teachers' understandings of inclusive science teaching. They used a constant comparative inductive analysis of student work and audio recordings from classroom discussions to identify preservice teachers' conceptions of knowledge, teaching, and learning.

This framework is often situated within social constructivist epistemological perspectives and lends itself to exploring the meanings others have interpreted of objects. As Jacob (1987) describes, "Symbolic interactionists are interested in understanding how individuals are able to take one another's perspective and learn meanings and symbols in concrete instances of interaction" (p. 29).

In this study, I explored STEM faculty members' meanings of the object learning. I was interested in understanding how STEM faculty think their students learn, based on their prior experiences as students, instructors, and colleagues of other instructors within the culture of STEM departments. These faculty members' understandings of teaching and learning will shape the learning opportunities they provide to their students.

In summary, symbolic interactionism provided a viable and useful theoretical framework through which I described the meaning STEM faculty assigned to the concept of student learning.

Overview of the Chapters

This dissertation is made up of two manuscripts which support the use of active-learning in undergraduate STEM courses in different ways. The first manuscript, Chapter 2, is titled, "Congruence of STEM Faculty Conceptions of Student Learning and Instructional Practices." This paper characterized 22 STEM faculty conceptions of how students learn and their instructional practices through interviews and observations. From these, five patterns of congruency emerged and are described. I also describe the range of faculty members' conceptions and instructional practices within each of four STEM PD programs. Implications for

PD facilitators are proposed to support the development of faculty members' conceptions of how students learn.

The second manuscript, Chapter 3, is titled, "A Case Study: Using an Authentic Scientific Investigation for Teaching and Learning of Evolution in the Context of Climate Change for Preservice Teachers." This manuscript is an application paper of instruction that implements active-learning. This paper describes an active-learning oriented lesson designed using a 5E lesson format, and reflects the enactment of my own conceptions of how students learn. This manuscript promotes the use of active-learning by explicitly describing the process of planning and implementing an active-learning oriented lesson. This paper also provides curricular materials (e.g. 5E lesson plan template) STEM faculty members can use in their teaching.

This dissertation is concluded with Chapter 4, which describes the contributions of this work. Chapter 4 also describes plans for future research that builds on the results of these manuscripts.

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CHAPTER 2

CONGRUENCE OF STEM FACULTY CONCEPTIONS OF HOW STUDENTS LEARN AND THEIR INSTRUCTIONAL PRACTICES

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Abstract

Active-learning can be beneficial for undergraduate STEM students, but difficult for faculty to implement without support. To provide the most effective support, it is important to consider factors that influence instructional practices. This qualitative study describes a subset of one influencing factor, faculty conceptions of how students learn. Participants were STEM faculty who were participating in one of four PD programs promoting the use of active-learning. Researchers inductively coded interviews to describe faculty members' espoused conceptions of how students learn. I then compared faculty members' espoused conceptions of how students learn to their theories-in-use using interview and classroom observation data. Results indicated faculty members have a wide range of conceptions of how students learn and instruction practices. Five patterns of congruency between espoused conceptions and theories-in-use emerged from the data. Each PD program was composed of a range of participants with diverse conceptions and instructional practices. Implications include that PD programs should explicitly connect active-learning pedagogy to theories of student learning to support the development of conceptions of how students learn. PD programs also should account for and leverage the diversity and range of faculty prior knowledge, beliefs, and instructional practices.

Introduction

Instruction that uses an 'active-learning' approach is one way to improve undergraduate student learning in STEM disciplines (Freeman et al., 2014; Prince, 2004). However, active-learning is often challenging for STEM faculty to implement. STEM faculty use less active-learning and more extensive lecturing than faculty in all other fields (Hurtado, Eagan, Pryor, Whang, & Tran, 2012). These instructional practices are at odds with many of the reform movements in undergraduate STEM education. For instance, *Vision and Change* (American Association for the Advancement of Science [AAAS], 2011) calls for a focus on student-centered learning through active engagement in multiple modes of instruction.

There are many factors that the influence instructional practices of faculty. These include contextual factors (e.g., subject area, the classroom, university, college, and department culture, etc.), personal factors (e.g. teaching experience, preparation, personality, etc.), and teacher knowledge and beliefs (e.g. knowledge and beliefs of teaching, knowledge and beliefs of learning, etc.) (Gess-Newsome, Southerland, Johnston, & Woodbury, 2003; Woodbury & Gess-Newsome, 2002). Of these, there is considerable literature on the central role teachers' knowledge and beliefs of teaching, learning, students, and content play on instructional practice, and efforts to change instructional practice (e.g. Brownlee, Boulton-Lewis, & Purdie, 2001; Gess-Newsome et al., 2003; Pajares, 1992).

This study explores instructors' knowledge and beliefs of how students learn. Despite advancements in research on how students learn instructional practices are still influenced largely by outdated theories (Brown, 1994; National Research Council (NRC), 2012; Olson, & Riordan, 2012). There is limited research characterizing how undergraduate STEM faculty think students learn. Older studies (e.g. Prosser, Trigwell, & Taylor, 1994) used earlier theories of learning, such as conceptual change, which do not account for recent advancements (e.g. socio-cultural perspectives). Other studies have relied on interviews alone, which only examines the espoused knowledge and beliefs of STEM faculty (Kane, Sandretto, & Heath, 2002). This approach risks not capturing implicit or tacit knowledge and beliefs that are difficult to articulate, but are exhibited in faculty members' instruction (Kane et al., 2002).

The research questions that guided this study were

- In what ways are faculty members' espoused conceptions of how students learn congruent with their instructional practice?
- In what ways are PD program participants' espoused conceptions of how students learn and their instructional practices similar or different to their peers?

Specifically, I was interested in comparing the types of learning opportunities (e.g. listening, solving problems, group work) faculty members describe students learn from to the learning opportunities afforded to students during observed instruction. Participants were engaged in one of four PD programs. Results from this study can support those who work with STEM faculty to better understand how to develop and implement PD programs that promote active-learning.

Conceptions of How Students Learn

I define conceptions as faculty members' knowledge and beliefs (Hewson & Hewson, 1989; Thompson, 1992). Instructors' conceptions of teaching and learning influence how they implement instructional practices (Brownlee et al., 2001; Pajares, 1992). However, this relationship is complex and dependent on contextual and personal factors (Gess-Newsome et al., 2003; Hora, 2014; Mansour, 2009).

Of the research on undergraduate faculty members' conceptions of teaching and learning, most is centered on conceptions of teaching, not learning. While conceptions of teaching are likely strongly related to conceptions about learning, they can be conceptually distinguished (Northcote, 2009). In a study of five faculty, Northcote (2009) found that while instructors' beliefs about learning were similar in nature to their beliefs about teaching, faculty held more idealistic beliefs about teaching and more realistic beliefs of learning.

An early study on faculty members' conceptions of student learning described a hierarchy of beliefs from teacher-centered to student-centered (Prosser et al., 1994). Through interviews, researchers characterized faculty members' conceptions of learning as information accumulation, concept acquisition, conceptual development, and conceptual change to satisfy either external or internal demands.

More recently, studies have described faculty conceptions of learning as a continuum ranging from teacher-centered to learner-centered (Hora, 2014; Samuelowicz & Bain, 2001). For example, Samuelowicz and Bain (2001) describe a range of orientations from teacher-centered orientations (e.g. imparting information, transmitting structured knowledge) to learner-centered orientations (e.g. negotiating understanding, encouraging knowledge creation). In another example, Hora (2014) utilized situated cognition as a theoretical framework to describe 15 beliefs STEM faculty members held on student learning. Results supported the framework of an underlying dimensionality of conceptions that exist on a continuum from teacher-centered to student-centered instead of an either-or dichotomy. Hora (2014) concluded that beliefs play an important role in instruction, but do not unilaterally cause behavior.

To date, few studies beyond Prosser et al. (1994) and Hora (2014) precisely characterize faculty members' conceptions of student learning. Prosser et al. (1994) categorized faculty beliefs into a hierarchical model using conceptual change. But many of the beliefs about student learning described by Hora (2014) are not accounted for in the Prosser et al. (1994) model. It is an open question whether Hora's (2014) list of beliefs is exhaustive given the limited research in this area and reliance on espoused knowledge and beliefs. It is also unclear how different beliefs in this list compare to each other and to faculty members' instructional practices, though two case studies are presented. I expand on these findings by further characterizing faculty conceptions of student learning and describing the ways in which faculty espoused conceptions are congruent or incongruent with their instructional practices.

Methods

This study sought to describe the congruence between faculty members' espoused conceptions of how students learn and their instructional practices. Because our goal was to inductively explore and understand faculty members' conceptions, qualitative research methods were most appropriate (Creswell & Creswell, 2017). Consistent with qualitative methods, data consisted of interviews with STEM faculty and observations of STEM faculty instruction.

Context

This study took place at a large research university in the Southeastern United States. Researchers recruited through email STEM faculty members who were participating in professional development (PD) programs promoting the use of active-learning. Of the 27 faculty recruited, 19 faculty members agreed to participate. Researchers also recruited 13 STEM faculty members who were not participating in professional development as a comparison group, and three agreed to participate. Participants differed in position and expertise and spanned from post-doctoral researchers with one year teaching experience to associate professors with 27 years' teaching experience. Participants also ranged in their discipline, including anatomy and physiology, biology, chemistry, computer science, ecology, mathematics, and physics.

Faculty members who were participating in a PD program were in one of four programs promoting the use of active-learning at their university. The four PD programs were: 1) The Student-Centered Active Learning Environment for Undergraduate Programs (SCALE-UP) Learning Community, which met once monthly during the 2015-2016 academic year. This program was organized by a center for teaching and learning at this university. The PD program also included a four-day intensive workshop over the summer 2016, during which faculty prepared and shared instructional materials participants designed for use in the SCALE-UP classroom. Faculty used these materials in the fall 2016 or spring 2017 semesters, during which data was collected (see Figure 2.1). 2) Experienced-Novice Instructor Parings, in which faculty members new to active-learning were individually mentored by more experienced faculty members. These mentorships varied in how much support mentors provided mentees based on the individuals in the pairings. The mentorships occurred while novices were teaching in either the fall 2016 or spring 2017, during which data was collected (see Figure 2.1). 3) Learning Assistants Program, in which faculty were provided undergraduate learning assistants but little additional support. Undergraduate learning assistants were used during instruction in the fall 2016 or spring 2017, during which data was collected (see Figure 2.1). 4) Department-Based Initiative, in which faculty members teaching similar courses within a single department held a discussion group that was largely instructor driven. The group met once monthly during the 2016-2017 academic year, during which data was collected (see Figure 2.1). This study did not evaluate the PD programs faculty members participated in but used these programs as a sample pool of STEM faculty members who were learning about and potentially implementing active-learning.

Data Collection

Participants were interviewed twice, before and after a semester in which researchers made three observations of their teaching (Figure 2.1). Interviews were semi-structured and utilized a standardized open-ended protocol in order to allow the participants to answer questions and talk about their experiences (Seidman, 1998). Initial interview questions were developed based on the literature that addressed the research questions. Questions elicited participants' demographics, conceptions of student learning, orientations towards active-learning, and self-reported instructional practices. The interview protocol was pilot tested with STEM faculty and refined prior to use in this study. Interviews ranged from 30-60 minutes. The second interview was structured based on the first, eliciting their experiences attempting to implement active-learning and any changes in their conceptions of teaching and learning.

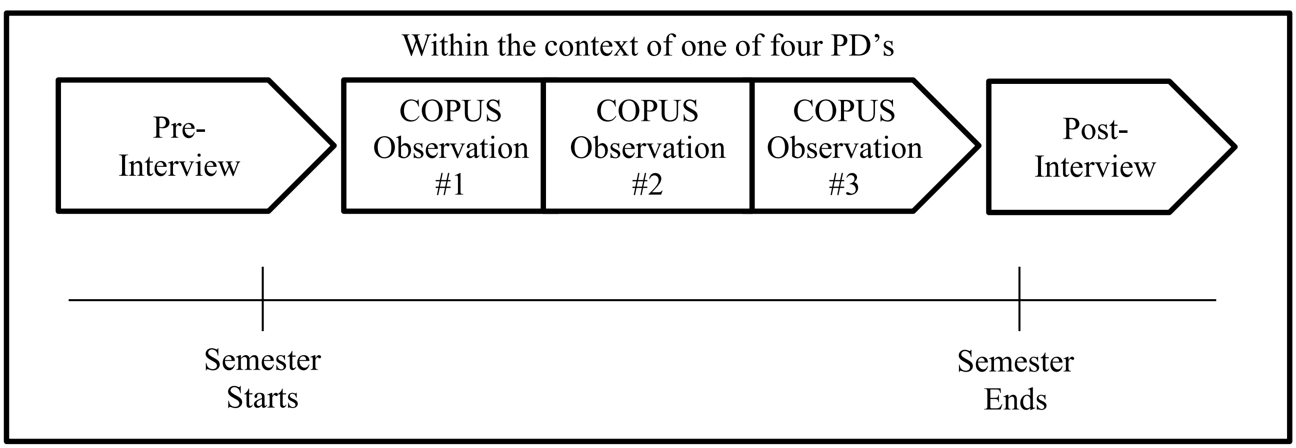

Figure 2.1. **S**chedule of data collection.

Data on participants' instructional practices were documented using the Classroom Observation Protocol for Undergraduate STEM (COPUS) (Smith, Jones, Gilbert, & Wieman, 2013). The COPUS allows researchers to identify behaviors that the teacher is exhibiting (from a list of 12) and behaviors the students are exhibiting (from a list of 13) during two-minute intervals. Behaviors include both passive and active-learning practices.

Prior to observations, six members of the research group went through a training process of using the COPUS. During an initial training session, researchers learned about the COPUS codes from an experienced user of the COPUS and practiced using it with videos of undergraduate STEM instruction implementing a range of instructional practices. After this initial session, researchers individually coded videos of classroom teaching. Any differences in observation coding were discussed and resolved. This process was repeated three times at the beginning of the fall 2016 semester to improve inter-rater reliability. In the final training observation, the average Cohen's kappa inter-rater score was 0.822 ± 0.037. These values indicate strong inter-rater reliability (Landis & Koch, 1977).

Researchers conducted three classroom observations of each participants' instruction, one during the beginning, middle, and end of the semester (Figure 2.1). This captured instructional practices representative of the course overall rather than a particular day or topic. Each of the three observations for any one faculty member were conducted by a separate researcher to reduce any potential for bias. Several participants had co-instructors who taught during one of the three observation windows, thus five participants were only observed twice.

Data Analysis

Transcribed interviews were initially analyzed using *a priori* codes to identify relevant responses from faculty members regarding their conceptions of student learning (Miles, Huberman, & Saldana, 2014). Next, *a priori* codes were further analyzed using *in vivo* coding with the participants' own language (Miles, Huberman, & Saldana, 2014). A secondary analysis used pattern coding of the *in vivo* codes to develop salient categories in the data (Miles &

Huberman, 1994). Researchers looked for disconfirming evidence to test the adequacy of the categories (Miles & Huberman, 1994). Throughout the process, I used multiple researchers to collect and code the data to enhance the internal validity and reliability of these findings (Merriam, 2009).

Faculty members were characterized as having either lecture-based, active-learning oriented, or mixed (containing both lecture-based and active-learning oriented) espoused conceptions of how students learn from the categories developed. Participants with mixed espoused conceptions were further characterized as having either predominantly active, predominantly passive, or evenly mixed espoused conceptions of how students learn.

To analyze the observation data using the COPUS, the prevalence of each code was determined by calculating the percentage of two-minute intervals each code is present in the observed class. For example, if the instructor lectured during five of the twenty-five two-minute intervals in a 50-minute class period, this would be calculated as 20%. This does not mean the instructor lectured for exactly 20% of the class period, but that lecturing was present during 20% of the two-minute intervals observed. The totals from each observation were averaged together. For example, if the same instructor lectured during five, seven, and 13 two-minute windows in three 50-minute classes, the total two-minute windows lectured in would be 25 out of a possible 75. The result would be 33.3% of two-minute windows containing lecture.

COPUS codes were collapsed into groups of student learning behaviors as described in Smith et al. (2013, p. 627). These groups include receiving, when students are receiving information through a lecture, video, or textbook; talking, when an individual student is answering a question, asking a question, or presenting while the rest of the class is listening; and working, when students are individually or collaboratively solving problems or answering questions.

In this study, I chose to focus on receiving and working codes. These code groups were inversely related to each other in our data set. The amount of student talking varied widely among faculty, regardless of levels of student listening and working. Student talking codes also only afford a single student the opportunity to answer or ask a question while the rest of the class is still listening. So, this analysis focused on receiving and working code groups, which represent the learning opportunities the majority of students in the class were engaged in.

I then looked for the presence or absence of these learning tasks (receiving and working) in the categories developed from each participant's interview data. I compared the presence or absence of these learning tasks in the categories to the learning opportunities afforded to students during observed instruction within the context of four PD programs. Through this process, I developed possible patterns of congruency or incongruency between espoused conceptions of how students learn and their instructional practices.

I used these patterns of congruency and incongruency to answer the second research question: in what ways are PD program participants' espoused conceptions of how students learn and their instructional practices similar or different to their peers? I compared the patterns of congruency and incongruency of participants to their peers within each PD group.

Results

The first research question asked 'in what ways are faculty members' espoused conceptions of how students learn congruent with their instructional practice?' Data revealed a wide range of espoused conceptions of student learning and observed instructional practices among STEM faculty. When comparing faculty espoused conceptions to their instructional practices, five patterns emerged reflecting various levels of congruence and incongruence. First, I describe faculty members' espoused conceptions of how students learn and their instructional practices. Then I describe each of the five patterns. Within each pattern I provide an illustrative case study. All names used in cases are pseudonyms. This study also asked, 'in what ways are PD program participants' espoused conceptions of how students learn and their instructional practices similar or different to their peers?' Data revealed participants within each PD program had different patterns of congruency or incongruency between their espoused conceptions of how students learn and their instructional practices. I illustrate the wide range of participants within each of the four PD programs.

Faculty range in their espoused conceptions of how students learn and in their instructional practices

Interview data revealed a wide range in the activities faculty claimed promoted student learning. These activities ranged from students receiving information (e.g. listening to lectures, reading) to students working with information and/or peers (e.g. solving problems, collaborating) along a continuum.

On one end of a continuum, a portion of participants exclusively described that students learn through listening to lectures and/or reading. For example, one faculty member stated, "I would say they learn through actively listening…paying attention and absorbing..." On the other extreme, other participants only described that students learn through active-learning activities, such as working problems. For example, another faculty member said, "Students have to work problems. It's much less about reading the textbooks as it is about practical problem solving, spending time doing that."

There was also a large portion of faculty members in the middle of this continuum who described students learning through a mix of passive and active opportunities. For example, one participant said “solve as many problems as possible, ask questions, if possible form groups with other students…show up for lectures, obviously. If possible taking good notes, read the textbook, compare notes to the textbook.” Of the participants who gave mixed responses, their descriptions of how students learn were characterized as either predominantly active, predominantly passive, or evenly mixed.

Two faculty members admitted not knowing how students learn, replying to questions with “I don’t know”. Even with probing questions, some faculty never described tasks or activities which they felt promoted student learning.

Observation data revealed a wide range in instructional practices used by participants. COPUS student behaviors were grouped into three categories: receiving information, talking to class, and working (Smith et al., 2013). On average, students received information during 68% of the two-minute observation windows, ranging from 21%-97%. No faculty members had student listening in the 60-80% range. This resulted in a bimodal distribution with a gap between two clusters of faculty. One cluster of faculty members had high student listening (80-100%), while the second cluster of faculty members had low student listening (0-60%). Those faculty in the high student listening cluster were characterized as enacting lecture-based instructional practices, while those faculty in the low student listening cluster were characterized as enacting active-learning oriented instructional practices.

On average students worked during 39% of the two-minute observation windows, ranging from 5%-84%. Faculty members in the high student listening cluster had students working in less than 30% of the two-minute observation windows. Faculty members in the low student listening cluster had students working in more than 30% of the two-minute observation windows.

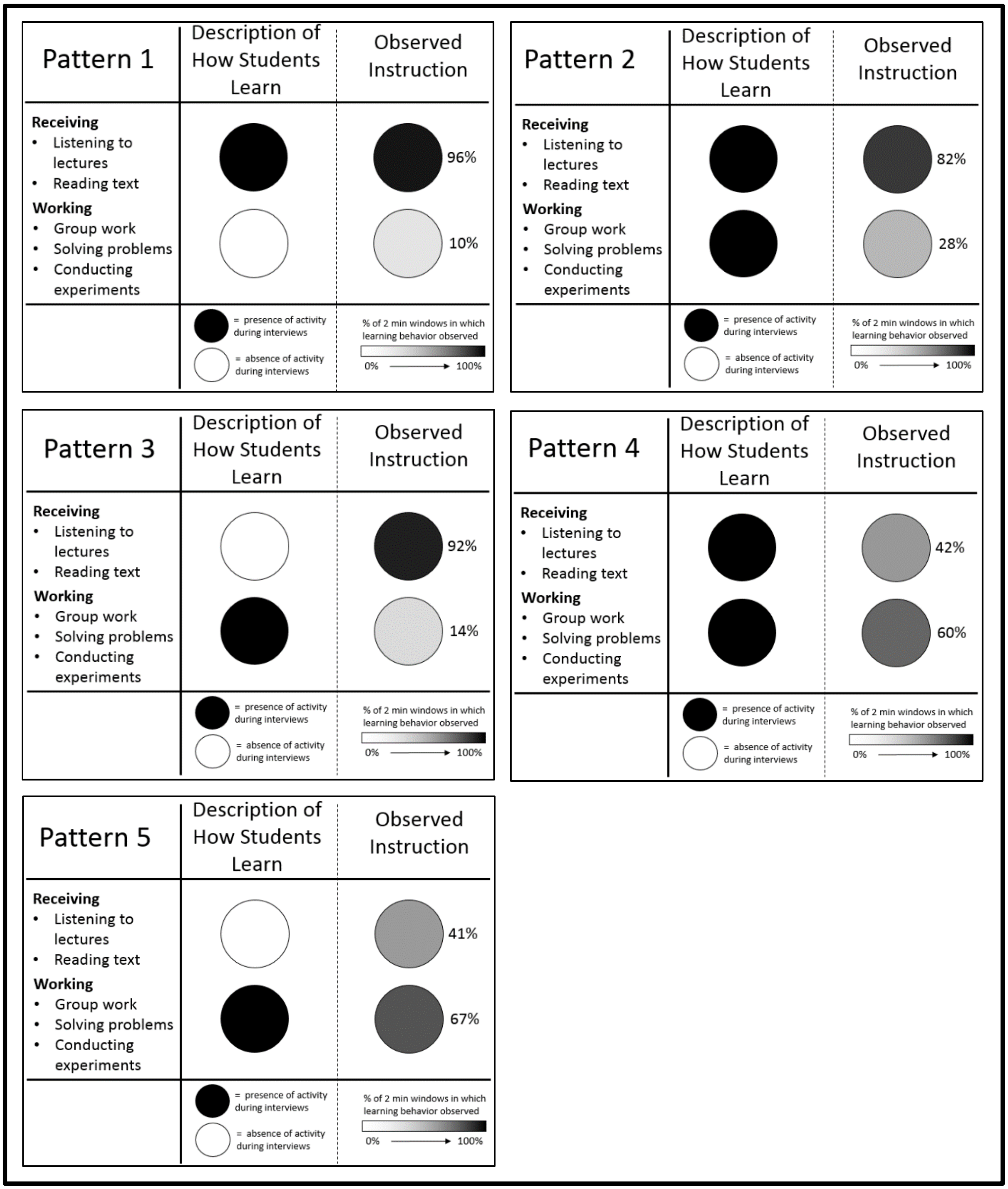

Figure 2.2. Patterns of congruency or incongruency between espoused conceptions of how students learn and their instructional practices.

Faculty can be characterized into one of five patterns of congruency between their espoused conceptions of how students learn and their instructional practices.

Analyses comparing interview data to observations revealed five patterns on congruency or incongruency between faculty members' espoused conceptions of how students learn and their instructional practice. These patterns are described below.

Pattern 1: Lecture-based or limited espoused conceptions of how students learn and lecture-based learning opportunities. Pattern 1 illustrates a strong congruence between faculty members' views of how students learn and their use of teacher-oriented instructional activities. Three faculty members were characterized by Pattern 1. Faculty members in Pattern 1 described student learning as a result of receiving information. According to faculty, learning happened as students listened to lectures, read textbooks, watched videos, or observed demonstrations. These descriptions aligned with the observations of faculty members in Pattern 1. Observational data of their students revealed extensive listening during class (>70% of two-minute windows), with few opportunities to work collaboratively with one another or engage with the material (<30% of two-minute windows and primarily composed of clicker questions). These instructional practices do not align with research-based instructional practices or calls for reform in science teaching found in *Vision and Change* (AAAS, 2011) and similar documents.

Pattern 1 also includes faculty members who have limited espoused conceptions of how students learn. When asked about student learning, these faculty members indicated that they did not know how students learned in class or provided descriptions of their teaching without addressing student learning. These faculty members frequently described their instruction as lecture-oriented interspersed with questions from students. COPUS (Smith et al., 2013) data aligned with this self-reported data.

Representative faculty member from Pattern 1. Stephen, an assistant professor in a life science discipline, taught an introductory course to nearly 300 students in a large auditorium. He had between 15-20 years of experience at this university. He was not participating in a PD program, unlike the other two faculty members in Pattern 1 (Figure 2.3). During observations of Stephen's instruction, students listened during 96% of the two-minute windows. Stephen's students worked during 10% of the two-minute windows, with 8% being individual work and 2% being group work (Figure 2.2).

When asked about how students learn, Stephen described that "students learn through actively listening…paying attention and absorbing." He described "distractions and the tendency for folks to multi-task" as things that hinder student learning, preventing students from engaging in active listening. Stephen expressed he was skeptical of active-learning being beneficial for students, especially within his content area in which he felt students just need to sit down and memorize the content.

Stephen used quizzes and exams to assess student learning but acknowledged that he does not always know if students are learning while he is teaching. For this he relies on sensing if students are "checking out" and on the questions that students ask before class, after class, and at office hours. When asked if his assessment of student learning influenced his instruction, Stephen stated,

> "I think I've done this material enough times, that I kind of know what I want to focus on and so, it doesn't really change the structure of the class or how much time I spend on different modules. I have to get through a number of things each semester one way or another."

Although Stephen expressed many traditional views of student learning, he described that learning should be a “continuous process that's always expanding or moving forward.” He said, “Things that you do in 11th grade, 12th grade are expected to be built on in college. Your sophomore and junior year are expected to be built on in your senior year...a continuous process that's always expanding or is kind of moving forward.” This quote reveals how Stephen considers student learning occurs over time, but he does not describe utilizing students’ prior knowledge during instruction to facilitate learning. He views learning as an accumulation of facts over time, where students’ knowledge from previous grades prepared them to learn more in his course.

Stephen did express interest in “trying to get more active engagement by the students” through the use of clicker questions. He did not pursue this interest because he was “not as familiar with the technology and didn’t want to test it out on a big class.”

Pattern 2: Mixed espoused conceptions of how students learn and lecture-based learning opportunities. Pattern 2 illustrates intermediate congruence between faculty members’ mixed views of how students learn and their use of teacher-oriented instructional practices. Four faculty members were characterized into Pattern 2. Faculty members in Pattern 2 described students learn through a combination of receiving information and active-learning. While several faculty members in Pattern 2 described a balance of listening to lectures and solving problems, others emphasized one of these activities over the other. This led to the emergence of three categories of espoused conceptions of how students learn within Pattern 2: 1) mixed emphasizing listening, 2) mixed balanced, and 3) mixed emphasizing active-learning.

Observational data of their students revealed extensive listening during class (>70% of two-minute windows), with few opportunities to work collaboratively with one another or engage with the material (<30% of two-minute windows). These instructional practices do not align with research-based instructional practices or calls for reform in science teaching as described in *Vision and Change* (AAAS, 2011). These practices aligned with portions of faculty members' espoused conceptions of how students learn (i.e. students learn through receiving information). Other portions of faculty members' espoused conceptions were largely not enacted in their classes (i.e. students working).

Representative faculty member from Pattern 2. A professor in a physical science, Patrick, taught an introductory course with over 150 students in a large auditorium. For more than 25 years, he has worked in this university. As a member of the Peer Learning Assistants (PLAs) PD program, he met once monthly to discuss instructors' teaching and the use of PLAs. Eight undergraduate PLAs facilitated instruction in this introductory course. PLAs met weekly with Patrick to reflect on the previous class and discuss the upcoming class. Meeting with the PLAs was a "grounding experience" for Patrick, as PLAs helped him realize when he was trying to cover too much in a lecture or pushing students too fast.

During observations of Patrick's instruction, students listened during 82% of the two-minute windows (Figure 2.2). We observed students working during 28% of the two-minute windows, of which 6% was individual work and 22% was group work. He did ask questions of students following students working and occasionally during lectures, with an individual student answering or asking a question while the rest of the class listened during 34% of the two-minute windows observed.

When asked how he thinks students learn, Patrick described that students learn "by doing…it's all problem solving. You gotta work through a lot of problems…It can be helpful to work in groups, but at the end of the day you gotta do it yourself." But when talking about problem solving, Patrick primarily referred to students doing their homework and never explicitly described problem solving in the classroom. Instead, during class he used lectures and demonstrations to prepare students to learn through completing their homework individually, or occasionally in groups.

Patrick assessed student learning through clicker questions, walking around class and listening to students, and ‘seeing it in their eyes’. He tried to adapt his instruction to address misconceptions that came up and tried to get feedback from students to “make sure students did not get left behind”. He sought feedback from students because he thinks the way undergraduates learn today “seems to be very differently from the way that I learned 30 years ago. The communication is different, the expectations are different.”

While Patrick’s instruction mostly engaged students with listening leaving problem solving to mostly be completed outside of class, he was planning on slowly adopting more active-learning. As he said,

> “I want to insert more active-learning activities into the course in a seamless and meaningful manner. Because you know, I can certainly take 10 minutes out and say I want you to do this. But that’s sort of just inserting it, but instead what I’d like it to do is, I’d like to develop a pacing where it goes in exactly where it’s needed. And quite frankly I don’t think that’s going to happen and probably won’t happen next semester, but maybe 2 years down the road, the product will really flow well.”

Pattern 3: Active-learning oriented espoused conceptions of how students learn and lecture-based learning opportunities. Faculty members in Pattern 3 only described learning occurring through students solving problems and/or interacting with each other and the instructor. Faculty members in Pattern 3 did not express any statements that students learn through receiving information through listening to lectures or reading a textbook. Five faculty members were characterized into Pattern 3.

The tasks that faculty members in Pattern 3 described promoting learning were largely incongruent to their instruction. Observational data revealed students extensively listened during class (>70% of two-minute windows), with few opportunities (<30% of two-minute windows) to work either individually or in groups.

Despite faculty members in Pattern 3 having espoused conceptions of student learning that align with calls for reform in undergraduate STEM teaching, they did not give students opportunities to engage in these activities in class. The incongruence between faculty members' espoused conceptions of how students learn and their instructional practices in Pattern 3 may be partially explained by barriers to implementing active-learning described in the literature (Brownell & Tanner, 2012; Michael, 2007).

Representative faculty member from Pattern 3. Evan, a lecturer in the life sciences, taught an introductory course with approximately 300 students in a large auditorium. He has less than five years of experience and was not participating in a PD program during this study. Evan has attended one-time workshops and seminars in an effort to improve his teaching.

Our observations of Evan's instruction revealed students listened during 92% of the two-minute windows observed (Figure 2.2). Students worked during 14% of the two-minute windows observed, with students always working in groups not individually. Evan used clicker questions in his lectures, which he described as "a low-level active-learning methodology." He also frequently asked individual students questions during his lecture, with a single student asking or answering a question during 42% of the two-minute windows.

Evan described that students learn through answering assignments, quizzes, and discussion boards, which all mostly occur outside of class. He stated that "revelation happens in the classroom", but learning happens outside of class when students are really "thinking about the information" previous presented in class during homework. Evan also described that students learn best when "confronted with their lack of knowledge." These confrontations occur by "getting things wrong" and stumbling through problems. Group discussions are an important avenue to create this type of dissonance. In describing student learning he felt student learning was analogous to advancements in science:

> "[Science] is a very dynamic, always changing cloud of information that we constantly sort of pull things from this cloud of knowledge and try to assimilate that and construct that into the universe that we think we know. I think that's how students really learn, too. That's a good way to think about how students really learn is, this thing we call science is a lot like an individual brain with prior knowledge and previous experience that they drag kicking and screaming sometimes in the classroom and then you try to add to that…and that's how science works, it's constantly dynamically always changing."

Evan was familiar with education research on assessing student learning. He noted the limitations of multiple choice tests, and he gains a "much better idea of students' processing and thinking about science through writing." As he stated,

> "When I've tried to teach it to them and then I give them a test and they make a 100 on it, does that mean they really know it? No, not

> really. That means they know...They know it from the way I know it, so they knew enough to give me back what I wanted."

Unlike other faculty members in Pattern 3, Evan explicitly described being aware of the incongruence between his espoused conceptions of how students learn and the way he teaches. He said,

> "I've taught myself to teach as a pure lecturer and there's a huge disconnect between that and what I know the research says about students, the way that students learn best. It's not from listening to a lecture. So I know there's this big gigantic disconnect between those two…I know that the best way that they learn is by sometimes being in those uncomfortable situations where you're confronted with your lack of knowledge and it would be hypocritical of me to also at the same time admit that when I was in college, I didn't wanna be put in those [dis]comfort zones."

As an instructor, Evan was most comfortable teaching when being an "engaging and entertaining lecturer." This type of instruction allowed him to be in control of the classroom, unlike during in-class activities which were uncomfortable for him to implement. He recognized it would be hypocritical to expect his students to learn through uncomfortable situations that expose their misunderstandings if he is not also willing to be uncomfortable and lecture less.

Pattern 4: Mixed espoused conceptions of how students learn and mixed instructional practices. Pattern 4 illustrates congruence between faculty members' mixed espoused conceptions of how students learn and their use of mixed instructional practices. Mixed instructional practices include substantial use (>30%) of both lecture and active-learning. Nine faculty members were characterized into Pattern 4. Faculty members in Pattern 4 described that students learn through a combination of receiving information and active-learning. As in Pattern 2, these descriptions were further categorized into 1) mixed emphasizing listening, 2) mixed balanced, and 3) mixed emphasizing active-learning.

These descriptions of how students learn were congruent with the learning opportunities faculty provided to students during class. Observational data revealed students were provided many opportunities to solve problems and work in groups in class (>30% of two-minute windows) and students spend limited time listening (<70% of two-minute windows).

Representative faculty member from Pattern 4. Susan, an associate professor in a technology discipline, taught an introductory course with approximately 75 students in a SCALE-UP classroom. While Susan had between 10 and 15 years of experience teaching, she said this was her first time teaching in a SCALE-UP classroom. Susan normally taught two-40 student courses, but during this study taught the introductory course with 75 students and an additional course with approximately 65 students.

Susan participated in the SCALE-UP PD program which “met once a month during the spring semester and then there was one week when we met from 8 to noon four days of that week during the month of May.” The program was organized by the center for teaching and learning at this university and included seminars from researchers and instructors who have taught in SCALE-UP classrooms at this and other universities.

Our observations of Susan’s instruction revealed students listened during 42% of the two-minute windows observed (Figure 2.2). Students worked during 60% of the two-minute windows observed, with students working in groups, not individually. Susan described that she attempted to implement a ‘flipped classroom’ for the first time in the SCALE-UP classroom. As she said, “I've always taught and had a little break to have students work on stuff, but this time it was completely flipped where I was had them watching videos or maybe doing reading and then in class they would just be working on worksheets.” The listening students were doing in class was not to lectures, but to follow-up on “something that [students] had already done, then I was going over it with them. So it was very different teaching [to a traditional lecture], 100% different.”

Susan described that “different people learn differently.” She described that,

> “Some people will learn by hearing…some people will learn by reading, and their time in the classroom isn’t going to contribute as much…some people are really visual, so when I teach I do try to use a lot of diagrams.”

She added that she knows there are “lots of different things that aid in student learning, and part of it is my teaching but certainly not all of it, they also need to be reading the text. I also really emphasize that they should be working together.” Susan later described she thinks students retain more when they teach themselves individually and in groups, rather than an instructor ‘feeding’ them information.

In Susan’s courses prior to this study she assessed student learning through asking students questions and encouraging students to ask her questions during class. She said that she “can’t teach without the feedback,” and when students do not ask or answer questions in class it is a difficult, “one-way street.” Susan felt she got more feedback by having students complete worksheets during class, which she implemented as a result of her engagement in the SCALE-UP PD program. When she has used worksheets instead of lecturing she felt her instruction was centered on the students instead of herself.

Susan felt this approach was very good for her students, but acknowledged it was a lot of work for her. Trying to implement an entirely flipped classroom approach with video recordings and worksheets for each class period was “more work than [she] realized.” She added, “By the end of the semester I was pretty burnt out…and I actually got really sick.”

Pattern 5: Active-learning oriented espoused conceptions of how students learn and mixed instructional practices. Pattern 5 illustrates intermediate congruence between faculty members’ espoused conceptions of how students learn and their use of active-learning oriented instructional practices. One faculty member was characterized into Pattern 5. Faculty members in Pattern 5 describe that students learn through solving problems individually and/or in groups, and did not mention students learn through listening to lectures or reading.

These descriptions of how students learn partially aligned with the learning opportunities faculty provided to their students. Observational data revealed students were provided many opportunities to solve problems and work in groups in class (>30% of two-minute windows), and students spend limited time listening (<70% of two-minute windows). Faculty in Pattern 5 had instructional practices that align with research-based instructional practices and calls for reform in science teaching.

Faculty in Pattern 5 were not characterized as having strong congruence between their espoused conceptions and instruction practices because they did not attend to students receiving information in their espoused conceptions of how students learn. Despite implementing a mix of active and passive instructional practices, faculty did not address how students learn through listening to lectures during class in interviews.

Representative faculty member from Pattern 5. Kevin, a lecturer in mathematics, taught an introductory course with approximately 20 students in a SCALE-UP classroom. Kevin had less than five years of experience, and this was his first year teaching in a SCALE-UP classroom. As a participant in the department-based initiative, he met once monthly with a group of instructors who taught similar introductory courses to discuss teaching and learning. Most participants in this PD program did not teach in a SCALE-UP classroom, so this program did not specifically support instruction in this classroom.

Prior to this study, Kevin said he mainly lectured and only occasionally used worksheets in class. In his pre-interview, however, he said he planned to use more problem-solving worksheets in class. Observations of Kevin's instruction revealed he engaged students in problem solving, with limited lecturing. Students listened during 41% of the two-minute windows observed. Students worked during 67% of the two-minute windows, of which 23% were students working individually and 44% were students working in groups (Figure 2.2).

Kevin spent more time preparing materials for students to work on and less preparing lectures. He described that the worksheets went well, but still needed improvement. As he said,

> "There's not really places where the students can stop and think about what it is they're doing, and reflect on what they're doing and try to extend it… right now my feeling is just go back at the materials and try to amend them. Maybe cut some things out and put in some more questions that will force them to think about the methodologies and the ideas, rather than the steps they need to take."

He described that students have misconceptions, and he tries to think about what "students are going to stumble over, and then try to confront those things." He does this by having students work through problems and explain their work. Kevin went on to say that "I think students learn math by doing math. I don't think they learn by watching me do it."

Kevin said he assessed student learning by "interacting with [students] and asking questions and seeing which parts they're getting at and trying to figure out. So just listening to what they're saying." He used these interactions to adjust his instruction and the questions he prepared for students. Kevin described needing to be flexible and trying to understand where student' struggle during problem solving. He noted that he "would like to be a little more organized in terms of how I think about what kind of questions and things are going to be asked and shared within the classroom, and do a better job at trying to anticipate what's going to come up."

Participants within each PD program held a wide range of espoused conceptions of how students learn and instructional practices

A comparison of the patterns of congruency among the PD program participants revealed each PD program was composed of faculty members with a wide range of espoused conceptions of how students learn and a wide range of instructional practices (Figure 2.3). In Figure 2.3, the percentage of two-minute windows in which students were listening was plotted along the y-axis. Faculty were sorted along the x-axis based on their espoused conceptions of student learning (e.g. lecture-based, mixed, or active-learning oriented). Faculty with mixed espoused conceptions were further characterized based on if their descriptions were predominantly passive, evenly passive and active, or predominantly active. Each dot represents a single faculty member, and the color of the dot represents the PD program in which they participated. The small variation (i.e. jitter) along the x-axis within each group (e.g. passive) is not significant, and only exists so that dots do not overlap for clarity.

Figure 2.3 shows faculty members participating in the four PD programs varied widely in their espoused conceptions of student learning and instructional practices. No PD programs participants were tightly clustered with similar espoused conceptions of student learning and percentage of students listening. This is true even of the one PD program with faculty members from the same discipline, the department initiative, in which faculty members were also teaching a similar course.

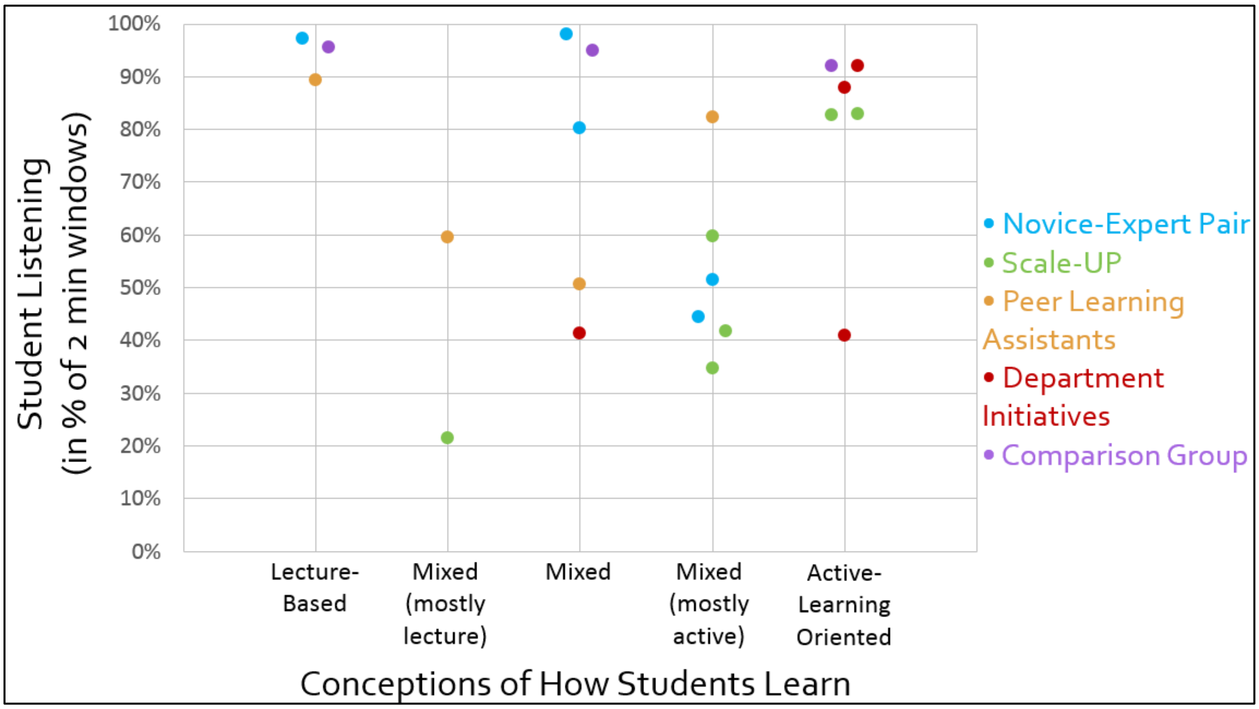

Figure 2.3. PD Participants' espoused conceptions of how students learn and instructional practices.

This study did not evaluate the PD programs faculty members participated in. It is possible that the PD programs in this study identified and accounted for the differences in faculty members' needs. For some PD programs, specifically novice-expert pairs, this might be likely given the individual nature of the PD program through one-on-one support if facilitators are trained and experienced. However, to our knowledge other PD programs did not identify and account for participants' individual needs based on their knowledge and use of instructional practices. Discussion of these results are described below.

The three faculty members who were in the comparison group all had high levels of student listening (Figure 2.3). This may indicate a self-selection effect in which those not in a PD program are most likely to use extensive lecturing. This may also indicate that PD programs supporting the use of active learning are necessarily but not sufficient for promoting change in instruction. A larger sample of STEM faculty not participating in a PD program would be necessary to confirm these hypotheses.

Discussion

Data show a wide range of STEM faculty espoused conceptions of student learning and instructional practices. From this data, five patterns of congruency between STEM faculty espoused conceptions of student learning and instructional practices emerged. PD programs had participants from a range of the patterns described.

Because of the discrepancy between STEM faculty members' current use of instructional practices (Hurtado et al., 2012) and the literature on how students learn (Freeman et al., 2014; Prince, 2004), it is clear that faculty need support in engaging students in active-learning. This support may require development of instructional practices, knowledge and beliefs of student learning, or both. As knowledge and beliefs influence instructional practices (Brownlee et al., 2001; Pajares, 1992), and thus student learning, support in implementing active-learning alone is not sufficient without also developing faculty members' conceptions of teaching and learning. Based on the results presented, I believe it is important faculty developers consider how faculty members are positioned in terms of their instructional practices and conceptions of teaching and learning.

Based on their current espoused conceptions and instructional practices, faculty members in Pattern 1 need support in developing their conceptions of student learning and engaging students in active-learning. In Pattern 1, faculty members' descriptions of how students learn and their instructional practices do not align with research-based instructional practices or calls for reform such as *Vision and Change* (AAAS, 2011). Because of this, faculty members in Pattern 1 would benefit from a combination of support that develops both instructional practices and knowledge and beliefs of student learning.

Faculty members in Patterns 2 and 4 have mixed espoused conceptions of student learning. This confirms previous studies that many faculty members hold beliefs that are not solely teacher-centered or student-centered (Hora, 2014). Faculty members in these Patterns would benefit from a combination of support that utilizes their current understandings of student learning to further develop their conceptions and instructional practices. This support may enable these faculty who already use active-learning to implement these technique more effectively to further promote learning. This support may also enable faculty members who already have bought in to using these techniques to better discuss why active-learning is effective in conversations and social networks with their peers. These discussions can promote change among colleagues in their teaching and/or research circles, departments, and other PD programs they are involved in such as faculty learning communities (Quardokus & Henderson, 2015). Faculty specifically in Pattern 2 may need additional support in overcoming barriers that are preventing them from implementing active-learning instruction in their courses.

Faculty members in Patterns 3 and 5 have incongruencies in their espoused conceptions of student learning and instructional practices. PD programs could be designed to create discrepant events that highlight these incongruencies to promote change. For faculty members in

Pattern 3, these programs should support faculty in implementing active-learning, which already aligns with their espoused conceptions of how students learn. For faculty members in Pattern 5, these programs should support faculty in developing conceptions of student learning that address the learning outcomes of lecture-based instruction they still implement in their instruction.

A sixth pattern emerged from initial analyses of the data, but ultimately no faculty members completely fit within this pattern so it was not presented in the results. This pattern would have included faculty members who only describe student learning occurring through students receiving information, but have minimal lecturing during class. Faculty members in this hypothesized pattern would not acknowledge students learn through interacting with other students or solving problems. Their instruction, however, would provide students with many opportunities to solve problems and work in groups in class (>30% of two-minute windows) and students spend limited time listening (<70% of two-minute windows).

It seems unlikely given for faculty to be in this hypothesized pattern given the predominant nature of lecturing in STEM instruction (Hurtado et al., 2012). For faculty members to enact high levels of active-learning, they would need some incentive or rationale to do so. I hypothesize that if faculty members exist in this pattern it is likely in faculty who teach courses that have historically used problem solving and/or student working in class. For example, computer science courses that engage students in coding during class might have instructors who still have lecture-based conceptions of how students learn. While this pattern is likely rare, it would still be valuable for PD facilitators to consider faculty members' conceptions of teaching and learning regardless if faculty members already implement higher levels of active-learning. As with faculty members in Pattern 4, these faculty may be able to implement active-learning more effectively by better understanding how students learn.

These data show faculty members enter PD programs with a wide range of espoused conceptions of student learning and experiences implementing active-learning. Based on the literature (e.g. Henderson, Beach, & Finkelstein, 2011) and our experiences, PD programs often provide similar development opportunities to all faculty members who elect to participate. These programs commonly promote and/or distribute instructional materials, which is known to be ineffective without also developing faculty members' knowledge and beliefs (Henderson et al., 2011). A one size fits all approach does not utilize or build on the prior knowledge faculty members bring to PD programs.

Having a range of faculty members' conceptions and instructional practices in a single PD program can either be problematic if unaccounted for or an affordance if utilized properly. Faculty members with different conceptions of learning and different instructional practices need support based on their current understandings (see Vygotsky, 1980). For example, faculty members in Patterns 2 and 3 who describe that students learn through active-learning but predominantly lecture in their classrooms need support implementing the ideas they already know support learning. PD program facilitators may need to assess faculty members' prior knowledge and instructional practices, to ensure each participant is receiving adequate support.

If accounted for, this diversity of faculty members' conceptions and instructional practices could be utilized to promote peer learning. If a PD facilitator could pair faculty members from Patterns 2 and 3 with faculty members from Patterns 4 and 5, their differences could be leveraged to support both faculty members' needs. Discussions with peers who hold different perspectives and utilize different instructional practices may facilitate the change process for all participants.

This approach would view faculty members as learners of teaching and learning (Beavers, 2009), and conceptualize PD using constructivist approaches. Just as I would encourage faculty members to identify the prior knowledge of their students to build on through active-learning approaches (NRC, 2012), PD programs should elicit the prior knowledge and experiences of participants. Our results show faculty members can enter PD programs with a variety of knowledge and experiences, resulting in a variety of individual needs for faculty members. These needs should be identified and addressed through targeted approaches that support faculty members in incrementally building faculty members' knowledge of teaching and learning.

As many studies have found, faculty have limited time to plan for and enact active-learning, including attending PD programs to support their development as instructors (AAAS, 2011; Henderson et al., 2011). It seems critical then to make the most of the time faculty allot to participate in PD by ensuring programs support their needs based on their prior knowledge and experience.

Future Directions

This descriptive study characterizes faculty espoused conceptions of how students learn and instructional practices and presents the opportunity for several follow up studies. First, I am interested in better understanding the change process of faculty conceptions and instructional practices. It would be valuable to know if the quantity or quality of development is related to the Patterns described in this study. For example, are faculty with incongruencies between their espoused conceptions of teaching and learning and their instructional practices better positioned for change than those with congruent espoused conceptions and practices?

I am also interested in understanding how conceptions of teaching and learning directly influence the instructional decisions faculty members make. An understanding of this might reveal what particular conceptions of teaching and learning are most important to develop to facilitate changes in practice. This also might help us understand the reasons behind incongruencies between espoused conceptions and instructional practices by understanding the role these conceptions play in planning for and implementing instruction.

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CHAPTER 3

A CASE STUDY USING AN AUTHENTIC SCIENTIFIC INVESTIGATION FOR TEACHING AND LEARNING OF EVOLUTION IN THE CONTEXT OF CLIMATE CHANGE FOR PRESERVICE TEACHERS

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Abstract

This article describes how we drew upon our current science and science education research to craft a learning experience for science teachers. Guided by the *Next Generation Science Standards* and *Vision and Change*, we adapted our science research to an investigation using the 5E lesson format. In the lesson, students collected, analyzed, and interpreted data to construct explanations about the potential for evolution to occur in response to climate change. Students investigated the standing variation of a climate relevant trait, chill coma recovery time, in a population of *Drosophila*, and they made inferences on the potential for natural selection to occur in response to climate change. This experience supported preservice teachers in learning core concepts and science processes, as well as modeled effective instruction as described in national reform documents.

Introduction

Science, technology, engineering, and mathematics (STEM) are playing an increasingly vital role in our society (President's Council of Advisors on Science and Technology (PCAST), 2012). Thus, there is a need to expand the number of students who have foundational knowledge of core concepts in STEM areas. This knowledge is critical in supporting students in becoming citizens who can engage in STEM related discussions, make informed decisions in their everyday lives, and potentially pursue STEM careers. To meet the increased demand for more STEM students from diverse populations, it is vital that preservice teachers are prepared to produce the next generation of scientists.

STEM teachers often teach in ways similar to how they were taught (Ball, 1990; Sakshaug & Wohlhuter, 2010), so it is important to support preservice teachers by offering high quality STEM instruction. Undergraduate science courses should provide preservice teachers with experiences that involve engagement in science practices and active-learning. These experiences should address the *Next Generation of Science Standards* (*NGSS*) (NGSS Lead States, 2013), but also adopt the orientation towards biology instruction that is found in *Vision and Change* (American Association for the Advancement of Science [AAAS], 2011).

Collectively, *NGSS* (NGSS Lead States, 2013) and *Vision and Change* (AAAS, 2011) challenge science faculty to create learning experiences that engage students in core concepts and scientific processes. Both documents call for instructors to focus on conceptual understanding instead of simply memorizing a multitude of facts. Core concepts in life science described by *Vision and Change* (AAAS, 2011) include

- The diversity of life evolved over time by processes of mutation, selection, and genetic change.

- Basic units of structure define the function of all living things.
- The growth and behavior of organisms are activated through the expression of genetic information in context.
- Biological systems grow and change by processes based upon chemical transformation pathways and are governed by the laws of thermodynamics
- Living systems are interconnected and interacting.

But a focus on concepts is not sufficient. Instructors also should give students opportunities to learn concepts by participating in scientific practices that include making observations, conducting experiments, testing hypotheses, analyzing and interpreting data, constructing explanations, and using models. In addition to learning content through these processes, instructors should explicitly teach about the nature of scientific knowledge and how it is constructed by scientists.

In this paper, I describe how we drew upon our current science and science education research to craft a learning experience for preservice science teachers. This learning experience was guided by the documents listed above, as well as the 5E format (Bybee et al., 2006) which is widely used in K-12 science teaching and emerging in undergraduate science instruction (see Sickel et al., 2013). The experience used an investigation adapted from our science research (e.g. Williams et al., 2014) to teach how organisms evolve through natural selection as a result of climate change. The purpose of this paper is to support undergraduate science faculty implement reform-based instruction in science content courses for preservice teachers.

The Science

Understanding the impact of climate change on organisms is important, and it constitutes a portion of our science research. Beyond increases in global mean temperatures, climate change is also expected to result in more frequent and intense extreme weather events, especially during seasonal shoulders in fall and spring. These extreme events include snap-freezes, in which cold fronts rapidly sweep into an area and cause local temperatures to shift from warm to cold. The combination of increased mean temperatures and extreme snap-freezes leads to larger thermal shifts.

Snap-freezes are well known for their impacts on agricultural crops and landscape plants, but can also have major effects on ectothermic animals, such as insects. Knowing how ectotherms interact with stressful temperatures is essential for understanding how insect populations will be affected by climate change. Insect populations are critical in many ecosystems, and their fluctuations will certainly affect ecosystems.

Our research focuses on chill coma recovery time, a genetically controlled trait relevant to climate change and snap-freezes, in a population of *Drosophila* (MacKay et al., 2012; Williams et al., 2014). An effect of cold temperatures on *Drosophila,* and many ectotherms, is an induced narcosis state known as 'chill coma' (Gibert et al., 2001). Chill coma recovery time is the time it takes an organism to return to an active state. This is often measured by recording when an organism regains the ability to stand on all six legs, an easily identifiable response.

Our research uses lines from the *Drosophila* Genetic Reference Panel (DGRP) (Mackay et al., 2012). Lines were inbred from females captured from a wild population in Raleigh, NC to create a series of almost 200 genetically distinct lines. This process of making inbred isofemale lines removes genetic variation within each line so that each line represents a single genotype. Together, the panel of isofemale lines represents a sample of the standing genetic and phenotypic variation in the wild population. By investigating this sample we can understand the genetic and physiological mechanisms underlying climate relevant traits, including chill coma recovery in a natural population (see MacKay et al., 2012; Williams et al., 2014).

Based on this line of research, an investigation was initially designed for secondary science students (Broo & Mahoney, 2017). This investigation was further adapted to an undergraduate biology course for preservice teachers to teach core concepts of evolution and is described in the current paper. The investigation asked students to record and analyze chill coma recovery times of a sample of *Drosophila*. From this data, students could explore how some isofemale lines are better adapted to handle snap-freezes than others. Students then predicted how the *Drosophila* population would respond to temperature fluctuations caused by climate change.

The Design of the Lesson

Using the template found in Figure 3.1, the lesson was designed for an undergraduate biology course for prospective middle-level science teachers. This template was designed to be used by undergraduate science instructors to plan a 5E lesson aligned with the NGSS and *Vision and Change.* The first square of the template gives space to describe the concept(s) targeted in the lesson. In this activity, the goal was to have prospective middle-level teachers understand the impact of snap-freezes on ectotherms and discuss this impact in the larger context of climate change.

The next two squares were designed to contain the specific learning objectives described in the *NGSS* (NGSS Lead States, 2013) and *Vision and Change* (AAAS, 2011). The lesson aligned with *NGSS* performance expectations in evolution and ecology, specifically Disciplinary Core Ideas LS4.B: Natural Selection and LS2.A: Interdependent Relationships in Ecosystems (NGSS Lead States, 2013). The lesson also engaged students in the science practices of carrying

SUMMARY OF INVESTIGATION (FOCUS ON PHENOMENA)

NGSS

Disciplinary Core Ideas:
Science and Engineering Practices:
Crosscutting Concepts:

VISION and CHANGE

Core Concept:
Core Competency:

ENGAGE	EXPLORE	EXPLAIN	ELABORATE	EVALUATE
(Describe activity that engages students and elicits prior knowledge)	(Describe activity within which current concepts, processes, and skills are identified and conceptual change is facilitated through generating new ideas, exploring questions, and designing and conducting an investigation)	(Describe how a concept, process, or skill is directly introduced by the instructor or other resources to guide learners toward a deeper understanding)	(Describe how students will apply their understanding of the concept through additional activities)	(Describe the evaluation of student progress toward achieving the learning outcomes)

REFLECTION ABOUT THE INVESTIGATION

(After the lesson, reflect on the enactment of the lesson and record evidence regarding student performance)

Figure 3.1. Template for the development of an inquiry-based investigation.

out investigations, analyzing and interpreting data, and constructing explanations, and the crosscutting concepts of patterns and cause and effect. From *Vision and Change* (AAAS, 2011), the lesson spanned two core concepts: evolution and systems. Within evolution, the lesson emphasized genetic variation and natural selection; within systems, the lesson emphasized the dynamic interactions of components in a system with a changing climate.

The entire lesson was placed in a 5E Format (see Table 3.1) (Bybee et al., 2006; Bybee, 2014). Throughout the 5E lesson, students interact with each other and the instructor. These interactions allow students to exchange their unique perspectives, and serve as a formative assessment for instructors to measure students' understandings (e.g. McDonald, 2016). In addition, the instructor can evaluate the design of lesson by interacting with students throughout the lesson.

Both during and after the lesson, the instructor should reflect on the lesson and record the evidence regarding student performance. For instance, after class the instructor could note areas in which additional instruction might be useful or concepts that students could easily grasp in the last box in the template in Figure 3.1. This type of reflection informs future enactment of that particular lesson, and it helps the instructor build a better understanding of teaching specific objectives.

Enacting the Lesson

Below I describe the enactment of a 5E lesson that teaches the science described above. First, I describe the context of the course the lesson was enacted in. Then I describe the enactment of each of the 5E's and provide examples of student work as evidence of student learning.

Table 3.1. The 5E's (Bybee, 2014).

Engagement	The teacher or a curriculum task helps students become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge. The activity should make connections between past and present learning experiences, expose prior conceptions, and organize students' thinking toward the learning outcomes of current activities.
Exploration	Exploration experiences provide students with a common base of activities within which current concepts (i.e., misconceptions), processes, and skills are identified and conceptual change is facilitated. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions, and design and conduct an investigation.
Explanation	The explanation phase focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. In this phase teachers directly introduce a concept, process, or skill. An explanation from the teacher or other resources may guide learners toward a deeper understanding, which is a critical part of this phase.
Elaboration	Teachers challenge and extend students' conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept and abilities by conducting additional activities.
Evaluation	The evaluation phase encourages students to assess their understanding and abilities and allows teachers to evaluate student progress toward achieving the learning outcomes.

The students and the class

The undergraduate general biology class for preservice teachers met once a week for three hours and required that the students engage in a variety of sequenced activities in order to make sense of the core ideas, science practices, and cross-cutting concepts (NGSS Lead States, 2013). Each lesson emphasized using claims, evidence, and reasoning following Sampson, Grooms, and Walker (2009). This approach requires that students collect and/or interpret data to use as evidence when making a claim. The course met in a standard classroom without laboratory space. The lessons had minimal lecturing and regularly required students to work in pairs or small groups and present their emerging conclusions to the class for further discussion.

The 11 students enrolled in the course were enrolled a middle school certification program. Most of the students were attaining a Bachelor of Science in Education (BSEd), and three students were completing their Masters degrees. Ten of the students were female, and one was male.

The 5E Lesson

The entire lesson was placed in a 5E Format, which is described below.

Engage. Prior to the investigation, students estimated their carbon dioxide footprint. Students then discussed the impact of emissions and climate change. To elicit students' prior knowledge students completed a concept sketch of how changes in climate affect various organisms (see problem 1 in Figure 3.2). The concept sketch process can be used as a formative assessment to understand the content knowledge of undergraduates (Johnson & Reynolds, 2005). The sketch included a plant, an ectotherm, and a mammal that were all part of a single food web. This formative assessment elicited students' preconceptions of how organisms are connected in ecosystems, and how environmental changes (e.g. climate change) can impact populations within ecosystems and drive natural selection.

Students' responses were used to drive a discussion on the effects of climate change, the influence of temperature on ectotherms, and directional selection as a mechanism of evolution. The instructor introduced students to the DGRP lines through a short, interactive presentation. The discussions centered on a series of questions that built on the formative assessment in Figure 3.2 to further elicit students' prior knowledge on climate change and natural selection. Questions included "how does temperature affect organisms", "what impacts would a changing climate have on organisms", and "what are ways in which organisms can respond to climate change"? Students first individually wrote their answers in lab notebooks they used throughout the course, then discussed their answers in small groups, and finally shared their answers in a large class setting.

Explore. Students were introduced to the chill coma assay procedure (David et al., 1998; Denlinger & Lee, 2010). In preparing for the investigation, six genetically isolated lines of *Drosophila* from the DGRP were obtained from a research lab. Three lines consisted of cold resistant flies that had faster chill coma recovery times (averaging approximately eight minutes), and three lines consisted of cold susceptible flies that had slower chill coma recovery times (averaging approximately 13 minutes). For each of the six fly lines, vials were prepared containing approximately 20 flies. Enough vials were prepared so each student pair could measure chill coma recovery times of a vial of cold susceptible flies and a vial of cold resistant flies. Fly lines were labeled as A, B, C, D, E, or F on the vials, and students did not know which lines were resistant or susceptible to cold temperatures. Three hours prior to the investigation, vials were placed in an ice bath (0 °C) to induce chill coma, causing flies to fall on their sides at the bottom of the vials.

At the start of the investigation, *Drosophila* vials were gently removed from the ice baths. Students placed *Drosophila* in petri dishes and measured chill coma recovery times, recording in seconds the time it took each fly to stand on all six legs. As a fly recovered, students used forceps to carefully remove the recovered fly from the petri dish and place it in a vial of ethanol for euthanization. Fast removal of recovered flies prevented these flies from touching other flies still in chill coma. Recovery times can be influenced when unrecovered flies are stimulated by the touch of recovered flies. Flight follows minutes after the righting response, so rapid removal of recovered flies before they can fly also prevents flies from escaping into the classroom.

During the investigation, students collected data and made observations, which were written in students' lab notebooks. Following data collection, each student pair entered the chill coma recovery times for each fly into a single Excel spreadsheet for data analysis. This resulted in approximately 40 flies in each of the six fly lines. The mean and standard deviation were calculated for each line.

Explain. Students compared chill coma recovery data of the six lines in pairs. Students used the data to make inferences about the variation within the population sample. After a class discussion eliciting these inferences, students were asked about the potential for these lines to adapt to climate change.

One ideal conclusion reached by the students would be that climate change (e.g. snap-freezes) can lead to directional selection in genetically diverse populations. Selection would favor advantageous traits (e.g. fast recovery time). For example, an exemplary inference made from students' data was: "Flies from line A had faster recovery times than flies from line C.

Since flies will experience cold snaps more often because of climate change, flies from line A will survive and reproduce more frequently than flies from line C. This will lead to selection for line A over line C in this population over time in response to climate change".

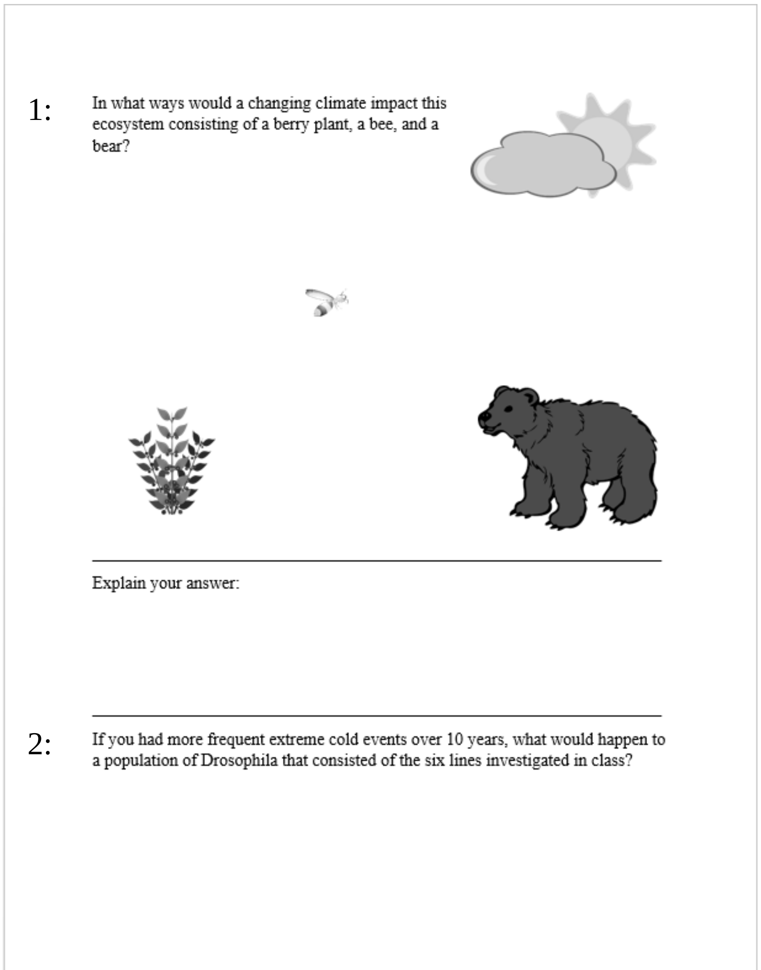

Figure 3.2. Assessment of student understanding of natural selection to climate change. Students completed problem 1 in the engage and evaluate portion of the lesson. Students completed problems 1 and 2 in an exam a week following the lesson.

Elaborate. In the elaboration phase of the lesson, students extended their understanding to a more complex system with plants, ectotherms, and endotherms. Students were given data from studies on oak trees (*Quercus robur)*, winter moths (*Opheroptera brumata)*, and birds – the great tits (*Parus major)* (Visser et al., 1998). Students observed the differences between date of egg laying in the great tits and the peak of the winter moth caterpillars. They then had to consider how climate change could impact the interactions between organisms in ecosystems. A thorough conclusion from a student group would describe that some organisms respond to climate change at different rates, adding that natural selection can act on some populations more rapidly than others. This differential in selection can ultimately disrupt the interactions in ecosystems. For example, a student described how "changes in one organism can affect others. For instance, if insects died from an extreme cold snap, they would not be able to pollinate plants leading to less food for herbivores and omnivores."

Evaluate. A week following the investigation, students were asked to again sketch or describe ways in which climate change impacts various organisms in ecosystems (Figure 3.2, Problem 1), and to explain their answers. The assessment was designed to elicit students' understandings of how climate change can have different impacts on various organisms, and that the impacts on one species can influence others.

In addition, students were asked a more direct question assessing students' understanding of the chill coma investigation (Figure 3.2, Problem 2). Students were asked to predict what would happen in the population of *Drosophila* that were investigated if extreme cold events occurred frequently over a 10-year period. This assessed if students understood that climate change can result in the selection for advantageous genetically controlled traits and selection against unfavorable genetically controlled traits. Over time, this will lead to directional selection within the population.

Exemplary responses included:

> "Organisms with traits that confer an advantage in response to environmental pressures survive and reproduce more frequently than those with less favorable traits".
>
> "It appears that it would be advantageous to be a fly from a strain that recovers most rapidly. Lines A and B will survive more than lines C, D, E, and F because they have shorter chill coma recovery times".

While not all students' responses reflected sophisticated understandings of evolution and ecology, all students demonstrated progress in their inferences and explanations from the first sketch to the final sketch. Students' final concept sketches built on their initial sketches in several important ways. In their original drawings, nearly all students focused solely on how individual organisms are affected by warmer temperatures. Students did not initially recognize how these affects could disrupt the interactions among other organisms within the same ecosystem. In the final concept sketch, many students recognized other effects of climate change (e.g. cold snaps) and described how the responses to climate change in one organism can affect other organisms. Many students described how plants, ectotherms, and endotherms might have different responses to climate change. For example one student stated, "Endotherms and ectotherms respond differently to temperatures changes." Several students added these differentiated responses can disrupt ecosystems. As one student described, "If one organisms falls out of the system, the system can crash."

Discussion and Conclusions

This lesson drew upon the calls for reform in the *NGSS* (NGSS Lead States, 2013) and *Vision and Change* (AAAS, 2011), which has implications for how teachers will teach. In addition to teaching content, this investigation engaged preservice teachers in science practices and active-learning by adapting our science research to a classroom-based investigation. It is important to engage preservice teachers in science practices and active-learning as students in science content courses, as teachers teach in the ways they are taught (Ball, 1990; Sakshaug & Wohlhuter, 2010).

I expect this type of instruction to have a strong impact on preservice teachers. This investigation promotes both the conceptual development of science content knowledge and models effective instruction preservice teachers can implement in their teaching. Without these experiences, one cannot expect future teachers to engage their students in science practices.

The lesson planning template was important in helping the instructors move beyond traditional instruction and implement the 5E's. This model of instruction allowed instructors to elicit and address the preconceptions students had of evolution and climate change through formative assessment. This further provided an effective model of instruction for preservice teachers.

Beyond calls for reform and lesson planning resources, I anticipate undergraduate STEM instructors will need support enacting this type of instruction through professional development (PD) programs. Effective PD programs for undergraduate STEM faculty members will 1) develop participants' knowledge and beliefs, 2) develop reflective instructors, 3) occur over an extended period of time, 4) incorporate feedback for instructors, and 5) be culturally responsive (see Henderson et al., 2011). This type of instruction will not be easy to implement, and instructors may benefit from slowly adopting reform-based teaching.

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CHAPTER 4

CONCLUSIONS

In this chapter I describe the major contributions of the studies within this dissertation and my plans for future research.

Major Contributions

This research explored faculty conceptions of how students learn, an understudied component of faculty knowledge and beliefs. Only two previous studies explicitly describe faculty conceptions of how students learn (Hora, 2014; Prosser, Trigwell, & Taylor, 1994). This study builds on these prior works by comparing these conceptions to faculty instructional practices.

The first major contribution of this dissertation is evidence of five patterns of congruency between faculty conceptions of how students learn and their instructional practices. Faculty hold a wide range of conceptions of how students learn along a continuum from lecture-based to active-learning oriented, a finding consistent with previous studies (Hora, 2014). Faculty also implement a range of instructional practices from extensive lecturing to high levels of active-learning. For faculty members in Patterns 2, 3, and 4, incongruencies exist between their conceptions of how students learn and their instructional practices. These incongruencies could potentially be used through discrepant events to create dissatisfaction in their current conceptions or practices to promote change (Posner, Strike, Hewson & Gertzog, 1982; Southerland, Sowell & Enderle, 2011).

The second major contribution of this dissertation is evidence that PD programs have faculty participants with diverse conceptions of how students learn and instructional practices. This finding reveals the diverse needs faculty members within a given PD program have, supporting the argument that a one-size fits all model of PD will likely be ineffective at promoting change for all participants. Given this evidence, it is critical faculty developers elicit PD participants' prior knowledge and experience to support learning using constructivist principles (e.g. Driver, Asoko, Leach, Mortimer, & Scott, 1994; Vygotsky, 1978). These principles would promote the use of individualized and targeted support for faculty members, and leveraging faculty members' diverse knowledge and experiences when faculty are in groups.

Finally, this dissertation provides an example of the application of active-learning techniques in Chapter 3. These techniques engage students in activities that reflect my own conceptions of how students learn. This work contributed a lesson planning template faculty members can use to engage students in active-learning through the 5E's (Bybee et al., 2006; Bybee, 2014). In addition, this paper described the added importance of using active-learning in undergraduate science courses for preservice teachers, as teachers often teach in ways similar to how they were taught (Ball, 1990; Sakshaug & Wohlhuter, 2010).

Future Research

Here I describe three potential lines of future research that extend this dissertation study. The first uses the same data set to explore faculty members' use of assessment in their instruction. The second is a plan for a future study to better understand the ways in which faculty draw upon their knowledge of how students learn when planning and implementing instruction. The last project is a plan to study changes over time in faculty conceptions of how students learn.

Using the same rich data set from Chapter 2, I will explore the assessment practices of faculty members in relation to their conceptions of how students learn. Assessment is an understudied area within undergraduate STEM education, with little mention of assessment in the 2012 Discipline-Based Education Research report (National Research Council, 2012). I will conduct a literature review on the self-reported assessment practices, observed assessment practices, and conceptions of assessment of STEM faculty members to prepare for this analysis.

During the semi-structured interviews described in Chapter 2, researchers asked faculty members how they assessed student learning. Faculty responded with a wide range of assessment techniques. Over half of participants (n=14 out of 22 total participants) mentioned they assess learning through summative assessments (i.e. tests and quizzes). Other assessment techniques described were clicker questions (n=3), asking questions and having discussions with students (n=14), moving and guiding during in class activities (n=8), sensing learning through body language (n=5), homework (n=1), and essay questions (n=2). I am interested in exploring how these assessment techniques align with faculty members' conceptions of how students learn and their instructional practices.

I also plan to conduct a future study to explore the ways in which faculty draw upon their knowledge of how students learn when planning and implementing instruction. While the current study elicited faculty members conceptions of how students learn in general over the course of a semester, this study will elicit these conceptions for a particular class that will be observed and video recorded. Video will be used during stimulated recall interviews (Lyle, 2003) occurring within a short time frame of the instruction (~less than one week) (e.g. Alonzo, Kobarg, & Seidel, 2012).

Interview data should help understand the ways in which faculty members draw upon their conceptions of how students learn in planning and implementing instruction. This should be especially useful in eliciting knowledge and beliefs that are difficult for faculty to describe outside of the context of the classroom, including tacit knowledge (Kane, Sandretto, & Heath, 2002; Lyle, 2003). It may also help us understand the factors that lead to incongruencies between conceptions of how students learn and their instructional practices. I predict the factors elicited will include knowledge and beliefs of other aspects of teaching that faculty prioritize over their conceptions of how students learn (e.g. conceptions of teaching, schooling, content, knowledge, etc.). I also anticipate faculty will report barriers to implementing various instructional practices that contribute to incongruencies in their conceptions and instructional practice.

Finally, I hope to also better understand the change process of faculty members engaged in PD programs. In my current work I did not capture strong evidence of changes in faculty conceptions of how students learn, consistent with literature describing the slow nature of changing knowledge and beliefs (Korthagen, 2010; Pajares, 1992). This could be for several reasons, including the short duration of the study (one semester) or the potential lack of explicit instruction on how students learn (unknown because PD programs were not directly observed). A future study could be designed around a PD program with a component specifically designed to develop faculty conceptions of how students learn.

My goal is to develop a line of research that supports faculty implement active-learning, develop research-based conceptions of how students learn, and use effective assessment practices to measure learning.

Conclusion

This chapter described how this dissertation expands the field by describing patterns of congruency between faculty members' conceptions of how students learn and their instructional practices, the range of faculty members' conceptions and practices within PD programs, and an application of active-learning instructional practices. These studies build on the limited prior work in this area and could lead to a line of research that supports faculty enactment of instruction centered on student learning.

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